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QUALITY EVALUATION OF GREEN BANANA (cv. Nendran) IN DIFFERENT STAGES OF MATURITY

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ABSTRACT

Aims: Banana (*Musa* spp.) is a globally significant tropical fruit crop, valued for its economic importance and as a staple food that contributes significantly to human nutrition. The Nendran banana variety (*Musa* AAB) is widely cultivated in the South Indian states of Tamil Nadu, Kerala, and Karnataka, and is also well-known in other regions worldwide. This study aims to examine the physical, chemical, and nutritional characteristics of Nendran bananas at various maturity stages—75, 80, 85, and 90 days after flower emergence.

Study design: Completely randomized design (CRD).

Place and Duration of Study: Department of community science, College of Agriculture, Vellayani, Kerala Agricultural University, between February 2024 to October 2024

Methodology: Nendran bananas for this study were obtained from a local farmer in Vellayani, Thiruvananthapuram. Maturity was monitored by tagging the plants on the day of flower emergence, and the fruits were harvested at intervals of 75, 80, 85, and 90 days post-emergence. At each stage, green fruits were selected from the middle three fruits of the third hand from the top of each bunch and taken for physical (fruit weight, fruit length, circumference, peel weight, pulp weight), chemical (moisture, acidity, TSS, crude fiber and tannin) and nutritional (starch, protein, total sugar, reducing sugar) analysis.

Results: The results indicate that the ripening process significantly impacts the physical, chemical, and nutritional properties of Nendran bananas. Physical attributes such as fruit weight, pulp weight, fruit length, and diameter reached their maximum at 90 days, while peel weight was highest at 75 days. Chemical analysis demonstrated that moisture content, acidity, and total soluble solids (TSS) were greatest at 90 days, whereas crude fiber and tannin content peaked at 75 days. Nutritional analysis revealed that protein, total sugar, and reducing sugar levels were highest at 90 days, while starch content was highest at 75 days. These findings highlight how understanding the nutritional profile of unripe green Nendran bananas at different maturity stages offers valuable insights into the chemical transformations that occur throughout the ripening process.

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Keywords: "Nendran", Maturity, Green banana, Nutrients, Physico-chemical,

1. INTRODUCTION

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Banana (*Musa* spp.) is a major tropical fruit crop globally, holding substantial economic importance and serving as a staple food with a vital role in human nutrition (Aurore *et al.*, 2009). India is the world's top banana grower, with China, Ecuador, Brazil, and the Philippines following closely after (Nayar, 2010). Bananas are nutritious, sweet, and readily digestible fruits high in carbohydrates and minerals such as potassium, magnesium, salt, and phosphorus. They even have more calories than potatoes (Pereira and Maraschin, 2015). Bananas are unique because they combine energy-boosting components with tissue-building nutrients, including proteins, vitamins, and minerals. (Qamar and Shaikh, 2018).

23 They can contribute significantly to the vitamin A, C, and B6 levels in the diet while also providing an instant source of
24 energy (Singh *et al.*, 2016).

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26 The raw banana variety Musa (AAB) cv. "Nendran" is extensively cultivated in the South Indian states of Tamil Nadu,
27 Kerala, and Karnataka, and is also popular in other regions worldwide. Kerala now generates less than 30% of its banana
28 requirements and relies on Tamil Nadu to assist cover the gap (Hassan, 2016). The state is home to a wide assortment of
29 banana cultivars, each having its own regional preferences and economic worth. Among them, the "Nendran" variety is
30 very popular in Kerala and is widely planted for both fresh fruit consumption and banana chip production. It is enjoyed in
31 both unripe and ripe stages. "Nendran" belongs to the French plantain family and is an important part of the local diet.
32 However, the area allocated to banana production in Kerala is shrinking as farmers turn to more profitable crops.
33 Nonetheless, bananas' profound historical, economic, and even religious significance in Kerala helps to keep the crop
34 from being fully eclipsed by other agricultural endeavors (Siji and Nandini, 2017).

35
36 "Nendran" bananas mature 5-6 months after blossoming, producing large, thick fruits with a high shelf life. Unripe
37 "Nendran" is ideal for Kerala banana chips and is often used as a first weaning snack for infants in India (Chitra, 2015).
38 The fruits average 20-27 cm in length, 14-18 cm in diameter, and have a thick peel with three ridges and a unique tip. A
39 Nendran bunch weighs 12-15 kg, consisting of 4-6 hands with 8-10 fingers each. The creamy pale-yellow flesh of unripe
40 fruits deepens to yellowish-orange as they ripen, while the peel transitions from green to yellow and later develops dark
41 spots (Sreejith and Sabu, 2017). Unripe flesh has a bland, starchy texture, which becomes sweet and creamy as starch
42 converts to sugar (Suman *et al.*, 2018). "Nendran" flower bracts are rich in anthocyanins with anticancer properties, its
43 peel contains a metalloprotease with collagenolytic and cytotoxic effects, and its fructans act as prebiotics by promoting
44 lactic acid bacteria (Shalini et al., 2017).

45 2. MATERIAL AND METHODS

46 2.1 Collection of Raw Materials

47
48 In this study, "Nendran" bananas were sourced from a local farmer at Vellayani, Thiruvananthapuram. To accurately
49 determine maturity, the bananas were tagged on the day of flower emergence. Fruits were harvested at 75, 80, 85, and
50 90 days post-emergence. For each maturity stage, green fruits were collected from the middle three fruits on the third
51 hand from the top of each bunch and brought to the laboratory for subsequent physical and biochemical analyses.

52 2.2 Physical Parameters

53
54 The physical parameters of unripe green banana fruits were assessed using the method described by Dadzie and
55 Orchard (1997).

56 The length of each fruit was measured along its outer curve from the distal end using a measuring tape. Measurements
57 were taken from a minimum of five fruits. The circumference of each fruit was measured at its widest midpoint using a
58 measuring tape, ensuring consistency in the measurement process. Readings were collected from three fruits at each
59 maturity stage to provide a representative assessment of fruit circumference across different developmental phases. In
60 addition, the weight of the unripe green fruits, as well as the individual weights of the pulp and peel, were accurately
61 determined using an electronic balance. This method allowed for precise quantification of the various components of the
62 fruit, facilitating detailed analysis of their physical characteristics.

63 2.3 Chemical parameters

64
65 For the analysis of chemical parameters, the fruit pulp was cut into uniform pieces and immersed in a pretreatment
66 solution (Karthikeyan, 2015) to minimize browning reactions. Subsequently, the treated pulp was ground into a fine paste
67 for further analysis.

68 2.3.1 Moisture Content

69
70 Moisture content was determined according to the AOAC (2010).

71 2.3.2 Titratable Acidity

72
73 Titratable acidity was measured according to the method established by Ranganna, (1977). A known volume of the fruit
74 sample was taken and titrated with a 0.1 N sodium hydroxide (NaOH) solution, using phenolphthalein as an indicator. The
75 acidity levels were reported as a percentage (%).

76 2.3.3 Total Soluble Sugars

83
84 Total soluble solids (TSS) were measured using a hand refractometer with a range of 0 to 32 °Brix and were expressed in
85 degrees Brix (°Brix) according to the method described by Ranganna (1977).
86

87 **2.3.4 Crude Fiber**

88
89 Crude fiber content was determined using the acid-alkali digestion method as recommended by Chopra and Kanwar
90 (1978).
91

92 **2.4 Nutritional Parameters**

93 **2.4.1 Starch Content**

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95 Starch content was determined using theAOAC(2010) method.
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98 **2.4.2 Protein**

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100 The protein content in banana samples was determined using the micro Kjeldahl wet digestion method (AOAC,2010).
101

102 **2.4.3 Total Sugar**

103 Total sugars in the sample were estimated following the AOAC (2010) method and expressed as a percentage on a fresh
104 weight basis.
105

106 **2.4.4 Reducing Sugar**

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108 Reducing sugars were determined by the copper reduction method using Fehling's solution (AOAC,2010) and expressed
109 as a percentage.
110

111 **3. RESULTS AND DISCUSSION**

112
113 Significant changes were observed in the physical, chemical, and nutritional parameters of bananas at different maturity
114 stages. The variation in these parameters highlights how maturation impacts the fruit's composition, including aspects
115 such as texture, sugar content, acidity, and nutrient levels. This underscores the importance of maturity in determining the
116 quality and nutritional profile of bananas, influencing both their consumer acceptability and potential applications in food
117 processing and nutrition.
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119 **3.1 Physical Parameters**

120
121 The physical characteristics of banana fingers showed significant variations across the different maturity stages tested
122 (Table 1). Fruit weight was notably affected by the stage of maturity, with the 90-day maturity stage (149.25) exhibiting the
123 highest fruit weight, while the 75-day stage recorded the lowest among those tested. In terms of peel and pulp weight, the
124 75-day maturity stage had a higher peel weight but a lower pulp weight. Conversely, the 90-day maturity stage showed an
125 increased pulp weight, highlighting the shift in fruit composition with advancing maturity. Fruit length was also influenced
126 by maturity stage, with the 90-day maturity showing the greatest length compared to the other stages. The 75-day and 80-
127 day maturity stages exhibited similar fruit lengths, indicating minimal variation between them. In terms of fruit diameter,
128 the 90-day maturity stage recorded the highest diameter, while the other maturity stages showed similar measurements.
129 Comparable changes have been documented by Rodriquez-Sosa *et al.* (1977) in their research on banana flour
130 preparation.
131

Table 1

Physical parameters of banana fingers					
Maturity (Days)	Fruit weight (g)	Peel weight (g)	Pulp weight (g)	Fruit length (cm)	Fruit diameter (cm)
75	115.25 ^b	50.75 ^a	56.50 ^c	18.175 ^b	11.175 ^b
80	109.50 ^b	39.50 ^{bc}	66.25 ^b	18.350 ^b	11.350 ^b
85	116.50 ^b	39.0 ^c	75.50 ^{ab}	21.05 ^{ab}	11.625 ^{ab}

90	149.25 ^a	48.0 ^{ab}	81.25 ^a	22.325 ^a	12.275 ^a
SE (d)	8.215	3.999	4.26	1.351	0.316
SE(m)	5.809	2.828	3.012	0.955	0.223
CD	17.898	8.712	9.281	2.943	0.688

3.2 Chemical Composition of Banana

The chemical composition of green Nendran bananas were evaluated, showing significant differences across various maturity stages (Table 2). This analysis highlights the unique chemical composition at each stage, demonstrating the progression of changes as the fruit matures. These findings underscore the importance of understanding such differences for applications in nutritional profiling and post-harvest management.

The moisture content in bananas is observed to be highest at 90 days of maturity (59.410%) and lowest at 75 days (49.603%). Typically, as bananas undergo the ripening process, their moisture content ranges from 60% to 68.6%, and progressively increases to levels between 68.6% and 78.1% (Sakyi *et al.*, 2008). This increase in moisture content during ripening is likely attributed to the breakdown of carbohydrates, which leads to the softening of tissue texture, as well as osmotic transfer from the peel to the pulp (Onwuka, G.I. and Onwuka, N.D. 2005).

The acidity of banana fingers has been analyzed, and findings indicate that the highest acidity levels are observed at 90 days of maturity compared to other stages. This suggests that as bananas progress through their ripening process, the acidity initially increases and peaks at the later stage of 90 days. High acidity at this point is often associated with the biochemical changes that occur as the fruit ripens, including the conversion of starches into sugars and the formation of organic acids (Wyman, 1964). These changes contribute to the flavor profile of the banana, enhancing its overall taste and sensory characteristics, Sreedevi and Suma (2015) reported similar results, as did Mayadevi (2016).

In the analysis of total soluble sugars across different maturity, it was observed that the concentration was highest at day 90 (14.200⁰brix) and lowest at day 75 (4.800⁰brix). This trend indicates a significant increase in soluble sugar content as the maturity of the sample advances. The increase in total soluble sugars during ripening is an essential trait that reflects the hydrolysis of starch into soluble sugars, including glucose, sucrose, and fructose (Meghwal *et al.*, 2021). This process underscores the enzymatic conversion that occurs as the fruit matures, contributing to the accumulation of sugars and enhancing the sweetness and overall quality of the produce (Turkey *et al.*, 2003). The significant rise in total soluble sugars at advanced maturity, such as day 90, highlights the culmination of starch breakdown and sugar synthesis. Conversely, the lower sugar content at day 75 indicates an earlier stage of development where this conversion is less pronounced. These observations are crucial for optimizing harvest timing to achieve the desired sugar profile in agricultural and food production practices (Mahato *et al.*, 2014).

Crude fiber content was found to be highest at the earlier stage of 75 days and decreased significantly by 90 days. This trend was similarly observed in unripe bananas, where the crude fiber composition was initially high but declined as the fruit ripened (Dhaval and Naik, 2010). Barnell HR (1940) noted in his work that the decrease in crude fiber during ripening is due to the enzymatic breakdown of complex polysaccharides into simpler, more easily digestible forms. This transformation, as the fruit ripens from an unripe to a fully mature state, involves the degradation of cell wall components like cellulose and hemicellulose, leading to a softer texture and improved palatability. Understanding this pattern is important for determining optimal harvest times, particularly for applications where fiber content plays a role in the nutritional or functional quality of the produce.

In the present study, tannin content was found to be highest at day 75 and decreased significantly by day 90. This finding aligns with previous research by Khawas *et al.* (2014), which demonstrated that the tannin content in banana samples varies significantly across different stages of development. The decline in tannin levels during maturation contributes to the sensory evolution of the fruit. As noted by Szajdek and Borowska (2008), tannins play a crucial role in shaping the sensory properties of fruits and fruit products, imparting a characteristic tartness and influencing color changes in both the fruit and its derived juices. The reduction in tannin content at advanced ripening stages corresponds to the softening of the fruit and a shift towards a sweeter taste profile, enhancing consumer appeal and usability in various culinary and processing contexts.

Table 2

Chemical parameters of banana fingers						
Sl.no	Maturity (Days)	Moisture (%)	Acidity (%)	TSS (^o brix)	Crude fiber (%)	Tannin (g 100 g ⁻¹)
1	75	49.603 ^d	0.133 ^d	4.800 ^d	4.043 ^a	8.017 ^a
2	80	53.457 ^c	0.160 ^c	7.013 ^c	3.337 ^b	7.347 ^b
3	85	55.813 ^b	0.190 ^b	10.900 ^b	3.290 ^c	6.770 ^c
4	90	59.410 ^a	0.233 ^a	14.200 ^a	2.850 ^d	5.897 ^d
	SE (d)	0.026	0.008	0.002	0.008	0.009
	SE(m)	0.018	0.006	0.002	0.006	0.006
	CD	0.06	0.018	0.005	0.018	0.021

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181 3.2 Nutritional Parameters

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183 The nutritional properties of green Nendran bananas were investigated, with an emphasis on starch, protein, total sugar, and reducing sugars. The research provides a full understanding of the nutritional composition of bananas at various development stages. Starch, being the major carbohydrate in unripe bananas, contributes significantly to the overall energy content and steadily diminishes as the fruit ripens and converts into simpler sugars. Protein levels add to the nutritional value, but in lesser proportions than carbs. Total sugars and reducing sugars, essential for flavor and palatability, were also analyzed, revealing their increase as starch breaks down during the ripening process. Understanding these nutritional profiles is critical for making the best use of green Nendran bananas in dietary planning and food processing applications.

189 In the current study, the starch content of unripe bananas was shown to fluctuate from 84% at day 75 to 76.4% at day 90. Starch levels peaked at day 75 and dropped as the fruit grew to day 90. According to Butani and Chovatia (2014), the breakdown of starch into simpler sugars during the ripening process results in the sweeter taste and softer texture characteristic of ripe bananas.

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196 In the investigation of green Nendran bananas, the protein content was shown to be greater at day 90 when compared to other maturity stages. This increase in protein content as the fruit matures may be due to biochemical changes that occur during ripening, such as the creation and accumulation of numerous enzymes and structural proteins. While proteins are not the predominant nutritional component of bananas, their contribution is considerable when considering the fruit's total nutritional profile. The rise at day 90 suggests that fully ripened bananas may have more protein content, adding to their nutritional worth (Vanilarasu and Balakrishnamurthy, 2014). This information, together with data on starch conversion and sugar buildup, helps to highlight the overall nutritional advantages of bananas at different stages of maturity (Lohi2010).

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204 The total sugars in unripe banana pulp were analysed at various development stages. The investigation revealed that the overall sugar level was greatest at day 90 when compared to the other stages. These findings align with previous research by Lodh *et al.* (1973), which found comparable patterns of total sugar concentration in bananas at various stages of maturation.

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209 Venkatarayappa *et al.* (1976) and Chellappan (1983) reported that dessert bananas contained significantly higher levels of reducing sugars, whereas cooking bananas and plantains exhibited greater non-reducing sugar content. This study found that reducing sugar levels were highest at the 90 maturity day compared to earlier stages.

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Nutritional Parameters of Banana Fingers					
Sl. no	Maturity (Days)	Starch (mg)	Protein (mg)	Total sugars (%)	Reducing sugars (%)
1	75	84.0 ^a	1.50 ^d	1.83 ^d	0.250 ^d
2	80	83.5 ^b	1.90 ^c	2.10 ^c	0.450 ^c

3	85	80.1 ^c	2.20 ^b	2.610 ^b	0.806 ^b
4	90	76.4 ^d	2.31 ^a	2.806 ^a	1.033 ^a
	SE (d)	0.071	0	0.025	0.024
	SE(m)	0.05	0	0.018	0.017
	CD	0.163	0	0.058	0.055

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4. CONCLUSION

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This study reveals how the nutritional makeup of bananas varies with development stage. The data shows that ripening has a substantial influence on the physical, chemical, and nutritional aspects of Nendran bananas. Physical measures such as fruit weight, pulp weight, fruit length, and fruit diameter were higher at day 90, but peel weight was highest at day 75. Chemical analysis revealed that moisture content, acidity, and total soluble solids (TSS) peaked at day 90, whereas crude fibre and tannin levels peaked at day 75. In terms of nutritional characteristics, protein, total sugar, and reducing sugar concentrations were highest at day 90, whereas starch content was highest at day 75. The findings showed that knowing the nutritional quality of unripened green Nendran bananas at various maturity stages provides insights into the chemical changes that occur during ripening. This knowledge can be used to extend the usage of bananas in a variety of culinary items. The outcomes of this study will help the food sector **optimize** nutritional contents when developing new products that incorporate the examined banana cultivar.

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COMPETING INTERESTS

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Authors have declared that no competing interests exist.

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Disclaimer (Artificial intelligence)

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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AUTHORS' CONTRIBUTIONS

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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