

Nutritional quality of Cavendish banana (*Musa acuminata*, AAA) as affected by basil oil and determination of basil oil residues by GC-MS

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ABSTRACT

The effectiveness of basil oil on the nutritional properties of Cavendish banana and chemical composition of basil oil and oil residue levels of treated banana fruits were evaluated in this study. Cavendish banana hands were treated with 1% alum (w/v), 1% alum (w/v) + 0.4% *Ocimum basilicum* (basil) oil, distilled water (control) and packaged in Low Density Polyethylene (LDPE) bags and stored at a cold room at 12-14°C. After two weeks of cold storage banana were induced ripened and nutritional contents of treated Cavendish banana were determined. Gas Chromatography - Mass Spectrometry (GC-MS) was instrumental in identifying the chemical constituents of basil oil as well as residues in basil oil treated Cavendish banana peel after two weeks of storage at 12-14°C.

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Nutritional properties of basil oil treated Cavendish banana showed no adverse changes compared to control. Methyl chavicol (estragole) was the most abundant component (74.44%) of basil oil followed by linalool (15.01%). GC-MS data revealed that negligible amount of residues of basil oil retained in treated Cavendish banana after 14 days. Basil oil treatment and subsequent modified atmosphere packaging of Cavendish banana is recommended as an ecofriendly strategy for air freight or long distance transport over land.

Keywords: Basil oil, Cavendish banana, Gas Chromatography-Mass Spectrometry (GC-MS), Nutritional properties

INTRODUCTION

Ocimum basilicum L. which is known as Sweet Basil in the family Lamiaceae is a native herb to Asia, enriched with plenty of phytochemicals with considerable nutritional and antioxidant properties as well as ample health benefits (Paton, 1992; Shafique et al., 2011). Basil is widely cultivated and extensively used for food, perfumery, cosmetics, pesticides, and medicine due to their natural flavor and aroma and bioactive properties (Kobaet al., 2009). Sweet basil is widely used for preparation of essential oils, dried leaves as a culinary herb, condiment/spice in various dishes and food preparations (salads, sauces, pasta and Mediterranean cuisine). In medicine it is used for treating of headaches, kidney malfunctions, constipation, coughs, diarrhea, worms and warts (Ben-aliet al., 2014).

Basil essential oil has attracted attention of many scientists due to its antimicrobial and antioxidant properties which is very valuable in terms of food Industry. Utilization of essential oil in the food industry reduces the usage of synthetic fungicides / additives, and subsequently improves the freshness and sensory quality of the produce. Further, there is an increasing demand from public for natural food additives (Koba et al., 2009). Several researchers had provided evidence on the antifungal action of basil oil. According to Doube et al.(1989) basil oil at 1.5 ml/l completely inhibited the growth of 22 mold species, including

aflatoxigenic *Aspergillus parasiticus* and *A. flavus*. Soliman and Badeaa (2002) reported that basil oil was effective as a fungistatic agent against *F. verticillioides* at 2000 ppm concentration, and as a fungicidal agent at 3000 ppm concentration. Fandohan et al. (2004) demonstrated a complete inhibition of growth of *F. verticillioides* at basil oil concentrations higher than 2.7 µl/ml. According to Zollo et al. (1998) basil oil showed a complete inhibition of the growth of *Candida albicans* and *A. flavus* at 5000 ppm concentration, during a 7-day incubation period. Further, this oil extract showed strong antifungal activity towards *Fusarium* spp. (*F. proliferatum*, *F. oxysporum*, *F. Verticillioides* and *F. subglutinans*) isolated from spoiled cakes and the fungal growth was inhibited completely at 1.5 ml / 100ml concentration of basil oil(Kocić-Tanackov et al., 2011).

Crown rot disease of Cavendish banana is a serious postharvest disease caused by a range of different fungi including *Colletotrichum musae*, *Lasiodiplodia theobromae* as well as *Fusarium* spp., *Verticillium* spp. and *Cephalosporium* spp. (Abd-Alla et al., 2014). In a previous study at the University of Kelaniya, efficacy of basil oil on crown rot disease control of Cavendish banana was evaluated (Siriwardana et al., 2016). During the study, basil oil at 0.4% (v/v) together with modified atmosphere packaging significantly managed crown rot disease of Cavendish banana and physicochemical and sensory properties of treated banana were not adversely affected in comparison to distilled water control (Siriwardana et al., 2016).

The aim of this research was to investigate the effect of basil oil on the nutritional aspects of Cavendish banana and to analyse oil residue levels of treated Cavendish banana after storage period of 14 days at 12-14°C, subjected to Modified Atmosphere Packaging (MAP).

MATERIALS AND METHODS

Preparation of Cavendish banana

Twelve (12) week mature Cavendish banana (Grande Naine cultivar) bunches were harvested from CIC banana plantation in Pelwehera, Dambulla, Sri Lanka from plants previously identified and tagged. Banana bunches were transported to the CIC banana pack house, at CIC Agri Business Centre. 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 potassium aluminium sulphate (alum) (1% w/v) except the control (only washed with water). Subsequently, bananas were allowed to drip dry.

Preparation of treatments

Ocimum basilicum (sweet basil) oil was purchased from Aromatica laboratories (Pvt.) Ltd. Sri Lanka. Basil oil (400 μ l) was added to 0.1 l of distilled water to prepare 0.40% (v/v) concentration with a drop of 'Tween'80 (Park Scientific Limited, Northampton, UK). The mixture was stirred using a magnetic stirrer for 10 minutes and transferred to a hand-sprayer and mixed well by shaking. The control was prepared by adding one drop of 'Tween' 80 to 0.1 l of distilled water and stirring for 10 minutes (Siriwardana et al., 2016).

Application of treatments

Cut surfaces of crown and fingers of banana hands were sprayed with 0.40% (v/v) basil oil emulsion, or distilled water. Another set was washed in 1% alum solution only. Hands were placed in low density polyethylene (LDPE) bags (150 gauge) of 74 \times 64 cm surface area and mouths of bags were tied with rubber bands and packed in (40 \times 29 \times 19 cm) ventilated 3-ply fibre board cartons. These treatments were considered as stored in Modified Atmosphere Packaging (MAP). Polyethylene foam liners were placed on top of

banana to provide protection to fruit. Each treatment comprised of five replicate boxes, each containing five hands (weighing 5.0 - 5.5 kg). All treatment boxes were stored in a cold room at CIC banana packhouse, Dambulla at 12-14 °C and 85-90% relative humidity. The experimental arrangement was a completely randomized design (CRD).

Ripening of banana

After two weeks storage period banana hands were subjected to induced ripening by exposure to ethylene (thrill - 480g / l ethephon, 1ml / 1 l of water) for 24-48 hours at ambient temperature (Siriwardana et al., 2016).

Nutritional properties

Moisture content

Five induced ripened fruits (randomly selected) 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 3 hours. After cooling, dried samples were reweighed. This process was repeated until a constant weight was obtained. The difference in weight was calculated as a percentage of the original sample according to formula given by AOAC (1990) and Nwosu et al. (2011). Five replicate samples were used per treatment and mean value was taken as moisture content.

$$\text{Percentage moisture} = \frac{[(W_2 - W_3) / (W_2 - W_1)] 100}{(1)}$$

Where,

W_1 = Initial weight of empty dish

W_2 = Weight of dish & sample before drying

W_3 = Weight of dish & sample after drying

Dehydration of banana samples

Five induced ripened banana fruits were selected randomly 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 and mineral contents at the Soil and Plant Analytical Laboratory, CIC Agribusiness Centre, Dambulla and ash and fat contents at the Postgraduate laboratory, Department of Botany, University of Kelaniya.

Ash content

One gram of dehydrated banana fruit 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. Incineration crucible 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 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).

$$\text{Percentage Ash} = \left(\frac{\text{Weight of Ash}}{\text{Weight of original of sample}} \right) 100 \quad (2)$$

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 without allowing the sample to cling the neck of the 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. Finally, boric acid solution was titrated with 0.1 N HCl solution. The Nitrogen content was calculated using the equation below 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).

$$\text{Percentage Nitrogen} = \frac{(V \times N \times 14 \times 100)}{(S \times 100)} \quad (3)$$

Where,

N= Normality of HCl

V= Volume of HCl used for sample titration

S = Weight of sample taken

Fat content

Two grams of the 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 with a heating mantle and allowed to reflux for 5 hours. 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 as a percentage (%).

$$\text{The percentage oil content is percentage fat} = [(W_2 - W_1) / W_3] 100 \quad (4)$$

Where,

W_1 = weight of the empty extraction flask

W_2 = weight of the flask and oil extracted

W_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 minutes) 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). Dilutions were done wherever necessary and mineral

contents (ppm) were determined using standard curves. Mineral content were expressed as mg/100 g of fresh weight (AOAC, 1990). Five replicate samples per treatment were used for determining each mineral and mean value were calculated and expressed as the final mineral content.

Residue analysis of Cavendish banana

Cavendish banana hands (3 hands) were treated with 0.4% basil oil and stored in a cold room at 12-14 °C and 85-90% RH for 14 days. Each treatment was replicated three times. One banana fruit from each hand was weighed using an electric balance and peeled and chopped. Hydro distillation of peel samples was carried out using a Clevenger apparatus. Any oil present in the peel was trapped in normal Hexane. The collected extract was passed through a nitrogen steam in order to concentrate (Cox et al., 1974). This extract was subjected to Gas Chromatography-Mass Spectrometry (GC-MS) analysis at Industrial Technology Institute, Colombo, Sri Lanka. GC-MS Analysis was performed using a TRACE 1300 Gas Chromatography Apparatus, fitted with a TG-WAX MS column (60 m x 0.25 mm x 0.25 µm) coupled to an ISQ QD Single Quadrupole Mass Selective Detector. A temperature program of 60 °C – 220 °C at a rate of 5 °C per min, maintained at 220 °C for 10 minutes was employed. Other Operational Parameters: Helium Flow Rate - 1.0 ml / min; Injection Volume – 0.2 µl; Injection Mode - split (1: 50 split ratio); Acquisition Mode – scan; Scan Range, 50 - 450 m/z. Identification of the essential oil components was based on the comparison of their retention times, retention indices relative to C₅ – C₁₈ n - alkanes and matching mass spectra with those obtained from authentic samples and / or the NIST/EPA/NIH Mass Spectral Library as well as published data (Li et al., 2013; Adjou et al., 2017).

Statistical analysis

Nutritional properties were analyzed by ANOVA, while mean separation was done using Tukey's Multiple Comparison test at $P < 0.05$ using Minitab.

RESULTS AND DISCUSSION

Nutritional properties

Moisture content ranged between 76.35 - 76.76% while protein content ranged between 1.37 - 1.55% of alum treated, alum + basil oil treated and (distilled water treated) control 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 indicating treatments had not adversely affected the nutritional properties of banana (Table 1).

Table 1: Nutritional properties of Cavendish banana after 14 days of storage at 12-14°C.

Treatment	Moisture (%)	Ash (%)	Crude Protein (%)	Fat (%)
1% alum	76.76 ^a	0.91 ^a	1.37 ^a	ND
1% alum + 0.4% basil oil	76.54 ^a	0.90 ^a	1.55 ^a	ND
control	76.35 ^a	0.91 ^a	1.53 ^a	ND

ND - Not Detected. Each data represent mean of 5 replicates. Means with the same superscript on the same column are not significantly different by Tukey's multiple comparison test at ($p \geq 0.05$).

Further, mineral element composition of alum, alum + 0.4% basil oil or distilled water treated and MAP stored Cavendish banana were not significantly different between

the treatments except Mn and Fe content. A high level of potassium (432.00 - 462.24 mg / 100 g) was noted in all samples as expected whereas Mg ranged between 35.64 - 37.26 mg / 100 g (Table 2).

Table 2: Mineral composition of Cavendish banana after 14 days of storage at 12-14 °C.

Mineral element composition (mg/100 g)								
Treatment	K	P	Mg	Mn	Fe	Zn	Cu	Ca
1% alum	432.00 ^a	31.86 ^a	35.64 ^a	2.85 ^a	2.00 ^a	0.54 ^a	0.02 ^a	ND
	± 15.27	± 1.32	± 1.57	± 0.16	± 0.12	± 0.02	± 0.01	
1% alum +	432.00 ^a	30.24 ^a	36.72 ^a	2.24 ^b	2.22 ^a	0.59 ^a	0.05 ^a	ND
0.4% basil oil	± 23.66	± 1.98	± 1.83	± 0.03	± 0.10	± 0.02	± 0.00	
Control	462.24	36.18 ^a	37.26 ^a	1.90 ^b	3.08 ^b	0.60 ^a	0.04 ^a	ND
	± 18.83	± 0.66	± 1.32	± 0.10	± 0.31	± 0.01	± 0.02	

ND – Not Detected. Each data represent mean of 5 replicates. Means with the same superscript on the same column are not significantly different by Tukey’s multiple comparison test at ($p \geq 0.05$).

According to Wall (2006), mineral content of ‘Williams’ Cavendish banana were reported 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.

Nutritive value of banana fruit (*Musa acuminata colla*) per 100 g is reported as, protein 1.09 g, ash 0.94 g, Potassium (K) 358 mg, Phosphorus (P) 23 mg, Magnesium (Mg) 27 mg,

Calcium (Ca) 5 mg, Manganese (Mn) 0.27 mg and Copper (Cu) 0.078 mg (USDA National Nutrient data base, 2016). Results of the current research are in accordance with the previously published literature. Small deviations could occur in different banana samples due to the variations in banana variety, maturity stage and differences of the geographical areas of cultivations.

Residue analysis of basil oil treated MAP stored Cavendish banana

Gas chromatogram of authentic Sweet basil oil displayed number of peaks (Figure 1) and relevant chemical components were identified and shown in Table 3.

Table 3: Main chemical components of *Ocimum basilicum* oil identified using GC-MS.

Component	Retention time	Percentage (%)
Methyl chavicol	16.23	74.44
Linalool	13.35	15.01
Cinnamaldehyde, (E)-	24.19	1.63
1,2-Oxolinalool	10.99	1.60
Epoxylinool	11.65	1.57
Trans-4-Methoxycinnamaldehyde	33.40	1.28
Eugenol	26.41	0.71
Trans- α -Bergamotene	14.23	0.43
Benzaldehyde	23.89	0.35
Anethole	18.21	0.27
1-methyl-4-(1-methylethyl)-Cyclohexanol,	15.51	0.24
Geranyl vinyl ether	17.71	0.19
iso- β -terpineol	6.07	0.13
α -Terpineol	16.83	0.10
α -Pinene	3.52	0.02
Total		95.97

Methyl chavicol (74.44) and Linalool (15.01) were the major components present while Cinnamaldehyde, 1, 2 - Oxolinalool, Epoxylylinalool and 4 - Methoxycinnamaldehyde were present in low proportions (1.28% – 1.63%). Eugenol was present at a level of 0.71%. α - Terpineol was present at 0.1% level while α - Pinene was detected at a level of 0.02% in basil oil.

Fig. 1.

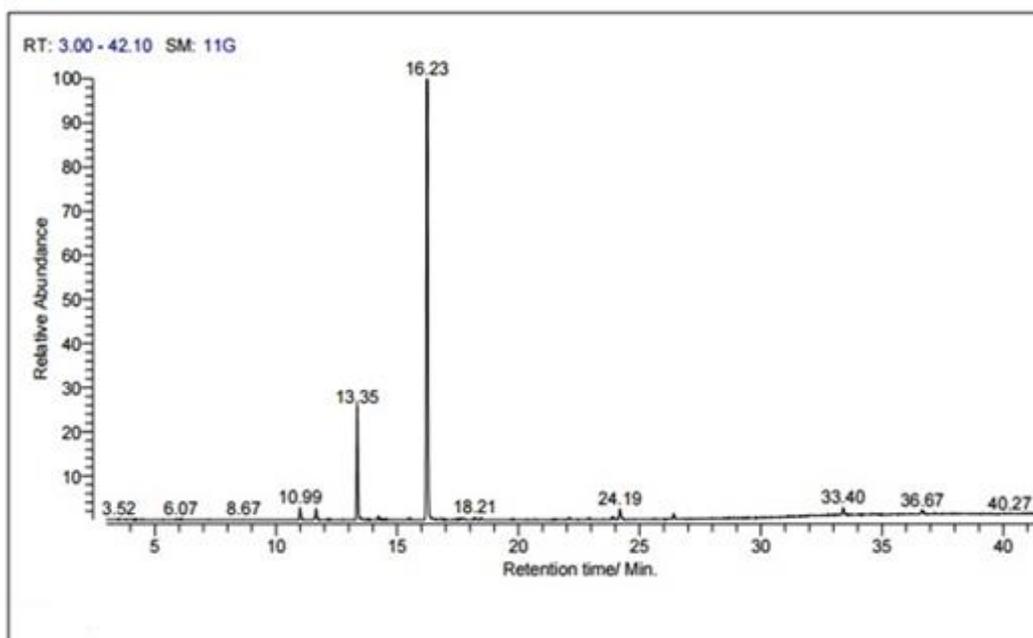


Figure 1: Chromatogram of authentic sweet basil oil resulted during GC-MS analysis.

Gas chromatogram of the extract of basil oil treated banana peel (Figure 2) displayed numerous peaks and Cinnamaldehyde and α - Terpineol were identified in trace amounts. Most of the peaks were correspondent to the flavor components of the fruit. Therefore, it can be concluded that residues of basil oil persisted on treated Cavendish banana peel after 14 days was an insignificant amount.

Fig.2.

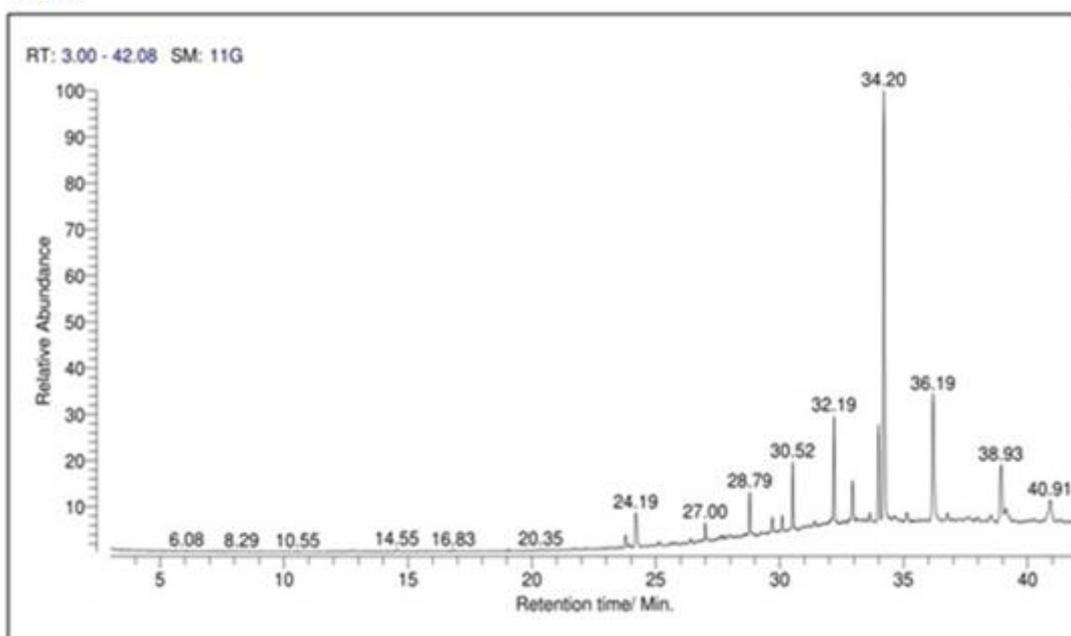


Figure. 2: Chromatogram of extract of basil oil treated banana peel resulted during GC-MS analysis.

Basil oil is a mixture of numerous compounds and its composition is extremely rich and varied. Senanayake et al. (1997) reported, eugenol (35%), β -selanine (15.5%) and β -caryophyllene (10.7%) as the major constituents of *Ocimum basilicum* oil, when analyzed using gas chromatography. Recent research identified the presence of methyl chavicol (72.54%), linalool (14.02%), eugenol (10.76%), methyl eugenol (1.78%) and β -caryophyllene (0.5%) in authentic sweet basil oil during gas chromatography analysis (Unpublished data). The majority of authors mentioned estragol (methyl chavicol), linalool, eugenol and methyl cinnamate as the major antimicrobial components of basil oil. The chemical composition of sweet basil oil could vary according to genetic, ontogenetic, and environmental factors, similar to other oil plants (Nurzyńska-Wierdak et al., 2013).

Out of the identified compounds in present study, methyl chavicol, linalool, eugenol, cinnamaldehyde, α -terpineol and α -pinene has been reported as components having profound antifungal properties (Marei et al., 2012; Nurzyńska-Wierdak et al., 2013; Costa

et al., 2015; Rahemi et al., 2015). They can even be present in minute amounts and exert considerable antifungal effect on pathogenic fungi.

Similar to results of present investigation, Lis-Balchin et al. (1998) reported estragol (methyl chavicol) as the main component of basil oil which showed profound antifungal effect on the growth of *Aspergillus niger*, *A. ochraceus*, and *Fusarium culmorum* (inhibition of growth of 71.0 to 94.76%). Baratta et al. (1998) reported that estragol type basil oil inhibited the growth of *A. niger* by 93.1%. Reuveni et al. (1984) reported on the effect of basil oil components on the growth of *Rhizopus nigricans* and *F. oxysporum*. They found linalool and estragol to be more efficient against *R. nigricans* (100% of inhibition), compared to eugenol (38.1% of inhibition). Eugenol exhibited stronger inhibition towards *F. oxysporum* (100% of inhibition), in contrast to linalool and estragol, where the inhibition values were 26.4 and 30.3%, respectively.

Kocić-Tanackova et al. (2012) reported that major component of basil oil was found to be estragole (86.72%). He further reported that the growth of *Penicillium chrysogenum* was completely inhibited by basil oil concentration of 1.50 ml / 100 ml which contained estragole as the major antifungal component. The growth of other *Penicillium* spp. was partially inhibited with colony growth inhibition of 63.4% (*P. brevicompactum*), 67.5% (*P. aurantiogriseum*) and 71.7% (*P. glabrum*). Higher concentrations (0.70 and 1.50 ml / 100 ml) reduced the growth of the aerial mycelium of all *Penicillium* species. Further, same extract concentrations, at microscopic level indicated deformation of hyphae with frequent occurrence of fragmentations and thickenings, occurrence of irregular vesicles and enlarged metulae. These macro and micro morphologic changes point to the possible changes at cellular level such as reduction in the cellular growth, decrease in the oxygen uptake, inhibition of the synthesis of lipids, proteins and nucleic acids, changes in the lipid profile of the cell membrane and inhibition of the synthesis of the fungal cell wall due to the action

of basil oil components with functional groups of cellular enzymes (Kocić-Tanackova et al., 2012).

According to Anthony et al. (2003) eugenol was the major compound in basil oil responsible for crown rot disease control. Conidial germination and appressoria formation of fungal pathogens were inhibited by eugenol and membrane permeability of fungal pathogens were affected. Conidia of *Colletotrichum musae* germinate after depositing on a plant surface and produce a melanised, thick walled appressoria which is essential to adhere firmly to the host surface. In a previous study, it was reported that, basil oil prevent melanisation of appressoria and cause leakage of cell contents in conidia of *C. musae* resulting in the death of microbial cells (Herath and Abeywickrama, 2008). However, synergistic effect of antifungal components present in basil oil such as methyl chavicol, eugenol, linalool, cinnamaldehyde, α -terpineol and α -pinene may lead to antimicrobial efficacy, which needs further investigation.

Mohamed et al. (2012) reported that basil oil at 0.1% level had a potent effect against growth of *A. flavus* and *A. Ochrachues* in pan bread during storage of 8 days. Further, aflatoxin (AFs) production was also reduced from 150 to zero ng / ml and ochratoxin A (OTA) from 135 to 98 ng / ml compared to the control. Mohamed et al. (2012) also noted that the addition of oil to bread indicated no significant changes in the chemical composition of bread. Our previous research findings confirmed that, crown rot disease was significantly controlled by 0.4% (v/v) basil oil without adversely affecting the physicochemical and sensory properties (Siriwardana et al., 2016).

The United States Food and Drug Administration (FDA) classify basil oil as one of the generally recognized as safe (GRAS) compounds for their intended use. Further, toxicological data of basil oil indicate that a dose of 2680 mg / kg of eugenol, 1400 mg / kg of methyl chavicol and 2790 mg / kg of linalool are needed to observe LD₅₀ (Lethal Dose,

50%) in rats (<https://www.nhrorganicoils.com>, 17/01/2018). Therefore, relatively high dose of basil oil is needed to observe lethal effect on mammals including humans. Current study revealed basil oil had no significant effect on the nutritional properties of treated banana as well as insignificant amount of basil oil residues persisted after 14 days due to volatile nature of the oil. These findings highlight the possibility of using basil oil as a promising alternative as an antifungal compound, facilitating its usage as a substitute for synthetic fungicides.

CONCLUSION

There was no significant difference of most of the nutritional properties of basil oil treated Cavendish banana stored in MAP compared to distilled water control. Methyl chavicol and linalool were found to be the most abundant chemical components present in the basil oil. Insignificant amount of residues of basil oil persisted in treated Cavendish banana after 14 days of storage at 12-14 °C. Therefore, basil oil could be recommended as an ecofriendly treatment strategy of Cavendish banana for Air freight or long distance transport over land.

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REFERENCES

- Abd-Alla, M. A., El-Gamal, N. G., El-Mougy, N. S., Abdel-Kader, M. M.(2014). Post-harvest treatments for controlling crown rot disease of Williams banana fruits (*Musa acuminata* L.) in Egypt. *Plant Pathology & Quarantine* **4** (1), 1–12. [http://dx.doi.org/Doi 10.5943/ppq/4/1/1](http://dx.doi.org/Doi%2010.5943/ppq/4/1/1).
- Adjou, E.S., Rene, D., Edwige, D.A., Soumanou, M. M. (2017). Chemical composition and biological activity of essential oil from *Mentha Piperita* L. leaves on the quality of

Mango puree during storage. *Journal of Microbiology, Biotechnology and Food Sciences* **7(2)**, 97-100.

- Anthony, S., Abeywickrama, K., Wijeratnam, S. W.(2003). The effect of spraying essential oils of *Cymbopogon nardus*, *C. flexuosus* and *Ocimum basilicum* on postharvest diseases and storage life of Embul banana. *Journal of Horticultural Science and Biotechnology* **78**, 780-785.
- A O A C. (1990). Official Method of Analysis. 15th Ed. Association of Official Analytical Chemists, Arlington, VA.
- Baratta, M. T., Dorman, H. J. D., Deas, S. G., Figueiredo, A. C., Baroso, J.G., Ruberto, G., 1998. Antimicrobial and antioxidant properties of some commercial essential oils. *Flavor and Fragrance Journal* **13**, 235-244.
- Ben-ali, M., Dhoubib, K., Damak, M., Allouche, N.(2014). Stabilization of Sun flower oil during accelerated storage: Use of Basil extract as a potential alternative to synthetic antioxidants. *International Journal of Food Properties* **17**, 1547-1559.
- Costa, L. C. B., Pinto, J. E. B. P., Bertolucci, S. K. V., Costa, J. C. D. B., Alves, P. B., Niculau, E. D. S.(2015). *In vitro* antifungal activity of *Ocimum selloi* essential oil and methyl chavicol against phytopathogenic fungi. *Revista Ciência Agronômica* **46(2)**, 428-435.
- Cox, J., Donegan, L., Pinegar, J. A. (1974). The estimation of surface residues of benomyl on treated banana. *Pesticide Science* **5**,135-145.
- Doube, S., Upadhyay, P. D., Tripathi, S. C.(1989). Antifungal, physicochemical, and insect repelling activity of the essential oil of *Ocimum basilicum*. *Canadian Journal of Botany* **67**, 2085-2087.
- Fandohan, P., Gbenou, J. D., Gnonlonfin, B., Hell, K., Marasas, W. F. O., Wingfield, M. J.(2004). Effect of essential oils on the growth of *Fusarium verticillioides* and *fumonisin* contamination in corn. *The Journal of Agricultural and Food Chemistry* **52**, 6824-6829.
- Herath, H., Abeywickrama, K.(2008). *In vitro* application of selected essential oils and their major components in controlling fungal pathogens of crown rot in Embul banana (*Musa acuminata* –AAB). *International Journal of Food Science & Technology* **43**, 440-447.
- Koba, K., Poutouli, P.W., Raynaud, C., Chaumont, J. P., Sanda, K.(2009). Chemical composition and antimicrobial properties of different basil essential oil chemotypes from Togo. *Bangladesh Journal of Pharmacology* **4**, 1-8.

- Kocić-Tanackov, S., Dimić, G., Lević, J., Tanackov, I., Tuco, D.(2011). Antifungal activities of basil (*Ocimum basilicum L.*) extract on *Fusarium* species. *African Journal of Biotechnology* **10** (50), 10188-10195.
- Kocić-Tanackov, S., Dimić, G., Pejin, D. J., Mojović, L.V., Pejina, J. D., Tanackov, I. J. (2012). Antifungal activity of the basil (*Ocimum basilicum L.*) extract on *Penicillium aurantiogriseum*, *P. glabrum*, *P. chrysogenum*, and *P. brevicompactum*. *Acta periodica technologica* **43**, 1-342.
- Lis-Balchin, M., Deans, S. G., Eaglesham, E. (1998). Relationship between bioactivity and chemical composition of commercial essential oils. *Flavor and Fragrance Journal* **13**, 98-104.
- Li, Y., Kong, D., Wu, H. (2013). Analysis and evaluation of essential oil components of cinnamon barks using GC–MS and FTIR spectroscopy. *Industrial Crops and Products* **41**, 269–278. <http://dx.doi.org/10.1016%2Fj.indcrop.2012.04.056>
- Marei, G. I. K., Rasoul, M. A. A., Abdelgaleil, S. A. M.(2012). Comparative antifungal activities and biochemical effects of monoterpenes on plant pathogenic fungi. *Pesticide Biochemistry and Physiology* **103**, 56-61.
- Mohamed, S. R., Mohamed, M. D., Abdel-Motaleb, N. M., Mohamed, S. S., Badr, A. N., Shaban, E. M., Khalil, A. F. (2012). Antifungal activity of basil and mustard essential oils against spoilage toxigenic fungi in Egyptian pan bread and its economic evaluation. *Journal of Applied Sciences Research* **8(11)**, 5536-5542.
- Nurzyńska-Wierdak, R., Borowski, B., Dzida, K(2013). Essential oil composition of sweet basil cultivars as affected by nitrogen and potassium fertilization. *Turkish Journal of Agriculture and Forestry* **37**, 427-36.
- Nwosu, J. N., Ogueke, C. C., Owuamanam, C. I., Onuegbu, N. (2011).The Effect of Storage Conditions on the Proximate and Rheological Properties of Soup Thickener *Brachystegia enrycoma (Achi)*. *Report and Opinion* **3(5)**, 52-58.
- Paton, A. (1992). Synopsis of *Ocimum L. (Labiatae)* in Africa. *Kew Bulletin* **47**, 403-36.
- Rahemi, D., Babae, N., Kazemi, S., Sefidgar, S. A. A., Moghadamnia, A. A.(2015). An *In Vitro* Study of the effect of cinnamaldehyde on the growth of *Candida albicans* compared to Nystatin and Fluconazole. *Crescent Journal of Medical and Biological Sciences* **2(3)**, 76-80.
- Reuveni, R., Fleisher, A., Putievsky, E. (1984). Fungistatic activity of essential oils from *Ocimum basilicum* chemotypes. *Journal of Phytopathology* **110**, 20-22.

- Senanayake, U. M., Chithran, V. J., Krishnaraja, S. R. (1997). Composition of essential oils and mosquito repellent property of local maduruthala plants (*Ocimum* sp.). *Chemistry in Sri Lanka* **14(8)**, 45-48.
- Shafique, M., Khan, S. J., Khan, N. H. (2011). Study of Antioxidant and Antimicrobial Activity of Sweet Basil (*Ocimum Basilicum*) Essential Oil. *Pharmacology online* **1**, 105-111.
- Siriwardana, H., Abeywickrama, K., Kannangara, S., Attanayake, S. (2016). Medium scale test marketing trials to identify the suitability of basil oil, alum plus modified atmosphere packaging in controlling crown rot disease of Cavendish banana. *Annals of Food Science and Nutrition* **1(1)**, 1-8.
- Soliman, K. M., Badeaa, R. I. (2002). Effect of oil extracted from some medicinal plants on different mycotoxigenic fungi. *Food and Chemical Toxicology* **40**, 1669-1675.
- Zollo, P. H. A., Biyiti, L., Tchoumboungang, F., Menut, C., Lamaty, G., Bouchet, P. (1998). Aromatic plants of tropical Central Africa. Part XXXII. Chemical composition and antifungal activity of thirteen essential oils from aromatic plants of Cameroon. *Flavor and Fragrance Journal* **13**, 107-114.
- USDA National Nutrient data base, 2016. [<https://ndb.nal.usda.gov>]. Accessed on 23/04/2016.
- Wall, M. M., 2006. Ascorbic acid, vitamin A, and mineral composition of banana (*Musa* sp.) and papaya (*Carica papaya*) cultivars grown in Hawaii. *Journal of Food Composition and Analysis* **19**, 434-445.