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Evaluation of banana varieties and osmotic agents on physical attributes of intermediate moisture (IM) banana

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Abstract

The study aimed to evaluate the effect of different osmotic agents on the physical attributes of Intermediate Moisture (IM) fruit, using six cultivars of banana (*Musa spp.*) belonging to different genomic groups *viz.* Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (ABB) and Yangambi km5 (AAA). Banana fruits were cut into longitudinal slices of 8mm thickness to evaluate the physical quality using seven osmotic agents (sucrose, glucose, sucrose + sorbitol, glucose + sorbitol, palm sugar, honey, sucrose + NaCl). The fruits were steam blanched for 2 minutes before being immersed in osmotic solutions for an 8-hour duration at a fruit: osmotic solution ratio of 1:2 and subsequently dried for two hours using a tray drier at 60°C. A significant difference (p=0.05) in water loss was only for the variety Grand Naine (62.12%) in fruits treated with honey and the lowest (29.77%) in the variety Karpooravalli in fruit slices immersed in sucrose. Higher (23.55%) solid gain was recorded in the variety Grand Naine in fruit slices immersed in glucose syrup and lowest (5.83%) in the variety Karpooravalli in fruit slices treated with honey. IM banana of variety Pisang Lilin had the highest (45.40%) weight loss in fruit slices immersed in honey and the lowest (19.13%) in variety Pisang Lilin in fruit slices immersed in glucose+sorbitol. IM banana from variety Njalipoovan had the highest (27.46%) moisture content in fruit slices immersed in palm sugar (T5) solution and the lowest (13.53%) in variety Nendran in fruit slices immersed in sucrose+NaCl. A higher value for water activity was in IM banana variety ‘Pisang Lilin’ treated with sucrose (0.86) and the lowest (0.79) was recorded in varieties Nendran and Grand Naine. IM banana developed from all six varieties treated with honey and combinations of sucrose, glucose, and sorbitol had the lowest water activity. It can be concluded that the more the ‘A’ genome in banana varieties, the higher its permeability for mass transfer. IM banana treated with honey, a combination of sucrose and glucose, and sorbitol had higher values for water loss, solid gain and weight loss and lower values for moisture content and water activity.

Key words: Banana; intermediate moisture; osmotic agent; physical characteristics

Introduction

Banana (*Musa spp.*) is one of the most important fruit crops in international trade, cultivated in the tropical and subtropical zones of more than 120 countries (Bakry *et al.,* 2009; Dayarani *et al.,* 2014). India is the largest producer of bananas, contributing to 25.7 per cent of the global production at 31747000 metric tonnes in an area of 898,612 hectares, with 52898.61 hectares producing 424948.07 tonnes from Kerala alone (GOK, 2020).

Even though India produces a large percentage of the world’s bananas, between 20 and 30% of post-harvest banana losses have been reported, generating challenges in the marketing system (Farooq *et al.*, 2018). Various banana cultivars, including commercially cultivated cultivars such as Nendran, Palayankodan, Rasthali, Monthan, Red Banana, Njalipoovan, Karpooravalli, and Robusta, have had post-harvest losses (GOI, 2015). Dehydration is one of the simplest preservation methods, with the benefits of enhanced shelf life and reduced fruit weight, which lowers handling and packaging costs. Dehydration by osmosis (osmotic dehydration) involves the partial removal of water from fruit pieces by immersing it in a concentrated solution of humectants such as sugars, low molecular weight polyols, protein derivatives, and mineral and organic salts (Carnovas *et al.*, 2007). Pretreatment procedures, such as blanching, combined with substances like sodium sulphate, citric acid, and potassium metabisulphite, play a vital role in preserving dehydrated products’ physical and chemical attributes (Ranjan *et al.*, 2014). Following the completion of these preliminary steps, the liquid is removed, and the fruit is then subjected to either freezing or drying processes to create a stable product with minimal water content, falling within the 0.65-0.90 water activity range (with 15-40% moisture content). This product is known as Intermediate Moisture (IM) fruit. The sugars investigated in this study are particularly popular due to their natural origins, limited processing, and low glycemic index, rendering them a healthier choice. Consequently, the current research underscores the potential of novel osmotic agents, as opposed to commonly employed ones, regarding their impact on the physical characteristics of Intermediate Moisture (IM) bananas. This has the potential to mitigate significant post-harvest losses caused by excessive yields and subsequent market oversupply.

This study aimed to examine the effects of various osmotic agents on the physical properties of Intermediate Moisture (IM) fruit in six banana cultivars from distinct genetic groups. The study also examined differences in water loss, solid gain, weight loss, moisture content, and water activity among varieties and osmotic agents.

Material and methods

The study was carried out in the Department of Post Harvest Technology, College of Agriculture, Vellanikkara, Thrissur, Kerala, between the period of December 2020 to March 2021 using six banana varieties of different genomic groups *viz.* Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA). The fruits of the respective varieties were collected from the Banana Research Station, Kannara, Kerala where they were grown under uniform conditions as per Package of Practice Recommendations of the Kerala Agricultural University (KAU, 2016).

Preparation of intermediate moisture banana: Firm, ripe banana fruits from the six varieties were cut into 8 mm longitudinal slices, followed by steam blanching for 2 minutes. The blanched fruits were then immersed in ice-cold water for 10 minutes and dipped in acid lime (*Citrus aurantiifolia*) juice for 30 minutes. The banana fruit slices were subsequently immersed separately in seven different osmotic agents combined with ascorbic acid (0.5%) and potassium metabisulphite (0.25%) at fruit: solution ratio of 1:2 for 8 hours. The osmotic solution was then drained from the fruit slices, blotted using an absorbent paper, and dried at 60 ^{o}C in a tray drier until it attained equilibrium moisture content between two successive hours. The treatment combinations of the experiment consisted of T1-sucrose (60 ^{o}Brix sucrose + 0.5% ascorbic acid + 0.25% potassium meta-bisulphite), T2-glucose (60 ^{o}Brix + 0.5% ascorbic acid + 0.25% potassium meta-bisulphite), T3-sucrose: sorbitol (60 ^{o}Brix (50:50) + 0.5% ascorbic acid + 0.25% potassium meta-bisulphite), T4-glucose: sorbitol (60 ^{o}Brix sucrose (50:50) + 0.5% ascorbic acid + 0.25% potassium meta-bisulphite), T5-palm sugar (concentrated product of sap from the palm, *Borassus spp*.) (60 ^{o}Brix + 0.5% ascorbic acid + 0.25% potassium meta-bisulphite), T6- honey + 0.5% ascorbic acid + 0.25% potassium meta-bisulphite), T7-sucrose+NaCl (60 ^{o}Brix sucrose + 0.5% sodium chloride + 0.25% potassium meta-bisulphite).

Physical qualities

Solid gain: The solid gain per cent was calculated using the method adopted by Panagiotou *et al.* (1999) which is as follows:

$$\text{Solid Gain (SG)} = \frac{m - m_o}{m_o}$$

Where:
m = dry mass (g) of fruit after time 't' of osmotic treatment
m_o = dry mass (g) of fresh fruit
M_o = initial mass (g) of fresh fruit prior to the osmotic treatment

Weight reduction: Weight reduction per cent of banana slices was calculated by the method described by Sridevi and Genitha (2012), which is as follows:

$$\text{Weight reduction (WR)} = \frac{M_o - M}{M_o}$$

Where
M_o = initial mass of sample (g)
M = mass of the sample after dehydration (g)

Water loss: The water loss percentage was calculated using the method described by Chavan *et al.* (2010) where per cent weight reduction (WR) and solid gain (SG) were summed WR+SG.

Moisture content: Moisture content of the fresh and IM banana was determined using an infra-red moisture analyser (Hallmark Mechatronics, Model-Sartorius, MA 150C, Germany) which records moisture in percentage.

Water activity: Water activity was estimated using a water activity meter (Aqua lab, Model- Pre 40412, Decagon Devices, USA) in which a digital output value was directly observed after filling the cup with a sample to about half of its capacity.

Data analysis: The experiment was laid out in a completely randomised design with three replications and presented as means in one-way ANOVA to examine the significant differences using Web Based Agricultural Statistics Software Package (WASP) for analysis. Duncan's multiple range test was used for the comparison of means at 95% confidence level (p=.05).

Results and discussion

Solid gain: Table 1 shows that IM banana slices of variety Grand Naine have a high solid gain, with the maximum (23.55%) values recorded in fruit slices immersed in glucose solution (T2) and the lowest (5.33%) solid gain recorded in fruit slices immersed in honey (T6) for variety Karpooravalli. Grand Naine, Yangambi km5 and Pisang Lilin, dominated by genome 'A', showed greater solid gains than Nendran, Njalipoovan, and Karpooravalli, dominated by genome 'B'. Fruits with a dominant "A" genomic group are softer in texture, making them more permeable to mass exchange during osmodehydration than those with a "B" genome. Since the molecular weight of glucose and honey is the same, which is both 180.16g/mol, the structural and biochemical differences between banana varieties reflect the heterogeneity of solid gain. These differences mostly relate to initial insoluble and soluble solid content, intercellular compactness, and enzymatic activity (Tortoe, 2010). This substantially affects the diffusion between fruit and osmotic agent, giving rise to considerable

Table 1. Effect of osmotic agents and varieties on solid gain (%) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine(AAA)	Yangambi km5 (AAA)
T1	12.28	12.59^{bcd}	13.63^{ab}	11.57	19.50	16.33
T2	15.40	9.04^{d}	10.90^{cd}	14.72	23.55	18.55
T3	14.03	19.53^{a}	16.00^{a}	12.07	21.08	13.13
T4	15.28	18.64^{ab}	11.80^{bc}	13.00	23.44	17.11
T5	11.75	15.98^{abc}	14.80^{a}	9.88	20.10	11.76
T6	12.25	10.00^{cd}	5.83^{e}	11.79	22.69	16.43
T7	13.70	15.50^{abcd}	8.83^{d}	9.63	18.35	13.98
Mean	13.50	14.47	11.68	11.81	21.24	15.53
CD (0.05)	NS	6.67	2.51	NS	NS	NS

T1: Sucrose (60 ^{o} Brix), Ascorbic acid (AA) 0.5%), Potassium metabisulphite (KMS)(0.25%) ; T2: Glucose (60 ^{o} Brix) AA (0.5%) KMS (0.25%); T3: Sucrose+ sorbitol (50:50 ratio) (60 ^{o} Brix), AA (0.5%). KMS (0.25%); T4: Glucose+ sorbitol (50:50 ratio) (60 ^{o} Brix), AA (0.5%). KMS (0.25%); T5: Palm sugar (60 Brix), AA (0.5%), KMS (0.25%); T6: Honey, AA (0.5%), KMS (0.25%); T7: Sucrose (60 ^{o} Brix), Sodium chloride (0.5%), KMS (0.25%);

differences in solid gain. According to Shanmugasundaram and Haripriya (2014), the high solid gain in the AAA genome banana variety Dwarf Cavendish is due to the lower initial total soluble solid content and the semi-permeable nature of the membrane, which allows more solids to permeate into the fruit than in the AAB genome variety Poovan, confirming the present study.

Water loss and weight reduction: The dehydration principle is to draw out moisture from the cell tissues to a desired moisture level. Table 2 shows the water loss of IM banana varieties, with Grand Naine having the maximum (62.21%) water loss in fruit slices immersed in honey (T6) and Karpooravalli having the least (22.97%) water loss in fruit slices immersed in sucrose: NaCl solution (T7). The osmotic agent's molecular weight corresponds to a higher osmotic pressure gradient in the cytoplasm and vacuole, resulting in water loss and weight loss in the fruit cells (Ahmed *et al.,* 2016). When compared to larger molecular weight osmotic agents like sucrose (342.30g/mol), palm sugar (256.50g/mol), and sorbitol (182.17g/mol), honey's low molecular weight (180.16g/mol) raised the osmotic pressure in the osmotic solution, allowing for increased driving force for water loss. Chavan *et al.* (2010) and Chauhan *et al.* (2011) reported similar ranges of values for water loss in banana and apple, respectively.

For ease of transport and storage, fruit weight loss while preserving their original shape during processing is very critical. Table 3 shows that the IM banana from Njalipoovan had the highest weight reduction (45.40%) in fruit slices immersed in honey (T6), while the variety Pisang Lilin had the lowest (19.13%) in fruit slices immersed in glucose+sorbitol solution (T4). IM banana fruits immersed in honey (T6) exhibited the highest weight reduction across all banana varieties, while glucose+sorbitol solution (T4) had the lowest. Respective studies on bananas and melons by Chavan *et al.* (2010) and Ferrari *et al.* (2010) demonstrate a direct relationship between water loss and weight loss, which is relevant to the present study. Similar studies on the protective effect of sorbitol solution compared to other agents on the weight reduction of IM fruit were also observed by Riva *et al.* (2005) on the geometric features of osmo-air-dried apricot cubes.

Moisture content: The shelf life of food is extended when the moisture content is reduced. From Table 4, IM banana from variety Njalipoovan had the highest (27.46%) moisture content in fruit slices immersed in palm sugar solution (T5) and the lowest (13.53%) recorded for Nendran in fruit slices immersed in sucrose+NaCl solution (T7). The function of sugars in terms of solubility and hygroscopicity dominates their physical qualities. The hygroscopicity of a sugar is proportional to its solubility. Fructose, a highly soluble and hygroscopic sugar that is prominent in palm sugar, and its cryoprotective actions, which are critical in maintaining the physical and biochemical condition of dried

Table 2. Effect of osmotic agents and varieties on water loss (%) of IM banana

Treatments	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	52.18	41.64	34.71	48.27	52.09^{c}	50.36
T2	52.15	45.00	33.40	51.15	58.35^{ab}	52.28
T3	52.18	55.94	35.57	50.42	54.38^{bc}	53.38
T4	52.18	41.24	31.63	50.43	54.52^{bc}	50.75
T5	52.15	41.409	30.60	51.73	53.64^{bc}	53.28
T6	52.15	42.18	40.53	57.20	62.12^{a}	56.68
T7	52.15	47.49	29.77	51.33	52.74^{bc}	50.42
Mean	52.20	45.00	33.74	51.50	55.41	52.45
CD (0.05)	NS	NS	NS	NS	5.89	NS

See the bottom of Table 1 for treatment abbreviations.

Table 3. Effect of osmotic agents and varieties on weight reduction (%) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	39.90	31.78^{ab}	21.23	36.70	32.58	33.98
T2	36.75	34.61^{a}	22.50	36.68	34.80	33.73
T3	38.15	35.18^{a}	19.57	38.35	33.30	40.25
T4	36.90	19.13^{c}	19.83	37.43	31.08	33.64
T5	40.40	25.43^{bc}	20.80	41.85	33.53	41.53
T6	39.90	37.50^{a}	34.70	45.40	39.43	40.25
T7	38.45	30.95^{ab}	20.93	41.60	34.38	36.44
Mean	38.60	30.65	22.79	39.72	34.12	37.12
CD (0.05)	NS	9.02	NS	NS	NS	NS

See the bottom of Table 1 for treatment abbreviations.

Table 4. Effect of osmotic agents and varieties on moisture content (%) of IM banana

Treatments	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	16.68	17.44	19.03	25.28^{ab}	16.22^{b}	14.39^{b}
T2	18.46	18.05	15.20	16.93^{d}	15.29^{b}	14.49^{b}
T3	16.50	17.10	17.50	21.85^{bc}	18.65^{a}	20.36^{a}
T4	18.12	18.38	16.99	25.36^{ab}	15.31^{b}	15.19^{b}
T5	15.10	16.37	20.00	27.46^{a}	15.12^{b}	16.60^{b}
T6	19.48	17.52	18.53	19.72^{cd}	15.01^{b}	15.45^{b}
T7	13.53	19.33	20.01	23.24^{abc}	16.64^{b}	15.97^{b}
Mean	16.84	17.74	18.18	22.83	16.03	16.06
CD (0.05)	NS	NS	NS	4.90	1.68	3.18

See the bottom of Table 1 for treatment abbreviations.

Table 5. Effect of osmotic agents and varieties on water activity (a_w) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	0.79^{bc}	0.86	0.85	0.83^{a}	0.80^{a}	0.82^{ab}
T2	0.79^{bc}	0.85	0.81	0.80^{ab}	0.78^{ab}	0.81^{abc}
T3	0.79^{bc}	0.82	0.82	0.79^{abc}	0.78^{ab}	0.80^{bc}
T4	0.74^{d}	0.80	0.80	0.78^{bc}	0.78^{ab}	0.78^{cd}
T5	0.87^{a}	0.82	0.82	0.82^{ab}	0.80^{a}	0.84^{ab}
T6	0.75^{cd}	0.78	0.75	0.75^{c}	0.75^{b}	0.75^{d}
T7	0.80^{b}	0.81	0.84	0.81^{ab}	0.80^{a}	0.84^{a}
Mean	0.79	0.82	0.81	0.80	0.79	0.80
CD (0.05)	0.04	NS	NS	0.04	0.04	0.04

products, describe palm sugar's high hygroscopicity (Davis, 1995; Le *et al.,* 2020). The low moisture content of IM banana treated with sucrose+NaCl (T7) is most likely due to high dehydration of sodium chloride, which can prevent sugar from creating a crust that acts as a barrier to water transport, as explained by Tsamo *et al.* (2005). Predictive studies by Rai *et al.* (2004) recorded the moisture content of IM papaya cheese to be in the range of 17.42 to 21.4 per cent. Panwar *et al.* (2013) observed the moisture content of IM aonla segments to vary from 24.67 to 31.33 percent in glycerol and sucrose, respectively, which decreased with storage.

Water activity: A direct relationship exists between high water activity and food spoilage. The water activity of IM bananas prepared by different osmotic agents and bananas of different varieties is presented in Table 5. Substantial variability was found between water activity recorded on half of the banana varieties selected for the present study, where the highest (0.87) values were in variety Nendran (0.87) in fruit slices treated with palm sugar solution (T5). The lowest water activity values among all the banana varieties, below 0.80, were IM bananas treated with honey (T6). The results also showed that when sucrose and glucose were combined with sorbitol, the water activity was lower than when the sugars were used singly. Yadav and Singh (2014) reported that a blend of osmotic agents successfully lowered the water activity of fruits and vegetables due to a combination of properties of both solutes, which supported the current investigation. Din *et al.* (2019) reported a_w values ranging from 0.4 to 0.7 in IM muskmelon chunks, whereas a_w values ranging from 0.44 to 0.85 were reported by Rodriguez *et al.* (2015) in osmo-air dried plums.

IM bananas of different cultivars showed similarities and differences in osmotic agent response to physical attributes. Physical characteristics determined the best osmotic agent. Honey, sucrose-glucose, and sorbitol were potential IM banana osmotic agents. IM banana treated with honey, sucrose-glucose, and sorbitol had higher water loss, solid gain, and weight loss and lower moisture content and water activity. IM bananas with AAA genomic constitutions like Grand Naine had better water loss, solid gain, weight loss, moisture content, and water activities than Karpooravalli of ABB genome.

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