Cymbopogon citratus (lemongrass) and citral a+b spray treatments alone or in combination with sodium bicarbonate in controlling crown rot in embul banana (*Musa acuminata* AAB)

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Accepted 30th November 2004

ABSTRACT

The mounting pressure against synthetic fungicidal dips and sprays, restrict their use in controlling crown rot, a major post-harvest disease in banana. Generally regarded as safe (GRAS) compounds have a great potential to be used as alternatives to fungicides. Identification of chemical constituents of *Cymbopogon citratus* oil revealed the presence of citral as the main component. *Cymbopogon citratus* and citral with sodium bicarbonate (SBC) was fungicidal against the 3 banana fungal pathogens at 0.10-0.20 % v/v and 0.07-0.08 % v/v respectively. Embul banana sprayed with *C. citratus* alone or in combination with SBC after induced ripening, indicated a crown rot severity of 25 - 50% whereas, citral treatment resulted in a slightly lower disease severity. The physico-chemical parameters tested were not affected by the treatments. Oil/citral, SBC treated bananas and control were ranked good to excellent with respect to odour, flavour, taste and overall acceptability. The low disease severity of crown rot due to spray treatment of citral and SBC highlights the importance in adapting this simple, alternate treatment strategy for quality maintenance.

Key words: *Cymbopogon citratus*, crown rot, banana, bicarbonate

INTRODUCTION

The major problem associated with the exportation of banana is the post -harvest loss caused by several fungi (Sarananda and Wijeratnam, 1994). Crown rot is one of the most important post harvest problems especially in the exportation of banana. In Sri Lankan "embul" banana this disease is mainly caused by the fungal pathogens *Colletotrichum musae*, *Lasiodiplodia theobromae* and *Fusarium proliferatum* (Anthony *et al.*, 2004).

Benlate (benomyl) was widely used as a post-harvest dip to control crown rot disease until recently (Perera and Karunarathna, 2001). However, this systemic fungicide has been banned in Sri Lanka and many other countries due to their possible carcinogenicity and reproductive toxicity on human health, and harmful effects on the environment (www.reinet.com/catz/ben.htm, 1999). Although similar fungicides such as Carbendazim, Imazalil are used commercially to control post-harvest diseases in fruits, there is a growing trend all over the world to reduce them as far as possible. This is mainly due to their harmful effects and development of resistant mutants among the pathogens against these compounds upon long-term indiscriminate use (Perera and Karunarathna, 2001).

West Indian Lemongrass (*Cymbopogon citratus*) is a perennial herb cultivated in India, Sri Lanka, Indonesia and many other Asian countries due to its popularity as a spice. The essential oil *C. citratus* has a intense lemon-like odour and is commonly used in perfumery, cosmetic industries (Wijesekera *et al.* 1997). Baratta *et al.* (1998) reported that oil from *Cymbopogon citratus* inhibited the growth of food poisoning and spoilage microorganisms. In addition, fungicidal and anti-aflatoxigenic effects of *C. citratus* oil against *Aspergillus flavus*, isolated from stored rice, have been established (Paranagama *et al.*, 2003). Citral obtained by fractional distillation of

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lemongrass oil is a valuable flavouring agent in confectionary and perfumery industries. The components of essential oils such as phenolic compounds, terpenic alcohols and aldehydes exert their antimicrobial activity on pathogenic fungi by causing damages to microbes by altering membrane permeability, denaturation and precipitation of cell protein, inactivation of enzymes and leakage of amino acids from microbial cells (Tewari, 1976, Hamilton-Kemp *et al.*, 2000). Generally regarded as safe (GRAS) compounds such as sodium bicarbonate, potassium metabisulphite and cinnamaldehyde have been reported for their potential use in controlling postharvest diseases in fruits such as Galia melons and rambutan (Aharoni *et al.*, 1997; Sivakumar *et al.*, 2002).

The aims of this study was to chemically characterize volatile oil of *C. citratus*, and screen the fungistatic and fungicidal efficacy of the oil and oil components - citral a+b alone or in combination with sodium bicarbonate in controlling the growth of *C. musae*, *L. theobromae* and *F. proliferatum* isolated from Sri Lankan embul banana fruits (*Musa acuminata*-AAB), using a liquid bioassay. Based on the findings of the preliminary experiments, we hope to evaluate the efficacy of the spray treatments of *C. citratus* oil, citral and sodium bicarbonate singly or in combination in controlling crown rot disease in Embul banana without altering physicochemical and organoleptic properties.

MATERIALS AND METHODS

Banana fruit fungal pathogens

Pathogens associated with crown rot in Embul banana were isolated from 12 localities in Sri Lankan and their pathogenicity and virulence were established during preliminary stages of research (Anthony *et al.*, 2004).

Essential oil and component

Cymbopogon citratus (lemon grass) oil and Citral A+b were purchased from EOAS Organics Pvt. Ltd., Rathmalana, Sri Lanka, and Fluka, Switzerland respectively.

Chemical analysis of *Cymbopogon citratus* oil using Gas Chromatography

Crude *Cymbopogon citratus* oil was analysed on GC under the following conditions. Shimadzu 14B GLC equipped with a Supelcowax TM 10 capillary column and flame ionization detector; The column was programmed as follows; 60°C for 0.5 min, 60°C to 225°C at 5°C/min., 225°C (10 min.) with Ar carrier gas (1.8 ml/min.). The injector and detector temperatures were 240°C and 230°C respectively and 5 µl of the oil solution in CH_2Cl_2 was injected. The major peaks were identified using published data (Paranagama 1991).

Liquid Bioassay to identify fungistatic and fungicidal properties

Conical flasks (100 ml) containing 50 ml of a semi-synthetic liquid medium SMKY (7 g yeast extract, 1.5 KNO_3, 20 g sucrose, 0.5 g Mg $SO_4.7H_20$ dissolved in 1 liter of distilled water) was autoclaved for 20 minutes at 1.03 kg/cm^2 at 121°C. The oil concentrations of 0.05-0.3% (v/v) were prepared by aseptically adding appropriate volumes of test oils (at intervals of 0.01) to the flasks. Tween 80 (Koch light) at 0.01% was incorporated as an emulsifying agent to disperse oil. Sodium bicarbonate (2% w/v) (Sigma chemicals, UK) was prepared and filter sterilized by passing through a 0.45 µm (47 mm) Millipore filter (Pall Corporation, Michigan, USA). One set of flasks were provided with 2% w/v sodium bicarbonate only, whereas another set of flasks were provided with bicarbonate and 0.05-0.3% oil or citral. Assay flasks without oil and bicarbonate (control A) as well as only bicarbonate (control B), and benomyl treatment were included for comparison purposes. All flasks were subsequently inoculated with a 5 mm mycelial disc cut from the periphery of a 7-day old culture of each test pathogen. Five replicates of each treatment and control were arranged according to a Complete Randomized Design (CRD). Contents were mixed thoroughly by placing the flasks on a shaker (Reciprocal water bath shaker, New Brunswick Scientific Model R76) for 7 days at 28°± 2°C. After 7 days, the minimum inhibitory concentration (MIC), i.e. the lowest oil concentration, which suppressed the growth of each fungus, was noted in each treatment. Where

the growth was completely inhibited by *C. citratus* oil or citral, fungal discs were transferred to fresh PDA plates, incubated for 7 days and then soaked in a 1% solution of Triphenyl Tetrazolium Chloride (TTC) for 30 min. MLC of each oil treatment against fungal pathogens were noted (Baratta *et al.*, 1998, Anthony *et al.*, 2004).

Banana

Embul banana with no record of any pre-harvest fungicide treatment were harvested from Ellaawala Plantation in Galkiriyagama, Dambulla, Sri Lanka. Bunches of banana, light green in colour with full and rounded fruits (within 11-12 weeks of maturity) were dehanded using sharp cuts in the field and transported safely to the research laboratory at Fruit Research Unit, Gannoruwa, Sri Lanka. The first and last hands of each bunch were discarded to eliminate maturity differences. Banana hands were first washed in an alum solution (1%) to remove the latex and then in water to remove any dirt. After allowing the hands to air dry, the weight of each hand was measured using an electronic balance (LS 2000, OHAUS, Portable-standard) and the weights were recorded. Hands of approximately one kilogram were selected randomly as the experimental units.

Preparation of treatments

Oil / citral emulsion

The minimum lethal concentration (MLC) of *C. citratus* and citral against each test pathogen was determined using the liquid bioassay. Preliminary investigations indicated that a 0.3% v/v *C. citratus* oil or citral were most effective in controlling crown rot *in vivo* without affecting organoleptic and physicochemical properties of the fruits. Concentrations of 0.3% v/v *C. citratus* oil or citral were incorporated into 100 ml of distilled water, together with a drop of Turkey red oil (TRO) (saponified castor oil, Konica Photochem Co., Sriracha Chonburi, Thailand), a food grade emulsifier. The mixture was stirred on a magnetic stirrer (Velp Scientifica, Italy) and transferred to a hand-sprayer and mixed well by shaking. A control of water with a drop of TRO, was also prepared (Anthony *et al.*, 2003).

Oil /citral with sodium bicarbonate (2% w/v) treatment

Two (2.0) g of food grade sodium bicarbonate (B.D.H., Laboratory, England) was added to oil or citral emulsion prepared as above and stirred and transferred to a hand-sprayer.

Bicarbonate treatment (2% w/v)

Sodium bicarbonate (2.0 g) was added to 100 ml of distilled water along with two drops of TRO; the mixture was stirred well and transferred in to a hand sprayer.

Benomyl treatment (0.1% w/v)

Benomyl solution (0.1 % w/v) was prepared by dissolving 0.1 g of Benlate powder (50 % w/w active ingredient) (Lankem Ceylon Ltd) in 100 ml of distilled water.

Control

Control spray solution, was prepared by adding two drops of TRO into 100 ml of distilled water and stirring on a magnetic stirrer.

Application of treatments

Banana hands with 13-15 fingers of uniform size were the experimental units and each treatment comprised 3 replicate boxes, each with three hands. Each treatment/control was sprayed on to the cut surface of the crowns and on to the fingers. Treated hands were allowed to drain for 5-10 min before packing in ventilated telescopic type, 3 ply cardboard cartons (CFB) (40 x 35 x 18 cm) lined with pin pricked high density polyethylene (HDPE; 30 μ thick) and perforated Manila paper (60 μ thick) (Anthony, *et al.*, 2003). All treatments were stored in a Cold room in a randomized manner at 13-14°C and 85-95% relative humidity (RH) at Food Research Unit, Gannoruwa. Observations were made after 21 d of storage. Banana fruits were subjected to analysis after induced ripening using 1 ml of ethral (2-chloroethane-phosphoric acid) per ft^3 of banana with 1 ml of 0.1N sodium hydroxide (Sarananda *et al.*, 2000). The pathological, physico-chemical and organoleptic properties of the bananas were

assessed.

Evaluation of pathological properties

The area affected by crown rot on each hand was recorded using a standard index developed by Hewage *et al.* (1995) [Crown rot severity (CRS) 0 = No rot, 1 = 25% crown rot, 2 = 50% rot, 3 = 75% rot, 4 = 100% rot, 5 = rot extending to finger stalk].

Physicochemical analysis

Fingers selected at random from each box were subjected to physico-chemical analysis (Hewage *et al.*, 1995). *Total soluble solids (TSS):* A 10 g sample of pulp from the middle of the finger was blended in 40 ml of distilled water in a homogenizer for 2 min. The homogenate was filtered through cotton wool and a few drops of the filtrate was used to measure total soluble solids using a hand-held Refractometer (Reichert; 10430 ^{0}Brix; 0-32%). Each reading was multiplied by the dilution factor to calculate the actual TSS content of the pulp which was expressed as ^{0}Brix (Hewage *et al.*, 1995).

Titrable Acidity (TA)

Samples (10 ml) of filtrates prepared for the TSS test were diluted with 20 ml of distilled water and titrated against 0.1 M NaOH with phenolphthalein as the pH indicator. The end point was taken as the sudden slight pink colour appearing in the solution. Acidity was expressed as % malic acid (Hewage, *et al.*, 1995).

Fruit Firmness

The firmness of the pulp was measured using a Fruit Firmness Tester/hand held Penetrometer (Model d-6336 Friedbery H, Germany). The probe of the gauge was gently pressed against a carpel lobe of a cross section (2 cm thickness) of the pulp of the fingers until it pierced in to the pulp, and the values were expressed in Kg cm $^{-2}$ (Hewage *et al.*, 1995).

Peel colour

Peel colour of banana fruits was assessed using a S tandard Colour Index developed by Anthony *et al.* (2003). (**1** = Green, **2** = Colour break, **3** = More green than yellow, **4** = More yellow than green,= Yellow with green tip, **6** = Full yellow, **7** = Over ripe).

Weight loss

The weights of treated and control banana hands were recorded, before and after treatment, using an Electronic balance (LS 2000 OHAUS; g = 2000 x1 ; portable). The difference in the weights was expressed as the percentage (%) weight loss (Hewage *et al.*, 1995).

Organoleptic properties

Flavour, taste, odour and overall acceptability of treated and control samples were tested by providing fruits to10 taste panelists at Food Research Unit, Gannoruwa along with a questionnaire. Each quality parameter was scored according to the ranks of 1=0-25 % = Poor, 2=25-50 % = Fair, 3=50-75 % = Good and 4=75-100% = Excellent (Jayasena, 2002).

Experimental design and statistical analysis

Data obtained for organoleptic and pathological properties were subjected to Kruskal Wallis non-parametric statistical test . The data obtained for physico chemical properties were subjected to ANOVA and Duncan's Multiple Range Test (DMRT).

RESULTS

Chemical analysis of *C. citratus* oil

According to the GC profile of *C. citratus* oil, the major constituents were citral a (41.76%), citral b (33.28%), Geranyl acetate (4.69%), Isobornyl acetate (3.51%) and Geraniol (2.86%). Citral a + b accounted for 75.04% of the total.

Fungistatic and fungicidal properties

Cymbopogon citratus oil was fungistatic on *C. musae, F. proliferatum* and *L. theobromae* at a very

low concentration of 0.05 % (v/v) as indicated by MIC values (Table 1). Citral a+b was fungistatic against the 3 test pathogens at a concentration range of 0.05-0.10% (v/v). Fungicidal activity of the *C. citratus* oil and citral was observed at a concentration range of 0.05-0.20% (v/v). Similarly, *C. citratus* and citral in combination with sodium bicarbonate was fungistatic and fungicidal against the 3 pathogens at narrow concentration ranges of 0.04-0.06 v/v and 0.07-0.08% v/v respectively (Table 1). Luxuriant growth of pathogens was observed in the control A (without oil and bicarbonate) whereas no growth of test pathogens could be noted in control B (bicarbonate treatment).

Table 1. Minimum Inhibitory Concentration (MIC) and Minimum Lethal Concentration (MLC) of essential oil of *Cymbopogon citratus*, citral a+b and combinations of *C. citratus*, citral and sodium bicarbonate against *Colletotrichum musae*, *Lasiodiplodia theobromae* and *Fusarium proliferatum* in liquid bioassay.

Treatments	Test pathogen	MIC[a] % (v/v)	MLC[b] %(v/v)
C. citratus	*C. musae*	0.05	0.20
	L. theobromae	0.05	0.10
	F. proliferatum	0.05	0.15
Citral	*C. musae*	0.10	0.10
	L. theobromae	0.05	0.05
	F. proliferatum	0.05	0.10
C. citratus + $NaHCO_3$	*C. Musae*	0.06	0.07
	L. theobromae	0.04	0.08
	F. proliferatum	0.06	0.08
Citral + $NaHCO_3$	*C. musae*	0.04	0.07
	L. theobromae	0.04	0.07
	F. proliferatum	0.07	0.08

[a] Zero colony diameter at Minimum Inhibitory Concentration (MIC).
[b] Zero revival of fungi at Minimum Lethal Concentration (MLC).
[c] Each data point represents mean of 5 replicateS.

In-vivo Experiment

Pathological Properties

Hands treated with *C. citratus* alone or in combination with sodium bicarbonate after induced ripening indicated a crown rot severity of 25 - 50% rot (CRS=1-2) (Table 2). Citral treatment had a slightly lower disease severity with a CRS of 1-1.2. Control indicated a CRS of 1.5 whereas benomyl treated banana under the same conditions showed no symptoms of crown rot until 21 days (Table 2).

Physico-chemical properties

Fruit firmness: Fruit firmness in fruits treated with oil/citral and combination treatments and benomyl as well as the control were within the range of 0.31-0.52 $Kgcm^{-2}$ and the values were not significantly different ($p>0.05$) (Table 3).

Total soluble solids: The TSS values of all treatments after 21 days at 13-14°C were within the range of 20.5 22.4 (°Brix) except in the citral treated fruits with a slightly lower TSS value of 16.8. However the values were not statistically significant ($p>0.05$) (Table 3).

Titratable acidity: TA (% malic acid): At the table ripe stage (SCI=6), the TA of all treatments were within the range of 2.8-3.3 (Table 3).

Weight loss: Weight loss of 5.3 8.6% was recorded in all treatments and the control and the losses were not significantly different ($p>0.05$) (Table 3).

Peel colour: The fruits in oil or combination treatments, benomyl as well as control were green (SCI= 1) after 21 days in cold storage (before subjecting to induced ripening).

Table 2: Disease severity of crown rot of bananas subjected tospray treatments in comparison to the control and benomyl treatment at 131 °C for 21 days and ripening induced

Treatment	Crown Rot Severity (CRS)
C. Citratus	1.67± 0.29
Citral (a+b)	1.22 ±0.15
C. citratus+$NaHCO_3$	2.00±0.63
Citral (a+b)+$NaHCO_3$	1.00±0.00
Benomyl	0.0
Control	1.44 ±0.24

Each value represents the mean of six replicates ± standa rd error.

Table 3: Physico-chemical properties of embul banana treated with single or combined treatments or benomyl and stored for 21 days at 13 1°C and ripening induced

Treatment	% Weight loss	Firmness Kg/cm²	TSS (°Brix)	TA (% Malic acid)
C. citratus	6.7± 0.51	0.31± 0.01	2 0.5±0.50	3.2±0.30
C.citratus +$NaHCO_3$	6.9±1.6	0.36±0.05	21.5± 0.60	3.3±0.35
Citral (a+b)	8.6±1.0	0.40±0.04	16.8±0.23	3.0±0.38
Citral (a+b) + $NaHCO_3$,5.	3±0.97	0.44+0.05	0.9±0.26	3.2±0.29
Benomyl	5.5±0.25	0.52±0.05	22.4±0.3	2.8±0.23
Control	5.9±1.57	0.50±0.01	21.0±0.22	3.0±0.21

Each value represents the mean of six replicates ± standard error (SE)

Organoleptic properties

The data obtained by sensory evaluation showed that there was no significant variability in fruits treated with oil, citral alone or in combination with sodium bicarbonate in comparison to benomyl treatment and control, with respect to odour, taste, flavour and overall acceptability. (ranks ranging from 2-5-3.7). *C. citratus* in combination with sodium bicarbonate was rated as the best treatment with ranks for all properties ranging from 3.4-3.7 with good to excellent mouthfeel (Table 4).

Table 4: Organoleptic properties of Embul banana treated with single and or combined treatments or benomyl and stored for 21 days at 13 1°C and ripening induced

Treatment	Odour	Flavour	Taste	Overall Acceptability
C. citratus	2.6±0.31	2.9±0.31	2.6±0.31	2.5±0.34
C.citratus +$NaHCO_3$	3.4±0.16	3.7±0.15	3.7±0.15	3.7±0.15
Citral (a+b)	2.8±0.26	3.1±0.21	3.2±0.23	3.5±0.21
Citral(a+b) +$NAHCO_3$	2.8±0.29	3.2±0.20	3.2±0.25	3.6±0.16
Benomyl	2.8±0.00	3.3±0.10	3.3±0.20	3.5±0.20
Control	2.8±0.25	3.2±0.29	3.3±0.21	3.2±0.25

Each value represents the mean of 10 replicates ± standard error (SE).

DISCUSSION

Citral a + b accounted for 75.04% of the total in the crude *C. citratus* oil when analyzed chemically. Wijesekara *et al.* (1997) has stated that the essential oil of *C. citratus* has a strong lemon-like odour due to its high citral content (75-90%). Citral has been reported to prevent the growth of *P. digitatum*, *P. italicum* and *G. candidum* when these fungal spores were exposed to citral in the volatile phase (Klieber *et al.*, 2002). In addition to citral a and b, strong antifungal activity by the other major constituents of the essential oil of *C. citratus*, geranyl acetate and geraniol had previously been observed (Delespaul *et al.* 2000, Farag *et al.*, 1989). Athough it cannot be proven conclusively whether the fungicidal activity of the oil of *C. citratus* is due to the most abundant component, i.e. citral, and not to the other associated substances, the fungicidal activity of these oils ar undisputed.

The findings of the *in vitro* bioassay confirms the fungicidal nature of *C. citratus* and citral. Baratta *et al.* (1998) previously reported that lemon grass oil (*C. citratus*) demonstrated fungicidal activity against a common spoilage fungus, *Aspergillus niger,* at a concentration of 1µl/ml in liquid medium. In a recent study, Paranagama *et al.* (2003) found that *C. citratus* oil at 0.1 mg/ml was fungicidal against *A. flavus* a mycotoxigenic fungus found in stored rice and the same concentration of oil was effective enough to completely inhibit aflatoxin formation.

The severity of crown rot of bananas treated with *C. citratus* oil (0.30% v/v) during *in vivo* studies was slightly higher than the control as well as the bananas treated with citral. This suggests that lemongrass oil was not completely effective in controlling crown rot disease. The disease severity of crown rot in banana treated with citral a + b at 0.30% v/v showed a slightly lower CRS (1.22) compared to the control. This indicates that the citral a + b have been effective to a certain extent in controlling the disease. However, the results obtained for the above 2 treatments and the control when subjected to non-parametric analysis of Kruskal-Wallis, data were not significantly different. (P= 0.118). Previous experiments conducted by Anthony *et al.* (2003), using East Indian lemongrass *C. flexuosus*, confirmed that when used as a spray, this oil was able to control crown rot disease in banana to a great extent (with CRS of only 0.5). The lesser ability of *C. citratus* oil to control disease *in vivo* could be due the rapid evaporative effect of certain bioactive components in the oil, before exerting any effect on the fungal pathogens (Jobling, 2000). The spray treatments of *C. citratus* oil and citral combined with $NaHCO_3$ did not indicate a significantly positive effect with

respect to crown rot control. However, citral showed a considerable controlling effect on crown rot when the CRS values were considered. The low severity of crown rot when citral is combined with sodium bicarbonate could be due to the synergistic effects of the 2 compounds.

Effect of 2% sodium bicarbonate alone had been tested by Aharoni *et al.* (1997) on Melons. Even though the exact mechanism of action is not known, sodium ions have previously shown to reduce turgor pressure in fungal cells which in turn cause collapse or shrinkage of hypha and spores (Karabulut *et al.*, 2001; Aharoni *et al.*, 1997). Terpenic antifungal aldehydes such as citral, could denature proteins in cells and membranes, change cell permeability and cause blockage of glycolytic pathway (Tewari *et al.*, 1976).

Bananas are typical climacteric fruits which ripen in the presence of increased respiration and ethylene production (Burden *et al.*, 1994). Reduced temperature benefits the fruit by reducing the respiration rate and ethylene production thus lengthening the green life of the fruit. During the normal ripening, the peel loses water to both the atmosphere and the pulp resulting in a higher water loss. In the current experiment there was no significant difference observed in the percent weight loss between the treatments. The percent weight loss of water were between 5.3% and 8.6% in the present study. Sarananda *et al.*, (2000) reported in a previous experiment that the water loss in bananas, subjected to induced ripening were significantly lower than the naturally ripened fruits.

The physicochemical parameters tested were not affected by the treatments significantly. The little variations in certain physicochemical parameters are unavoidable as the fruits vary in their postharvest behavior due to slight maturity differences. The values of total soluble solids, titratable acidity, and firmness of *C. citratus* oil and citral treatments in the presence and absence of sodium bicarbonate were not significantly different. However, bananas treated with sodium bicarbonate alone, benomyl and in the control were significantly firmer than the oil and citral treated bananas. This indicates that volatiles components in crude essential oils exert some effect on the sequential degradation process of pectic, hemicellulossic polysaccharides and starch, to sugars during ripening (Mitra, 1997). Previous experiments have established that the firmness of bananas treated with essential oil of O. *basilicum* and *C. flexuosus* had slightly low firmness values. (Anthony *et al.*, 2003).

According to the organoleptic evaluations, no significant difference was observed between the treatments as observed by the panelists. Oil/citral treated, sodium bicarbonate (SBC) treated bananas and bananas in controls were ranked good 50-75% to excellent 75-100% with respect to odour, flavour, taste and overall acceptability. This finding is supported by previous similar research of organoleptic evaluation of embul banana treated with *O. basilicum* and *C. flexuosus* (Anthony *et al.*, 2003).

CONCLUSIONS

Cymbopogon citratus crude oil could be subjected to fractional distillation to obtain natural citral a+b, in countries where lemon grass is cultivated in mass scale. Banana treated with GRAS compounds will be more acceptable to consumers as citral and sodium bicarbonate are being used in many industries due to their food preservative action through controlling microorganisms. . The low disease severity of crown rot during combined treatment of citral and sodium bicarbonate highlights the importance in adapting this simple, alternate treatment strategy.

Spray treatment of these GRAS compounds in combination with modified atmosphere cold storage is currently being tested for prolonging storage life of embul banana for sea shipment.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the financial assistance provided by the International Foundation for Science (IFS), Sweden, The Organization for the Prohibition of Chemical Weapons (OPCW), The Netherlands. The assistance of Mr. R. Dayananda at Industrial Technology Institute, the Technical staff at the Department of Botany, University of Kelaniya and Fruit Research Unit, Gannoruwa are acknowledged.

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