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SHORT COMMUNICATION

Starch and amylose variability in banana cultivars

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Abstract Unripe banana fruit flour based products has a more beneficial effect on stomach related ailments in human beings due to the presence of more resistant starch (RS), which is strongly associated with amylose content. The present study was carried out to analyse sugars, starch and amylose content of mature unripened banana fruits of nine banana cultivars. Among tested cultivars, starch content varied in the range of 80.53–86.76 % and amylose content ranged from 24.41 to 36.87 %. Amylose content differentiates the dessert bananas from plantain and cooking bananas. The plantain and cooking bananas viz, Nendran, Monthan and Saba recorded >34 % of amylose and they have greater potential in food industries as raw material. Preparation of amylose rich banana fruit flour products reduces considerable post-harvest losses, especially in Nendran, thereby converting the rejected/culled banana fruits into flour based food products.

Keywords Amylose · Cooking bananas · Dessert bananas · Starch · Sugars · Unripened banana fruit flour

Globally, dessert bananas (*Musa* spp., AA, AB, and AAA genome), plantain (AAB) and cooking banana (ABB), constitute fourth most important commodity after rice, wheat and maize. It is grown in more than 130 countries across the world in an area of 4.8 million ha producing 93.39 million tonnes of banana and plantain. India is the largest producer of banana in the world, contributing 29 per cent to the global production of banana with a total production of 29.78 million tonnes from an area of 0.83 million ha (NHB 2013).

Starch is one of the most important carbohydrate constituent available in cereals, roots, tubers and fruits, which are consumed worldwide as diet. The unripe banana pulp contains up to 70–80 % starch on dry weight basis, which is comparable to the endosperm of corn grain and white potato (Zhang et al. 2005). There is a growing trend to reduce the consumption of glycemic carbohydrates in food products and to increase the level of indigestible carbohydrates (Acevedo et al. 2012). Consumption of unripe banana flour based products provides beneficial effects on human health, which is associated with indigestible components of carbohydrate, i.e. resistant starch (RS) (Faisant et al. 1995), which is related to amylose content much more strongly than amylopectin (Haralampu 2000). Starch fractions in raw banana flour (starch content 75 %) have 3 % of readily digestible starch, 15 % of slowly digestible starch and 57 % of RS (Englyst et al. 1992). While there is limited commercial use for raw banana starch in foods but substantial usage exists in cooked starch (Zhang et al. 2005).

In India, different banana cultivars are grown in various parts of the country for dessert and cooking purposes. About 15–20 % of harvested bananas are rejected at the harvest site and at the wholesale market. Converting these rejected banana fruits for banana flour based products leads to the development of the banana industry thereby profitable to farmers. Green banana flour is a low-cost raw material for the food industry and an alternative to minimizing banana wastes. To prepare unripened banana starch based products and to increase the banana fruit starch potential, information on starch, amylose and sugar content

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at maturity are necessary and such information are not available for Indian banana cultivars. In this study, fruits of common banana cultivars were analysed for different carbohydrate fractions in matured green banana fruits.

Nine banana cultivars of *Musa,* viz, AB 'Ney Poovan' (Safed velchi), AAA (Cavendish subgroup) 'Robusta', AAB 'Rasthali'(Silk), AAB 'Poovan'(Lal velchi), AAB 'Pachanadan'(Pome), AAB 'Nendran' (Plantain subgroup), ABB 'Karpuravalli'(Pisang Awak), ABB 'Monthan' (Cooking banana) and ABB 'Saba' (Cooking banana), were field grown during 2005–06 at National Research Center for Banana farm located in Trichy at 11.50°N latitude and 74.50°E longitude, 90 MSL. Three month old sword suckers were planted at a spacing of 2 × 2 m and the experiment was laid on Randomized Complete Block Design with three replications. Each replication had twenty plants for each cultivar. All recommended agronomic practices were uniformly adapted till harvest. Tagging was done at flowering in all cultivars from November 2005 to February 2006 as duration for flowering differs among cultivars. Plants flowered on same or next day were tagged for each variety. Two batches (November to December 2005 and January to February 2006) of tagging were done for each variety to take samples for physical and biochemical analyses. Three plants were tagged for each replication in each batch. We maintained more number of plants (20 per replication) in order to get more or less same date of flowering in each cultivar for two batches. At 90 % maturity, the green fruits were harvested from top 2nd hand of the bunch and brought to the laboratory immediately for physical and biochemical analyses.

The physical parameters of unripened green banana fruits were measured following the method of Dadzie and Orchard (1997). Following fruit measurements were recorded from fifteen fruits in each replication. Fruit length was measured on the outer curve of the individual fruit with a measuring tape from the distal end. Readings were taken from a minimum of five fruits from the second hand per bunch. Fruit circumference of individual fruit was measured with a measuring tape at the widest midpoint of each fruit. Readings were taken from a minimum of five fruits from the second hand per bunch. Fruit weight of Unripened matured green fruit, pulp and peel weight were determined in an electronic balance with two decimal places.

Fifteen green fruits from each replication were separated into pulp and peel with clean sharp razor and cut into ca. 5 mm^2 size. Five grams of pulp and peel were plunged into 95 % hot ethanol for measuring reducing and total sugars. For starch analysis, as soon as fruits were peeled off, the pulp was sliced and completely immersed in 2 % ascorbic acid solution to prevent oxidative browning. These treated sliced pulps were dried in hot air oven at the 55 °C for 48 h, milled into powder and sieved with 0.2 mm mesh and stored at 25 °C in air tight plastic containers for further analyses. The chemicals used for all biochemical analyses were AR or equivalent grade.

For sugar estimation the fruit samples preserved in 95 % ethanol were homogenized with mortar and pestle repeatedly with 20 ml of 80 % (v/v) ethanol in water following the method of Mc Cready et al. (1950). The extract was evaporated and subsequently treated with 1 ml of saturated lead acetate and the filtrate was collected in 3 ml of saturated disodium hydrogen phosphate. An aliquot was used for determining total and reducing sugars by Nelson (1944) and Somogyi (1952) arsenomolybdate method respectively. For starch estimation five g banana dry powder was hydrolyzed in 1°N HCl in glycerin bath at 112–115 °C and the starch was estimated by anthrone method following the method of Mc Cready et al. (1950) and Scott and Melvin (1953). The absorbance was read at 620 nm and starch content was calculated by multiplying the glucose values by 0.9 (Pucher et al. 1948). Amylose was estimated following the method given by Sadasivam and Manickam (1992) in powdered starch sample using distille. Amylopectin was calculated by subtracting the amylose from starch. The data were analysed using IRRISTAT ver. 5.0 software, a window based operating system.

Banana fruit at 90 % maturity recorded significant variations for the physical characteristics among the tested banana cultivars (Table 1). Fruit length and circumference varied with cultivars. Nendran and Monthan recorded significantly higher fruit length and Ney Poovan recorded the shortest fruit length among tested cultivars. Monthan and Saba recorded significantly higher fruit circumference than all other cultivars and Ney Poovan recorded the lowest circumference of all the cultivars tested. In case of fruit and pulp weight, Monthan recorded significantly higher weight and Ney Poovan recorded least fruit weight than other cultivars. A similar trend was observed in pulp and peel weight. In case of pulp and peel ratio, Ney Poovan recorded the highest followed by Rasthali and Poovan, indicating that theses cultivars had relatively thinner peel than other cultivars. The Monthan had thicker peel and recorded lower pulp and peel ratio. From these data, it was inferred that cooking banana and plantain banana had higher fruit weight and relatively thicker skin compared to common table cultivars like Ney Poovan, Rasthali and Poovan. Among dessert bananas, Pachanadan, Robusta and Karpuravalli recorded relatively thicker skin.

In unripened banana fruit pulp, sugars were analysed at maturity. In the fruit pulp, total sugar was recorded more than 2 mg/g of pulp on dry weight basis in all banana cultivars (Table 2). This range of total sugars in the unripened banana fruit pulp at maturity stage is in agreement with the earlier reports in banana (Lodh et al. 1972;

Table 1 Physical parameters of 90 % matured unripe banana fruits

Cultivars	Fruit length (cm)	Fruit circumference (cm)	Fruit wt. (g)	Pulp wt. (g)	Peel wt. (g)	Pulp/Peel ratio
Ney Poovan	12.83	11.00	57.93	43.80	14.13	3.09
Robusta (Cavendish)	20.83	13.00	135.21	85.65	49.55	1.74
Rasthali (Silk)	15.00	12.50	86.58	64.76	21.82	2.97
Poovan (Mysore)	14.67	12.50	91.38	67.35	24.03	2.80
Pachanadan (Pome)	15.83	13.78	130.55	80.12	50.43	1.59
Nendran (Plantain)	23.83	13.50	155.77	97.71	58.06	1.70
Karpuravalli (Pisang Awak)	14.16	12.30	88.47	64.34	24.13	1.60
Monthan' (Cooking banana)	19.83	16.67	192.94	114.57	78.38	1.46
Saba (Cooking banana)	15.67	16.62	136.45	90.32	46.13	1.97
CV %	5.90	4.30	10.20	10.70	9.10	8.30
LSD, $p = 0.05$	1.68	0.98	11.85	8.86	3.74	0.24

Venkatarayappa et al. 1976; Chellappan 1983). Reducing sugar was significantly higher in dessert bananas while non-reducing sugars were significantly higher in cooking bananas and plantain. Only Saba recorded more or less equal amount of both reducing and non-reducing sugars. From these data, it is very clear that there is a difference in the accumulation of reducing and non-reducing sugars in the fruit pulp at maturity in cooking and dessert banana. The Ney Poovan and Rasthali bananas recorded significantly lower total sugars; Karpuravalli, Nendran and Saba recorded significantly lower reducing sugar content and Ney Poovan recorded significantly lower non-reducing sugar content (Table 2).

In this study, starch content of unripened fruit of different banana cultivars was recorded in the range of 80.35–86.76 % (Table 2). Present finding was in agreement with the results of Gibert et al. (2009), who found that banana flour starch content on dry weight basis varied from 74.2 to 88.2 %. Starch content of tested cultivars did not vary much, except Ney Poovan recording significantly higher (86.62 %) than Pachanadan (80.35 %). Amylose content was recorded in the range of 24.41 % (Karpuravalli) to 36.87 % (Nendran). Dessert banana cultivars recorded amylose content in the range of 24.41–29.08 % except Pachanadan (34.83 %). In cooking banana and plantain (Saba and Nendran) amylose content recorded significantly higher (Table 2) than dessert bananas (Robusta). But, Pachanadan normally consumed as ripe fruit, recorded higher amylose content. Peroni et al. (2010) reported that total amylose content in Nanicão bananas was 15.1 and 15.6 % at harvest and ripe fruit respectively. Waliszewski et al. (2003) recorded higher amylose content (40.7 %) in cv.Valery. But these data cannot be compared to the present investigation due to differences in cultivar, stage of maturity and climate condition in which such banana cultivars were grown. In the present study amylose

Table 2 Total sugars, reducing sugars, non-reducing sugar, starch, amylose and amylopectin content of fully matured banana pulp

Cultivars	Total sugars (mg/g of pulp dry weight)	Reducing sugar (mg/g of pulp dry weight)	Non-reducing sugars (mg/g of pulp dry weight)	Banana pulp starch (%)	Banana pulp amylose (%)	Banana pulp amylopection (%)
Ney Poovan	2.05	1.66	0.39	86.62	29.08	57.54
Robusta (Cavendish)	2.15	1.55	0.6	84.76	25.46	59.29
Rasthali (Silk)	2.08	1.13	0.95	84.46	27.03	57.43
Poovan (Mysore)	2.47	1.85	0.62	82.18	26.40	65.78
Pachanadan (Pome)	2.28	1.84	0.44	80.35	34.83	45.52
Nendran (Plantain)	2.64	0.8	1.84	84.75	36.87	47.88
Karpuravalli (Pisang Awak)	2.53	0.78	1.75	82.67	24.41	58.27
Monthan' (Cooking banana)	2.62	0.84	1.78	83.29	36.64	46.65
Saba (Cooking banana)	2.56	1.02	1.54	83.26	35.18	48.08
CV %	3.60	2.60	1.30	8.21	7.30	8.03
LSD, $p = 0.05$	0.11	0.09	0.06	4.04	2.92	3.03

content distinguishes dessert bananas from plantain and cooking bananas.

Matured unripe banana flour has both nutritional and nutraceutical values. Unripe banana flour based products have beneficial effects to human health, because of its higher content of RS (Faisant et al. 1995). Besides, amylose positive association with RS content (Haralampu 2000) and its ratio to amylopectin indicates the pattern of crystallization during the starch composite making (Guimarães et al. 2010). As amylose is highly related to RS and there is substantial potential exists in banana starch flour based foods. RS is not digested in the upper gastrointestinal tract, but is fermented by microorganisms in the colon that produce short chain fatty acids (SCFA). SCFAs provide additional energy to the body along with a high proportion of butyrate that is beneficial to colonic health (Topping et al. 2003). Awareness among people are becoming more with nutritional requirements other than minerals and vitamins (WHO/FAO 2003). They consume diet not only starch for satiety and also for health (Park et al. 2004). Cookies prepared with unripened banana flour had favourable starch digestion characteristics and, therefore, could be a nutritional alternative for people with health problems such as diabetes and obesity (Acevedo et al. 2012). Literatures revealed that unripe banana starch flour mixed foods such as pasta (Saifullah et al. 2009), bread (Juárez-García et al. 2006) and cookies (Aparicio-Saguilán et al. 2007) had high resistant starch content.

Functional food like cookies prepared with unripened banana flour could make nutritional alternative to people with health problems such as diabetes and obesity. Unripe banana starch flour mixed foods such as pasta, bread and cookies had high resistant starch content. In this scenario, Nendran, Monthan and Saba unripened fruit flour with higher amylose content are having high potential for food industries and farmers who are growing conventional cooking bananas like Monthan and Nendran can get more profit. Banana flour based fruit industries paves way for reducing considerable post harvest losses as rejected bananas at wholesale market could be used in banana flour preparation and subsequently in food industries.

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