

Efficacy of alum treatment and vacuum packaging in controlling crown rot disease of Cavendish banana

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Abstract

Cavendish is the widely grown banana cultivar in the world today and the most prominent cultivar in the international trade. Crown rot, one of the most drastic postharvest diseases of Cavendish banana can cause severe postharvest loss both in the local and export markets. In the industry, cut crowns of banana are treated with fungicides to control this disease. Due to hazardous effects of fungicides, finding suitable alternatives in the management of crown rot of banana is essential. In this study, effect of alum (potassium aluminium sulphate) in combination with vacuum packaging was investigated in controlling crown rot disease and extending the shelf life of Cavendish banana at cold storage.

Twelve week mature Cavendish banana (*Musa acuminata*, AAA, Grande Naine cultivar) hands were treated with 1% (w/v) alum or distilled water (controlled). Treated and control fruits were packed in Low density polyethylene bags, air inside bags were removed using vacuum and placed in fiberboard cartons and stored in a cold room at 12-14 °C. Each treatment comprised 10 replicate boxes each with 5 hands. In-package gases were analyzed after 14 days of cold storage. Physicochemical properties (pH, TSS, TA and firmness), sensory properties (peel colour, flesh colour, aroma, flavour, taste and overall acceptability) and crown rot disease severity were determined in ripening induced fruits. Test marketing trials were conducted at CIC fruit outlet in Dambulla, Sri Lanka where treated fruits were provided to consumers and staff to obtain feedback on the quality of treated banana.

At the end of 14 days, mean O₂ in packages remained between 5.1 to 5.5% while mean CO₂% was maintained at 5.3%. Alum in combination with vacuum packaging

significantly controlled crown rot disease of Cavendish banana compared to the control. Physicochemical and sensory properties were unaffected by alum + vacuum packaging treatment when compared to control. Treated banana obtained higher score values from the customers and staff of fruit outlets for the sensory properties compared to the control. Therefore, this eco-friendly treatment strategy could be recommended in preparing Cavendish banana for local market as well as commercial scale export to various destinations which require a transit time of two weeks.

Key words: *Crown rot, Cavendish banana, vacuum packaging, alum, postharvest*

Introduction

Banana is the fourth most important food crop used globally and it is the staple food and economic life line for many countries. The sugar rich and low-fat bananas have varied uses as infant food, functional food, dessert, carbohydrate based staple food and many more diversified food / feed uses (Mohapatra *et al.*, 2010). Banana is ranked as the first most important traded fresh fruit in terms of volume, while it ranks second after citrus fruits in terms of value (Ewané *et al.*, 2012). Banana is considered as a good source of many vitamins and minerals, particularly vitamins A, B₆ and potassium. Due to low sodium and high potassium content of this fruit they are recommended in low-sodium diets. Banana is useful for patients with peptic ulcers, for treatment of infant diarrhea, in celiac disease and in colitis. They are also ideal for patients with gout or arthritis, blood pressure and heart disease (Robinson, 1996). Apart from their high nutritional value, they have a delightful flavour and are available in all seasons of the year (Mitra, 1997). Of the various banana cultivars, Cavendish (genome AAA) is the predominant commercially grown and largely traded banana cultivar in the world today (Alvindia, 2013).

Being a delicate and highly perishable fruit, banana suffers severe postharvest losses, due to poor handling and diseases. Crown rot is the most drastic postharvest disease of Cavendish banana causing severe losses both in the local and export markets. This disease develops rapidly during fruit ripening, reducing the quality and marketability of fruits. Crown rot is caused by a broad unspecific and opportunistic fungal parasitic complex

including *Lasiodiplodia theobromae*, *Colletotrichum musae*, *Fusarium spp.*, *Verticillium spp.* and *Cephalosporium spp.* (Abd-Alla *et al.*, 2014). Crown rot fungi colonize decaying banana leaves, flowers, bracts, and field debris and conidia are dispersed by wind or rain onto the banana bunch (Williamson *et al.*, 2008). Although, fruit contamination could occur within the field, mostly it happens in the washing tanks at the packing station where processing favors the penetration of pathogens into the crown tissues. The banana crowns, healthy at harvest, could develop a fungal infection after a few days of shipping and upon arrival, the degraded quality of the banana fruits does not allow to secure the position in export market (Ewané *et al.*, 2012). In order to protect fruit against fungal attack which causes crown rot during shipment, banana crowns are treated with fungicides such as thiabendazole, imazalil and bitertanol. The application methods vary markedly, including dipping, spraying and cascade treatment, but in every case the bananas are thoroughly wetted to ensure the fungicide treatment efficacy (Jijakli *et al.*, 2010).

However, inorganic banana production, finding suitable alternatives for fungicide usage in controlling of crown rot is essential. Alum (potassium aluminum sulfate), in the chemical formula of $KAl(SO_4)_2 \cdot 12H_2O$, is an odourless and colourless crystalline solid which turn white in air, and is used as an astringent and antiseptic in food preparation practices such as pickling and fermentation and as a flocculant for water purification (Clark, 1970). Further, alum has been recommended as a category I active ingredient in mouthwashes by Food and Drug Administration (FDA) (Olmez *et al.*, 1998). Alum is non-toxic and is used to cure canker sores. Alum solution has also been used to prolong shelf-life of tomatoes. In the banana industry 1-2% of alum is added to delatexing tanks to prevent flow of latex from the wounds of cut crown to prevent causing of dark stains, which results in an unattractive appearance of fruits (Cemanes and Gabornes, 2013).

In this study, efficacy of alum in combination with vacuum packaging was investigated in controlling crown rot disease and extending the shelf life of Cavendish banana during cold storage. Test marketing trials were conducted in order to obtain feedback on the quality of alum treated and vacuum packed banana. Therefore, the aim of this study was to examine in-package gas composition and crown rot disease severity and to evaluate physicochemical, nutritional and sensory properties of alum treated Cavendish banana

which were subjected to vacuum packaging and stored at 12-14 °C for 14 days and to identify consumer and supermarket staff acceptability of the alum treated banana during test marketing trials.

Materials and methods

Twelve (12) week mature Cavendish banana (Grande Naine cultivar) bunches were harvested from CIC banana plantation in Pelwehera, Dambulla, Sri Lanka. Banana bunches were transported to the CIC banana pack house, at Dambulla. Bunches were deheaded and approximately 1 kg hands were selected as experimental units. All hands were washed in water to remove dirt and then with alum (1% w/v). The control sample was washed only with water. After drying, hands were placed in low density polyethylene (LDPE) bags (150 gauge) of 74×64 cm surface area and polyethylene foam liners were placed on top of banana to provide protection to fruit. Air inside the bags was removed using a vacuum cleaner and mouths of bags were tied tightly with rubber bands and packed in (40×29×19 cm³) 3-ply fiberboard cartons. Each treatment comprised of ten replicate boxes, each containing five hands (weighing 5.0-5.5 kg). All treatment boxes were stored in a cold room at CIC banana pack house, Dambulla at 12-14 °C under 85-90% relative humidity. The experimental arrangement was a completely randomized design (CRD). Six boxes per treatment were transported to University of Kelaniya on the 14th day of storage and immediately subjected to in-package gas analysis, pathological, physicochemical, nutritional and sensory evaluation. The rest of the boxes kept at cold room at CIC banana pack house were subjected to induce ripening on 14th day and subjected to pathological evaluation and subsequently, samples were provided to CIC staff and consumers visiting CIC fruit outlet in Dambulla along with a questionnaire (Siriwardana *et al.*, 2016).

In-package gas analysis

In-package gas (O₂ and CO₂) concentrations within bags were measured using an Oxygen and Carbon Dioxide Head Space Gas analyzer (Model 902 D, Quantek Instruments, Grafton, MA) on the 14th day of treatment before ripening banana. A needle was inserted

in to each polyethylene bag and a small sample of package headspace gas was pumped into the gas analyzer and O₂ and CO₂ measurements were taken. Five replicate measurements were taken per treatment (Kudachikar *et al.*, 2011; Siriwardana *et al.*, 2016).

Ripening of banana

Samples taken out from bags after two-week storage period were subjected to induced ripening by exposure to ethylene (thrill (480 g/L ethephon), 1 mL in 1 L of water) for 24-48 h at room temperature inside plastic buckets at University of Kelaniya. When banana fruits attained the fully ripe stage, pathological and other properties were assessed in ripe fruits as below (Siriwardana *et al.*, 2016).

Pathological properties

Crown rot disease severity of each hand was recorded using a standard index developed at the Department Botany, University of Kelaniya (Crown Rot Severity (CRS) 0 = No rot, 1 = 25% Crown rot, 2 = 50% Crown rot, 3 = 75% Crown rot, 4 = 100% Crown rot) (Abeywickrama *et al.*, 2009; Siriwardana *et al.*, 2016).

Physicochemical properties

Ten fingers selected at random from each treatment were subjected to physicochemical analysis. The firmness of the cross sections of ripe fruits (1 cm thickness) were measured using a fruit firmness tester (FT 011, QA Supplies, Italy). pH of the filtrates were measured using a digital pH meter (PC 510, EUTECH Instruments, Singapore). Total soluble solids (TSS) of filtrates were recorded using a hand-held Refractometer (ATC, ATAGO, Japan, Brix; 0-32%) (Abeywickrama *et al.*, 2009; Siriwardana *et al.*, 2016).

Sensory properties

Ten randomly selected fingers from each treatment and control were provided to a ten member trained sensory panel at University of Kelaniya along with a questionnaire to evaluate peel colour, flesh colour, aroma, flavour, taste and overall acceptability. Score values were obtained for each parameter according to an evaluation scale (Excellent = 9-

10, Good = 6-8, Fair = 4-5, Poor = 1-3). Twenty replicate samples were used per treatment. The treated banana were stored in cold room at CIC, Dambulla was ripened as mentioned previously and were made available to the consumers and staff at the CIC fruit outlet in Dambulla. Questionnaires were given to consumers and staff to obtain feedback with respect to peel colour and taste. Twenty replicate samples were used per treatment (Siriwardana *et al.*, 2016).

Nutritional properties

Moisture content

Five induced ripened fruits selected at random from each treatment were used. Ten grams of pulp from each finger were placed in a dried weighed crucible. The crucible with samples were placed in a drying oven (FEB87, Astell Hearson, UK) at 105 °C and heated for 3h. After cooling, dried samples were reweighed and this was repeated until a constant weight was obtained. The weight difference was calculated as a percentage of the original sample (AOAC, 1990; Nwosu *et al.*, 2011). Five replicate samples were used per treatment and mean value was taken as moisture content.

$$\text{Percentage moisture} = \frac{M_2 - M_3}{M_2 - M_1} \times 100 \text{ -----} \rightarrow (1)$$

Where,

M_1 = Initial weight of empty dish

M_2 = Weight of dish & sample before drying

M_3 = Weight of dish & sample after drying

Dehydration of banana samples

Five induced ripened fruits selected at random were used from each treatment. Flesh from each fruit was diced and dehydrated in a drying oven (FEB87, Astell Hearson, UK) at 70 °C until constant weight was obtained. Dehydrated samples were ground and sealed in polythene bags and kept in a desiccator. Dehydrated samples were used in determining crude protein, ash, fat and mineral contents.

Ash content

One gram of dehydrated sample was placed in a clean, oven dried incineration crucible of known weight. Crucible was covered with pricked aluminium foil and total weight was recorded. Sample was incinerated at 550 °C in a muffle furnace (ECF 12/6, Lenton Furnaces, UK) until it turned white and free of carbon. Weight of the cooled crucible with the sample was measured and the percentage of ash was calculated. Five replicate samples were used per treatment and mean value was taken as ash content (AOAC, 1990; Nwosu *et al.*, 2011).

$$\text{Percentage Ash} = \frac{\text{Weight of Ash}}{\text{Weight of original of sample}} \times 100 \text{-----} \blacktriangleright (2)$$

Crude protein content

The Kjeldahl method was used in determining the crude protein content. From each of the dehydrated banana samples, 0.5 grams was transferred to the 30 mL Kjeldahl flask. Ten (10) mL of tri-acid mixture of HNO₃:H₂SO₄:HClO₄ (9:4:1) and Kjeldahl catalytic mixture (0.5 g) were added to the flask and digested using digestion chamber until a clear solution is obtained. Digested sample dissolved in minimum amount of NH₃ free distilled water was transferred to the Kjeldahl distillation apparatus which was previously conditioned by passing steam for several minutes. Twenty five (25) mL of 4% boric acid and 3 drops of Kjeldahl indicator were added to a titration flask and clamped to the end of the distillation apparatus. Ten (10) mL of 40% NaOH solution was added to the distillation flask and liberating ammonia was trapped using boric acid solution. Boric acid solution was titrated with 0.1 N HCl solution. The Nitrogen content was calculated using the below equation and multiplied with 6.25 to obtain the crude protein content. Five replicate samples were used per treatment and mean value was taken as protein content (AOAC, 1990; Nwosu *et al.*, 2011).

$$\text{Percentage Nitrogen} = \frac{V \times N \times 14 \times 100}{W \times 100} \text{-----} \blacktriangleright (3)$$

Where,

N= Normality of HCl

V= Volume of HCl used for sample titration

W = Weight of sample taken

Fat content

Two grams of dehydrated banana sample was loosely wrapped with a filter paper and put into the thimble which was fitted to a clean round bottom flask, which has been cleaned, dried and weighed. The flask contained 120 mL of petroleum ether. The sample was heated to 50 °C with a heating mantle and allowed to reflux for 5h. The heating was then stopped and the thimbles with the spent samples kept and later weighed. The difference in weight was recorded as mass of fat and is expressed a percentage (%).

$$\text{The percentage oil content is percentage fat} = \frac{M_2 - M_1 \times 100}{M_3} \text{ ----} \rightarrow (4)$$

Where,

M_1 = weight of the empty extraction flask

M_2 = weight of the flask and oil extracted

M_3 = weight of the sample

Mineral content

Mineral content of banana fruit samples were determined using dehydrated samples. A sample of 400 mg dehydrated banana fruit flesh was wet digested (180 °C for 15 min) with 10 mL of 69% HNO₃ using a microwave digester. Digested samples were filtered through a filter paper layer and the filtrate was raised up to 25 mL using distilled water. Blank digestion was carried out without adding samples. Digested sample were collected into plastic vessels and the concentration of metals; magnesium (Mg), potassium (K), calcium (Ca), copper (Cu), manganese (Mn), iron (Fe) and Zinc (Zn) were determined using an Atomic Absorption Spectrophotometer (SpectrAA-110, Varian, Australia). Phosphorous (P) was tested using a UV-Visible Spectrophotometer (Cary 60, G6860A, Agilent Technologies, Australia). Mineral content were expressed as mg/100g of fresh

weight (AOAC, 1990). Five replicate samples per treatment were used for determining each mineral and the mean values were calculated.

Results and discussion

In-package gas analysis

Mean O₂% in vacuum packaged (VP) alum treated and control Cavendish banana were within 5.1-5.5 % while CO₂% recorded a value of 5.3% at the end of the storage period (Table 1). Further, gas concentrations in alum treated banana were not significantly different from control samples.

In vacuum packaging, air around the banana within polyethylene packages is removed. However, a certain amount of oxygen is remained, since it is not possible to create a total vacuum. By removing air around the banana, oxygen level in the packaging is reduced, impeding the metabolism of some pathogenic agents that can survive on the banana crown. The lack of oxygen also reduces the amount of spoilage due to oxidation, which could cause browning in banana. Altered gas composition of packages through vacuum packaging result decrease of fruit respiratory intensity and endogenous ethylene synthesis, and thereby increase the length of the pre-climacteric phase. Kader (1997) reported that oxygen levels below 1-1.5 % could cause off-flavour, grayish / brown peel discoloration and inability of proper ripening while CO₂ levels greater than 6-8% could cause undesirable flavour and texture and softening of pulp while the peel is still green. However, in the present study, no such defects were seen.

Pathological properties

Alum treatment significantly controlled crown rot disease showing a CRS value of 0.2 (5% rot) compared to control samples which showed CRS value of 1.08 (26.2% rot) (Figure 1). In accordance with the present results, Abeywickrama *et al.*, (2009) reported that, 1% alum washed and vacuum packed Embul banana showed lower crown rot disease compared to control samples in cold storage at 13-15 °C. During *in vitro* assay by Abeywickrama *et al.*, (2012), 1% (w/v) alum prevented mycelial growth of crown rot

pathogen *L. theobromae* and papaya stem end rot pathogen *Phomopsis caricae-papayae*. Mode of action of alum against crown rot pathogen is not exactly known. However, alum would cause competition for nutrients and sites in the wound of the cut crown impeding the ability of pathogen to grow. Controlling of crown rot disease is challenging since a complex of fungi are associated with the disease and the cut crown tissue allows for a large area of entry for pathogens. Further, fungal spores could go 5-7 mm in to the crown tissue and establish deep-seated infections which may be difficult even for fungicides to reach (Ewané *et al.*, 2012). However, in the present study, alum treatment significantly controlled the crown rot disease indicating the efficacy of alum as an alternative to fungicide usage.

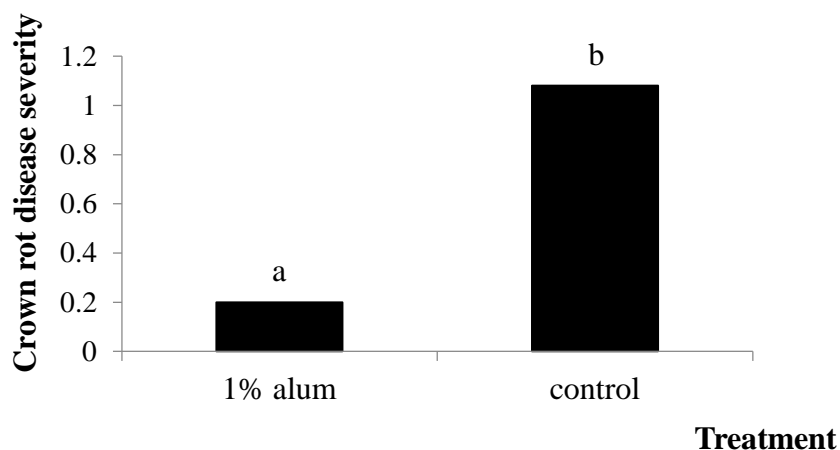


Fig 1: Crown rot disease severity of vacuum packaged Cavendish banana treated with 1% alum and control after 14 days of storage at 12-14 °C

(0 = No rot, 1 = 25% Crown rot, 2 = 50% Crown rot, 3 = 75% Crown rot, 4 = 100% Crown rot, extended up to the finger stalk).

Each data point represents the mean of fifty replicates.

Means sharing a common letter (s) are not significantly different by Kruskal Wallies non parametric statistical test.

Physicochemical Properties

TSS, firmness and pH of alum treated and control Cavendish banana were within the range of 15.9 - 16.0 °Brix, 0.42 - 0.43 kg cm⁻² and 4.93 - 4.99 respectively. TSS, pH and

firmness of alum treated Cavendish banana were not significantly different from the control samples (Table 1).

Table 1: Physicochemical properties and in-package gas concentrations of vacuum packaged Cavendish banana stored at 12-14 °C after induced ripening

Treatment	Property				
	TSS (⁰ Brix)	Firmness (kg cm ⁻²)	pH	O ₂ %	CO ₂ %
alum	16.0 ^a ± 0.43	0.43 ^a ± 0.01	4.93 ^a ± 0.04	5.5 ^a ± 0.1	5.3 ^a ± 0.1
control	15.9 ^a ± 0.41	0.42 ^a ± 0.02	4.99 ^a ± 0.01	5.1 ^a ± 0.1	5.3 ^a ± 0.1

Each data point of TSS, firmness and pH represents the mean of ten replicates ± standard error; TSS, pH and firmness values were recorded after subjecting banana to induced ripening.

Each data point of O₂% and CO₂% represents the mean of five sample bags ± standard error; Headspace O₂ and CO₂ values were obtained in vacuum packaged banana before ripening.

Means sharing a common letter (s) in each column are not significantly different by Tukey's multiple comparison test at (p ≤ 0.05).

pH of a fruit depend on the total quantity as well as the strength of acids present in a fruit and it is used as an important parameter depicting the fruit palatability. Dadzie (1998) reported, pH of Grande Naine' banana was 4.93 after ripening. Opara *et al.*, (2013) reported pH of Dwarf Cavendish banana was within the range of 4.98 - 5.43 during the ripening process. According to Marin *et al.*, (1996) after ripening pH of Grande Naine' (AAA) banana were within 4.94 - 4.95. Total soluble solids are the solids dissolved within a substance. In ripened banana major portion of TSS consists of sugar. According to Opara *et al.*, (2013) TSS of Dwarf Cavendish banana were within 19.6 - 21.2 ⁰Brix. However, Dadzie (1998) reported that in ripe Grande Naine banana TSS was in the range of 14.00 ⁰Brix. According to Dadzie (1998), firmness of banana decreases down to an optimal eating range of 0.7 - 0.4 kg cm⁻² during ripening process. Therefore, values

obtained for pH, TSS and firmness in the present study are in accordance with previously published literature.

Sensory properties

Alum treated VP Cavendish banana obtained higher score values from the trained sensory panel at University of Kelaniya for all sensory properties compared to control. Sensory properties of alum treated banana were not significantly different from control banana on day 14 (Table 2).

Table 2: Sensory scores obtained for VP Cavendish banana stored for 14 days at 12-14 °C after induced ripening from sensory panel at the University of Kelaniya

Treatment	Sensory property						
	peel colour	flesh colour	flavour	aroma	taste	texture	overall acceptability
1% alum	6.6 ^a	6.2 ^a	6.6 ^a	6.2 ^a	6.6 ^a	6.2 ^a	6.4 ^a
control	6.0 ^a	6.0 ^a	6.0 ^a	6.1 ^a	6.4 ^a	6.0 ^a	6.3 ^a

Each data point represents the mean of twenty replicates.

(Excellent 9-10, Good 6-8, Fair 4-5, Poor 1-3).

Means sharing a common letter (s) in each sensory property are not significantly different by Kruskal Wallies non parametric statistical test.

Alum treated banana obtained higher score values over the control for peel colour and taste from the staff and customers of CIC (Figure 2). Further, score values of peel colour and taste of alum treated banana were not significantly different from the control.

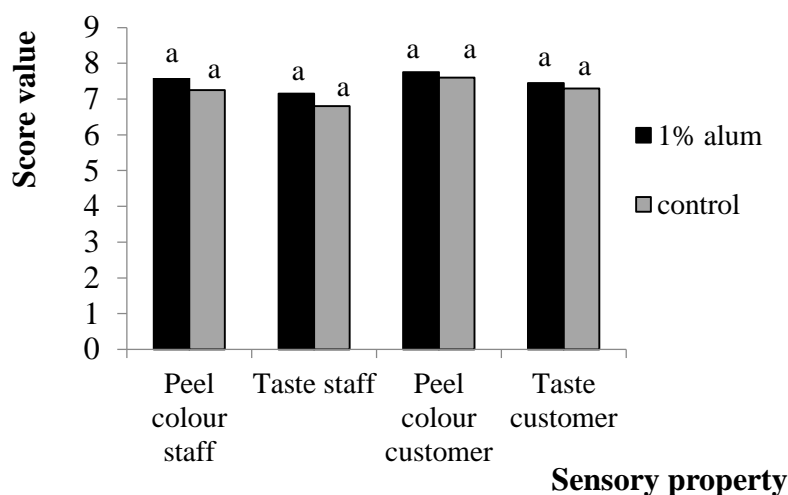


Fig 2: Effect of alum and control on sensory properties of vacuum packed Cavendish banana as scored by the CIC staff and customers

(Excellent 9-10, Good 6-8, Fair 4-5, Poor 1-3)

Each data point represents the mean of twenty replicates.

Means sharing a common letter (s) in each sensory property are not significantly different by Kruskal Wallies non parametric statistical test.

In accordance with the present results, Abeywickrama *et al.*, (2009) reported that most of the physicochemical and sensory properties of 1% alum washed and vacuum packed Embul banana were not adversely affected compared to untreated fruits.

Alum addition remove the latex from banana crowns, promotes the proper healing of the wound at crown and controls pathogens in the wash water (Anyasi *et al.*, 2013). Normally, 1-2% of alum is added to delatexing tanks to prevent flow of latex from banana crowns. In Philippines, 12 ppm Al^{3+} solution is used in de-handing and flotation tanks, for coagulation of banana sap (Speiser and Berge, 2014). This latex removal from banana crowns could lead to enhanced peel colour of alum treated banana compared to control which is evident by the higher score values obtained for peel colour from the sensory panelists and staff and customers of CIC.

Nutritional properties

Moisture content ranged between 76.26-76.85% while protein content ranged between 1.51-1.68% of alum treated and control VP Cavendish banana. Ash contents were within the range of 0.90-0.91% while fat was not detected in all samples. However, these values were not significantly different between the treatments (Table 3).

Table 3: Nutritional properties of VP Cavendish banana after 14 days of storage at 12-14 °C

Treatment	Moisture (%)	Ash (%)	Crude Protein (%)	Fat (%)
1% alum	76.85 ^a	0.90 ^a	1.68 ^a	ND
control	76.26 ^a	0.91 ^a	1.51 ^a	ND

ND - Not Detected.

Means with the same superscript on the same column are not significantly different by Tukey's multiple comparison test at ($p \leq 0.05$).

Further, mineral element composition of alum treated VP Cavendish banana were not significantly different compared to control except for P, Mn, Zn and Fe content (Table 4). A high level of potassium (444.96 - 518.40 mg/100 g) was noted in samples where as Mg ranged between 32.94 - 35.10 mg/100 g. Phosphorous level ranged from 29.16 - 31.86 mg/100 g while Mn level ranged between 1.74 - 2.76 mg/100 g. Iron level ranged from 2.96 - 3.39 mg/100 g while Zn level ranged between 0.56 - 0.66 mg/100 g. Recorded Cu values were between 0.04 - 0.05 mg/100 g for all samples tested. Further, Ca was not detected in any of the samples tested.

Table 4: Mineral composition of VP Cavendish banana after 14 days of storage at 12-14 °C

Treatment	Mineral element (mg/100g)						
	K	P	Mg	Mn	Zn	Fe	Cu

1% alum	518.40 ^{a±}	31.86 ^{a±}	35.10 ^{a±}	1.74 ^{a±}	0.66 ^{a±}	3.39 ^{a±}	0.05 ^{a±}	ND
	44.26	0.54	1.70	0.11	0.02	0.14	0.01	
control	444.96 ^a	29.16 ^b	32.94 ^{a±}	2.76 ^{b±}	0.56 ^{b±}	2.96 ^{b±}	0.04 ^{a±}	ND
	± 24.24	± 0.54	1.32	0.22	0.01	0.10	0.01	

ND - Not Detected.

Means with the same superscript on the same column are not significantly different by Tukey's multiple comparison test at ($p \geq 0.05$).

Wall (2006) reported mineral content of 'Williams' Cavendish banana as, P 19.2 - 25.0 mg/100 g, K 287.1- 355.2 mg/100 g, Ca 3.8- 6.3 mg/100 g, Mg 26.1 - 36.6 mg/100 g, Fe 0.62- 1.01 mg/100 g, Mn 0.13 - 0.31 mg/100 g, Zn 0.17- 0.30 mg/100 g and Cu 0.17- 0.46 mg/100 g. The mineral content values reported in the present study are slightly higher compared to the values reported by Wall (2006). However, mineral content of different banana samples could vary according to banana variety, maturity stage and cultivation areas.

Storage temperature is very vital for safe storage of banana. High temperatures could result off flavour and mushy flesh of banana while low temperatures below 11 °C could result in chilling injury. Low temperature could slow down the growth of microorganisms mainly fungi on banana fruits. Therefore, during the present study, temperature of treated samples were maintained at optimum level of 12-14 °C.

During the present research efficacy of alum in controlling crown rot disease of Cavendish banana was identified. Alum treated samples showed no significant differences of physicochemical, sensory and nutritional properties indicating that alum could be used as a substitute for fungicide usage in the organic banana production.

Conclusions

Alum in combination with vacuum packaging significantly controlled crown rot disease of Cavendish banana. Most of the physicochemical, sensory and nutritional properties were not adversely affected by the treatment.

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