Carboxyl methylcellulose (CMC) containing moringa plant extracts as new postharvest organic edible coating for avocado (*Persea americana* Mill.) fruit

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ABSTRACT

Organic edible coating products are reported in enhancing fruit quality and their acceptability for postharvest fruit treatment is increasing due to consumers' health awareness. This study investigated a novel edible carboxyl methylcellulose (CMC) containing moringa leaf and seed extracts as 1: Postharvest coating application to improve avocado fruit quality, and 2: Postharvest disease control agent that contains antimicrobial properties for reducing disease incidence. Postharvest treatments containing CMC (1% w/v) blended with moringa leaf (MLE) and seed extracts (MSE) (2%) were used to treat 'Hass' or 'Gem' fruit. A CMC containing moringa significantly improved fruit quality of the two cultivars. Treated fruit had significantly lower mass loss, ethylene and respiration rate compared to the untreated control. Various media of moringa extracts from seed and leaf tissues using different solvents were also tested against postharvest fungi in reference to potato dextrose agarose (PDA) (control). Both moringa leaf and seed extracts had a significant effect on the growth of *C. gloeosporioides* and *A. alternata*. Moringa extracts significantly inhibited the growth of the fungi. A result of image analysis also revealed that a destruction in the hyphal structure for all pathogens, which was exposed to moringa extracts, while their respective control (no moringa extract) remained intact. The results found in this investigation showed that CMC containing moringa extract suppresses or delays postharvest diseases of avocado and improves the shelf life of avocado during storage. The CMC blended with moringa extracts could potentially be commercialised as a new organic edible coating for avocado fruit for future industry application.

Keywords: Carboxymethyl Cellulose (CMC), Edible coatings, Antimicrobial Antioxidant, Moringa Extract

INTRODUCTION

Avocado (*Persea americana*, Mill) is a climacteric fruit, with high ethylene accumulation and high fruit respiration, subsequently stimulating onset of ripening during postharvest storage (Blakey *et al*., 2012). Huge magnitudes of postharvest fruit loss is due to high rate of biological process as well as fruit diseases. Various types of step wise postharvest fruit treatments have been used to reduce these losses, to improve fruit quality and shelf life.

Nowadays, the avocado industry do not apply any synthetic waxing substance for export fruit to Europe to slow down fruit moisture loss and fruit appearance, for example glossiness. Therefore, it causes fruit shrivelling and to some extent affects fruit shelf life. Commercially, prochloraz is used to control postharvest fruit diseases with regulatory conditions linked to different maximum residual limits (MRLs) in order to ship the proposed fruit to global markets (Le Roux *et al*., 1985). Application of this chemical still imposes pressure to comply with safety regulations. It therefore warrants an alternative less risky material to comply with this regulation and facilitates effective disease protection and smooth fruit export.

According to Pavlath and Orts (2009), different types of materials were used for coating and wrapping various fruits and vegetables to extend their shelf life. This is eaten together with foods and with or without removal is considered an edible coating. An edible coating protects outer membrane of fresh fruits and vegetables (Mohamed *et al*., 2013). The edible coatings are served as carrier of texture enhancer, antioxidants and it is used as a nutraceutical (Undurraga *et al*., 1995; Rojas-Grau *et al*., 2008).

CMC has been reported on avocado fruit (Maftoonazad & Ramaswamy, 2005). Banks *et al.* (1997) reported that coating fruit with CMC (2 g/100 g) substantially increased the risk of fermentation.

Moringa oleifera Lam. is a tree that grows widely in many tropical and subtropical countries. The antimicrobial properties of *M. oleifera* leaf extracts were as a result of its active phytochemicals, which include, Sitosterol, Niazin A, Stigma sterol, Kaempferol and Quercetin (Rao *et al.*, 2011). Studies have shown that the leaves of *M. oleifera* have an antibacterial potential against several organisms (John *et al.*, 2013; Rao *et al.*, 2010).

Leaf extracts exhibit the greatest antioxidant activity. This study therefore investigated the efficacy of commercially known hydrophilic polysaccharide based edible coatings carboxymethyl cellulose (CMC) which composites with moringa leaf and seed extracts as novel approach in enhancing fruit quality as well as antifungal agent mainly postharvest diseases, this eventually enhances fruit shelf life.

MATERIALS AND METHODS

Fruits were collected from Westfalia fruit Merensky packhouse in Howick. Two avocado cultivars, 'Hass' and 'Gem', were used for the experiment, 180 fruit were assigned for three treatments (control, MLE+CMC 1%, MSE+CMC 1%), each treatment had 60 fruits for 3 replications, there were 20 fruit per replication.

The fruits were dipped in the treatment solutions for 1 min and left on the bench top until drained out. These fruits were then transferred to cold room which were set at 5.5°C for 21 days and afterwards moved to ambient condition for ripening and evaluated for fruit shelf life of each treatment.

Over the course of the experiment, various physical and chemical quality attributes were measured:

Fruit firmness measurement

Fruit firmness was determined every seven days during cold storage using a hand-held firmness tester (Bareiss, Germany). Two readings, on a scale of 100 (hard, unripe) to <60 (ready to eat), were taken at the equatorial region of the fruit on opposite sides. Firmness readings with 100 representing hard, unripe fruit and 60 soft, ripe fruit (Standard ISO 7619, International Organisation for Standardization).

Fruit ethylene production measurement

Fruit ethylene production was measured with a F 950 handheld ethylene analyser (Felix Instruments QC Applied Food Sciences) using fixed volume mode which samples 15 ml from the headspace every seven days (Tesfay *et al*., 2012). Each fruit was sealed in a 1 L jar for 15 min, the readings recorded as a rate of ethylene in ppm.

Fruit CO_2 production measurement

Fruit CO_2 production was measured with an environmental gas monitor (EGM-1, PP Systems, Hitchin, UK) every seven days (Tesfay *et al.*, 2012). Each fruit was sealed in a 1 L jar for 10 min, after which the headspace CO_2 concentration was determined and the results calculated as a rate of CO_2 production (mg $kg^{-1}{}_{FW}$ h^{-1}), taking into account fruit mass, headspace and ambient room CO_2 concentration.

Testing antifungal properties of plant extracts

Avocado pathogen isolation

The pathogens were isolated from the collected avocado fruits by aseptically cutting internally infected tissues using an alcohol-sterilised scalpel. The tissues were surface sterilised for 30 seconds in 70% ethanol, rinsed twice in distilled water and placed on the potato dextrose agar (PDA) plates and incubated at 28°C for one week to allow fungal growth. A growing media was prepared using 78 gram of Potato Dextrose Agar (PDA) and poured in a 2000 ml bottle containing two liters of distilled water. The PDA media was autoclaved for 15 minutes at 121°C and cooled to 50°C in a water bath. The prepared media was supplemented with 100 milligram of chloramphenicol dissolved in 20 ml of ethanol and poured into 90 mm petri dishes. After seven days of incubation, a block of mycelia from the edges of growing colonies were cut and transferred into a fresh PDA plates to obtain pure cultures.

Isolates identification

The isolates were identified on the basis of their cultural and morphological features, such as the colour of the colonies, hyphae orientation and the shape of their spores using light microscope.

Pathogenicity test

The pathogenicity of the isolates was tested on symptomless unripe avocado fruits collected from the Westfalia farm. The fungal mycelium was cut from the pure cultures by a sterilised scalpel and inoculated on an artificial injured healthy fruit. The inoculated wounds were covered by sterilised cotton wool and sealed with tape. The fruit were stored for two days at 25°C to ripe. The tape was removed after two days and the fruit were left at 25°C for five days for further ripening. After seven days of inoculation, disease severity was measured using a visual scale of 0-3; where 0 = no visible symptoms; 1 = 5%; 2 = 10%; 3 = ≤15% of the fruit area covered by lesions. Results were subjected to GenStat statistical software for analysis.

Extraction of plant extracts

The moringa plant seed and leaf extracts were extracted using three different methods of extraction, namely methanol, ethanol method 1 and ethanol method 2, following the extraction procedure used by Mendoza *et al*. (2013) with some modifications.

Methanol extraction: 100 g of moringa seeds and leaves were extracted with 1 L of methanol/HCL 1% (v/v) for 4 hours with constant agitation at 4°C. Extracts were concentrated in a rotary evaporator and 20 mL of distilled water was added. Water addition

will be repeated three times. The crude extracts were subjected to sequential liquid-liquid extraction with hexane, chloroform and finally ethyl acetate.

Ethanol method 1-extraction: The extraction method was similar to methanolic extraction except that there was no HCL and water addition on the extracts.

Ethanol method 2 extraction: similar to methanolic extraction except that there was no HCL addition on the extracts.

***In-vitro* screening**

The antifungal activity of moringa plant extracts was screened against the isolates, C. *gloeosporiodes*, *A. alternata* and *L. theobromae* in petridishes. The PDA media were separately amended with moringa leaf and seed extracts of different extraction methods. The amended PDA was poured into 90 mm sterile Petri plates (20 mL/plate). Discs of mycelium (3 mm diameter) were excised from the edge of seven-day old cultures of the isolates and transferred to the amended PDA media. In control sets, equal amounts of sterilised distilled water was amended with PDA. PDA plates were inoculated with 3 mm mycelial plugs of the isolates. Inoculated Petri plates were then incubated at 28°C for seven days. Radial growth of cultures was measured using a ruler.

***In-vivo* test screening**

The avocado fruit were first dipped into the pure isolated fungi suspensions. The two suspensions were the anthracnose and stem-end rot for 1 min. The fruit were then left on top of a desk until drained out. Afterwards the fruit were coated with the already prepared treatments (control, MLE+1% CMC, MSE+1% CMC) and inspected for % disease incidence and % disease severity.

Data analysis

The data collected were analysed using statistical software using GenStat 17.1. Standard error values were calculated where a significant standard deviation was found at $P \leq 0.05$ between individual values.

RESULTS AND DISCUSSION

1. THE EFFECT OF EDIBLE COATING COMPOSITE WITH MORINGA ON FRUIT QUALITY ATTRIBUTES

The edible coating had a significant effect ($P < 0.05$) in fruit ethylene productions. The MLE and MSE+1% CMC had the highest effect in slowing down the ethylene respectively while the control had the least effect in slowing down ethylene diffusion within membrane cell structures (Fig. 1). The findings from this experiment further insights the treatments' effect in slowing down the ethylene production, potentially delays the fruit sensitivity to onset fruit ripening which results in extending shelf life. Similar fruit response trend was found for both cultivars, 'Hass' and 'Gem'.

The edible coating had a significant effect ($P < 0.05$) in fruit mass loss (%) of 'Hass' and 'Gem' fruit as compared to control fruit. The MLE and MSE+1% CMC had the highest effect in slowing down the mass loss respectively while the control had the least effect (Fig. 2). The fruit moisture loss can have an effect on membrane structure as well as cell turbidity, further interferes with other quality attributes, such as fruit appearance leading to shrivelling. The fruit moisture is somehow correlated with fruit shelf life, higher fruit moisture can have better shelf life compared to less fruit moisture. The results

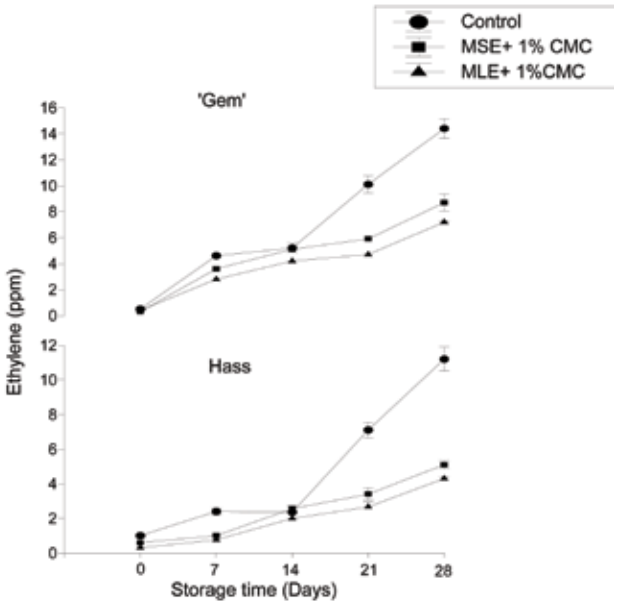


Figure 1. Effect of edible coatings in avocado fruit ethylene. Vertical bars represent standard error of the mean value (n = 5).

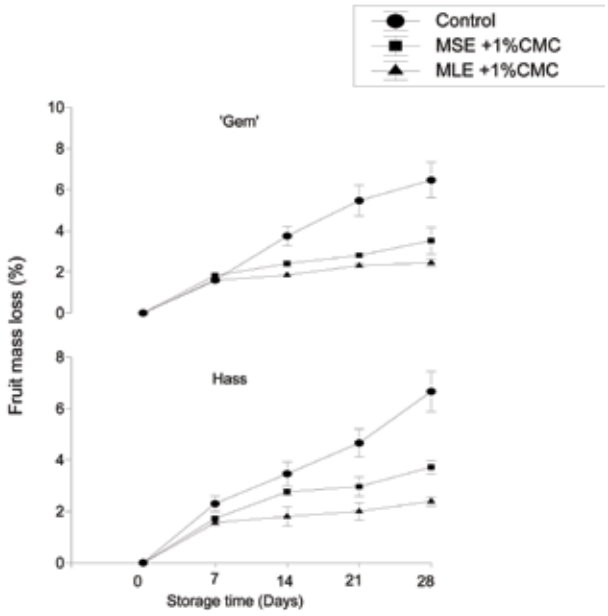


Figure 2. Effect of edible coatings in avocado fruit mass loss. Vertical bars represent standard error of the mean value (n = 5).

observed in the current study are also in agreement with Maftoonazad and Ramaswamy (2005) who showed that methyl cellulose retards moisture loss in avocado fruit. Higher postharvest mass loss observed in the untreated control fruit could also be explained by the removal and re-organisation of natural wax on the fruit surface which is brushed down and re-organised by standard commercial brushing and washing (Magwaza *et al*., 2013).

The edible coating had a significant effect ($P < 0.05$) in fruit CO_2 productions for 'Hass' and 'Gem' fruit, as compared to control fruit. The MLE and MSE+1% CMC had the highest effect in slowing down the fruit respiration respectively while the control had the least effect (Fig. 3). The differences in fruit CO_2 production, although progressive effect on accumulation of CO_2 during cold storage and shelf life is imminent, the treatments showed significant differences when only fruit exposed to higher temperature or ambient condition. Similar fruit response trend was found for both cultivars, 'Hass' and 'Gem'. In avocado, typical a climacteric fruit, the increase in respiration rate, which is triggered by ethylene accumulation, is accompanied by a complex of biochemical changes resulting in fruit softening. The results observed herein are similar to those reported in other studies on avocado fruit, where respiration have been shown to increase with time and the rate reduced by coating treatments (Jeong *et al*., 2002, 2003).

Treatments significantly ($P < 0.05$) improved fruit firmness. The treatment for MLE and MSE with 1% CMC had the highest firmness compared to control (Fig. 4). The treatment improved the membrane structure, this would barrier the gaseous diffusion intra- and inter-cellularly. Among the volatiles, the ethylene gas is one of the molecules that can regulate ripening and shortens fruit shelf life. The treatments effect as a barrier to this gas has a direct effect to individual fruit and ethylene accumulation in storage rooms. The softness of fruit is typical of avocado fruit resulting from the weakening of the cell wall structure, loss of membrane integrity, hydrolysis of cellulose and hemicellulose as well as depolymerisation of pectin and starch (Seymour *et al*., 1993). The hydrolysis and depolymerisation of these components are catalysed by the action of several enzymes, including polygalac-turonase, pectin methylesterase, pectate lyase, Rhamnogalactur-onase and b-galactosidase (Yaman & Bayoindirli, 2002; Payasi *et al*., 2009). Structural changes in the integrity of cell wall are likely to result from the activities of cellulase (Pesis *et al*., 1978; Tucker & Laties, 1984) which decreases cellular cohesion by cell disarrangement and degradation of pectin (Awad & Young, 1979). The gaseous composition of lower O_2 and higher CO_2 percentage in coated fruit is likely to limit the activities of oxidising enzymes allowing the retention of firmness during postharvest storage (Salunkhe *et al*., 1991). Our findings are therefore in agreement with this argument and that of Jeong *et al*. (2000) who stated that firmness of untreated avocado fruit decreased faster whereas fruit treated with both 1-MCP and wax retained firmness for a longer period. Loss of firmness during marketing negatively affect fruit quality, hence the ability of these coating treatments to reduce the rate of softening is advantageous in extending shelf-life and reducing postharvest losses.

The moringa leaf and seed extracts displayed various compounds (Tables 1, 2). Most of these compounds are reported to have huge benefits during plant development and any intended use, for example antimicrobial agent. The leaf extracts of *M. oleifera* have been reported to exhibit antioxidant activity both *in vitro* and *in vivo* due to abundant phenolic acids and flavonoids (Chumark *et al*., 2008).

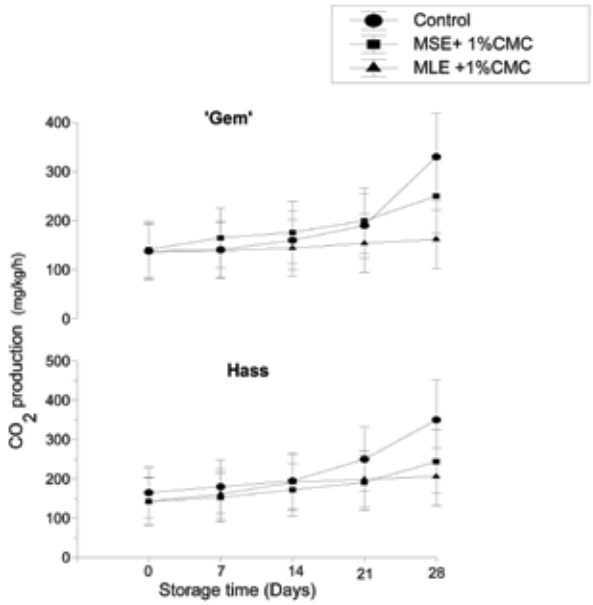


Figure 3. Effect of edible coatings in avocado fruit respiration. Vertical bars represent standard error of the mean value (n = 5).

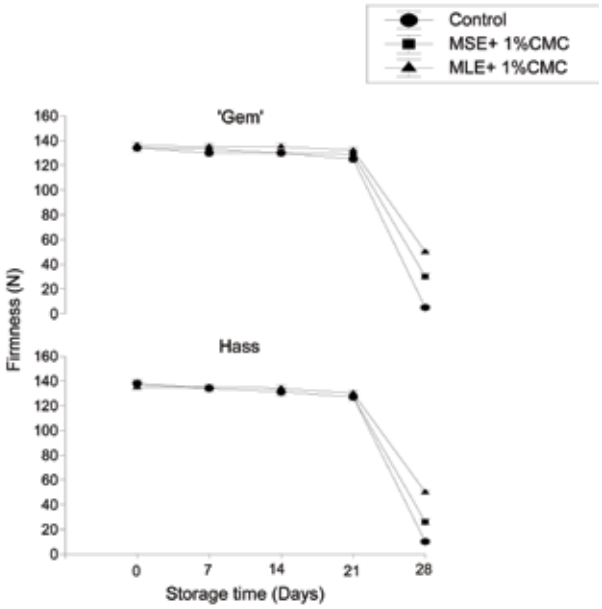


Figure 4. Effect of edible coatings in avocado fruit firmness. Vertical bars represent standard error of the mean value (n = 5).

Table 1. Plant bio-chemicals from moringa leaf extract (LC/HPLC/MS).

S.N.	Compounds	RT (min)	Concentration (area)
1	5-hydoxyferulic acid	2.3	1228747
2	Glucosinolates	5.1	57988463
3	Diferuloyl-(5OH-feruloyl)spermidine	5.4	29386496
4	hexadecylferulate	7.6	12698660
5	Dicoumaroyl putrescine	9.1	12724980
6	Kaempferol	11.1	55680932
7	Di(dihydrocaffeoyl) spermidine	10.2	9930245
8	Isorhamnetin-rhamnosyl-glucoside	13.0	29945537
9	Kaempferol with rhamnose and glucose	15.8	4913797
10	Apigenine-C-glucoside	23	37354025
11	Quercetin-3-O-glucoside	27	368874
12	Quercetin-3-O-(6-malonyl)glucoside	30	728606
13	Kaempferol-3-o-glucoside	32.9	2601380

Table 2. Plant bio-chemicals from moringa leaf extract (GC/MS).

S.N.	Compounds	RT (min)	Concentration (area)	Extracts
				Leaf/seed
1	5-hydoxyferulic acid	2.3	1228747	93.3
2	Glucosinolates	5.1	57988463	4403.4
3	Diferuloyl-(5OH-feruloyl) spermidine	5.4	29386496	2231.5
4	hexadecylferulate	7.6	12698660	964
5	Dicoumaroyl putrescine	9.1	12724980	966
6	Kaempferol	11.1	55680932	4228
7	Di (dihydrocaffeoyl) spermidine	10.2	9930245	754
8	Isorhamnetin-rhamnosyl-glucoside	13	29945537	2273.9
9	Kaempferol with rhamnose and glucose	15.8	4913797	373.1
10	Apigenine-C-glucoside	23	37354025	2836.5
11	Quercetin-3-O-glucoside	27	368874	28
12	Quercetin-3-O-(6-malonyl)glucoside	30	728606	55.3
13	Kaempferol-3-o-glucoside	32.9	2601380	197.5

2. EFFICACY OF THE MORINGA EXTRACTS AS ANTIFUNGAL AGENT

Pathogen identification

With regard to their identification, *C. gloeosporioides* was cultural identified based on its pale grey, pale pinkish-orange to light pink cultures on PDA plates (Fig. 5A). Its identity was supported by its cylindrical, straight conidia with pointed ends that were observed with the aid of light microscopy (Fig. 5B). *A. alternata* cultures produced a profuse brownish mycelium on PDA plates (Fig. 5C). Microscope observation of *A. alternate* revealed a hyaline mycelium with septate hyphae with irregular branches with brownish ellipsoidal, muriform conidia which have three septa (Fig. 5D). *L. theobromea* produced cultures which varied from greyish white, light grey and black greyish with fluffy rope-like mycelia (Fig. 5E), which later turned into black colour. Under light microscope, a septate hyphae with single and two celled subovoid to ellipsoidal conidia were observed (Fig. 5F).

Pathogenicity test

A disease severity was measured using a visual scale of 0–3, where 0 = no visible symptoms; 1 = slight infection with small lesions; 2 = moderate infection; and 3 = severe infection. There was a significant difference ($P < 0.05$) in disease severity between the fruits inoculated with the three different isolates (Fig. 6). The most pathogenic isolate was found to be *C. gloeosporioides*, followed by *L. theobromae* causing severe and moderate infections, respectively, on the inoculated fruits. Most of *Alternaria* isolates have been found to be less pathogenic to the inoculated avocado fruit, causing slight infections and some of them did not cause any visible symptoms. Statistically, there was no significant difference ($P < 0.05$) between *A. alternata* and sterile water (served as a control) inoculated fruit. According to Peres *et al*. (2002), *C. gloeosporioides* is a major problem in subtropical and tropical fruits. The pathogen causes anthracnose in many tropical fruits, including avocado, papaya and mango. On other hand *L. theobromae* and *A. alternata* are known to be associated with stem-end rot in avocado.

In-vitro screening of moringa plant extracts against the isolates

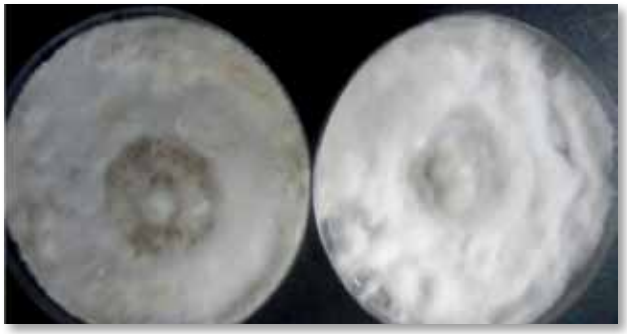
There was a significant difference between the type of moringa plant tissue and method of extraction, and their interaction, with respect to the growth of the isolates (Table 3, 4 & 5). Both moringa plant extracts had a significant effect on the growth rate of the isolates compared to the control sets. However, only methanol extracted seed extracts remained effective against *L. theobromae* after seven days of inoculation (Table 5). The other extracts lost their effectiveness against the pathogen after seven days. The growth rate of *C. gloeosporioides* and *A. alternata* was significantly reduced by ethanol extracted leaf and seed extracts. The extracts of ethanol extraction of both tissues were the least effective in the reduction of growth rates of the two isolates.

The ethanol (method two) extracted leaf extracts were the most effective extracts resulting in 43.6% and 42.9% inhibition against *C. gloeosporioides* and *A. alternata*,

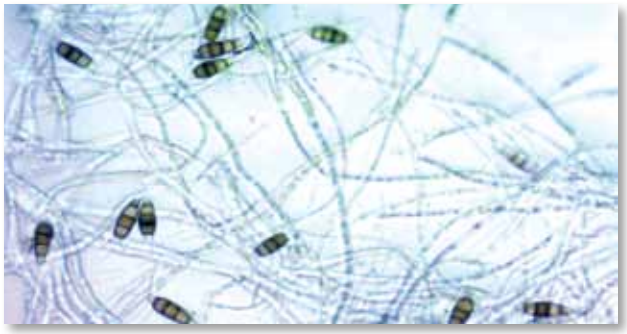
A) *Colletotrichum gloeosporioides* cultures

B) *Colletotrichum gloeosporioides* conidia

C) *Alternaria alternata* cultures



D) *A. alternata* mycelia and conidia



E) *Lasiodioplodia theobromae* cultures

F) *L. theobromae* mycelia and conidia

Figure 5. The seven days old pure cultures of the three isolates on PDA plates and their respective micro-morphological structures (conidia and mycelia) observed under light microscope at 40 X magnification.

Table 3. The growth rate of the *C. gloeosporioides* on the moringa extracts amended PDA plates in comparison to the control over a period of 10 days.

Pathogen	Plant tissue	Extraction method	Mycelial growth (cm)		
			Day 1	Day 2	Day 3
Colletotrichum	Leaf	Methanol	3.156 bc	5.261 c	6.711 c
		Ethanol A	3.222 c	5.283 c	6.661 c
		Ethanol B	2.661 a	4.033 a	4.772 a
	Seed	Methanol	3.267 c	5.8 d	7.55 d
		Ethanol A	2.672 a	4.75 b	5.911 b
		Ethanol B	3.061 b	5.167 c	6.867 c
Control		Water	4.75 d	7.567 e	8.456 e
		P value	<0.001	<0.001	<0.001

*Means followed by the same letter within columns are not significantly different according to Fisher's least significant difference test at P < 0.05. Day 1 = 5 days after inoculation, Day 2 = 7 days after inoculation, Day 3 = 10 days after inoculation

Table 4. The growth rate of the *A. alternate* on the moringa extracts amended PDA plates in comparison to the control over a period of 10 days.

Pathogen	Plant tissue	Extraction method	Mycelial growth (cm)		
			Day 1	Day 2	Day 3
Alternaria	Leaf	Methanol	4.789 c	6.822 b	7.994 c
		Ethanol A	3.506 b	4.744 a	5.811 ab
		Ethanol B	3.222 b	4.156 a	4.85 a
	Seed	Methanol	3.267 b	4.806 a	6.639 b
		Ethanol A	3.239 b	4.422 a	5.667 ab
		Ethanol B	2.661 a	4.517 a	6.494 b
Control		Water	5.644 d	8 c	8.5 c
		P value	<0.001	<0.001	<0.001

Table 5. The growth rate of the *A. alternata* on the moringa extracts amended PDA plates in comparison to the control over a period of 10 days.

Pathogen	Plant tissue	Extraction method	Mycelial growth (cm)		
			Day 1	Day 2	Day 3
Lasiodiplodia	Leaf	Methanol	7.061 c	8.5 c	8.5 b
		Ethanol A	8.272 d	8.378 c	8.5 b
		Ethanol B	6.883 c	8.244 bc	8.5 b
	Seed	Methanol	5.222 a	7.617 a	8.039 a
		Ethanol A	6.111 b	8.444 c	8.5 b
		Ethanol B	6.461 b	8 b	8.5 b
Control		Water	8.5 d	8.5 c	8.5 b
		P value	<0.001	<0.001	<0.001

Table 6. Means value of disease incidence and severity of *Colletotrichum* and *Alternaria* in 'Gem' fruit (N=100).
In the column's means followed by the same letter are not significantly different using Duncan's test at 5% probability.

Treatments	*Colletotrichum* spp.		*Alternaria* spp.	
	Incidence (%)	Severity (%)	Incidence (%)	Severity (%)
Control	66.67a	39.4a	61.2a	32.1a
CMC 1% + MLE	19.21b	8.23b	10.2b	8.1b
CMC 1% + MSE	29.55b	19.4b	26.1b	12.4b

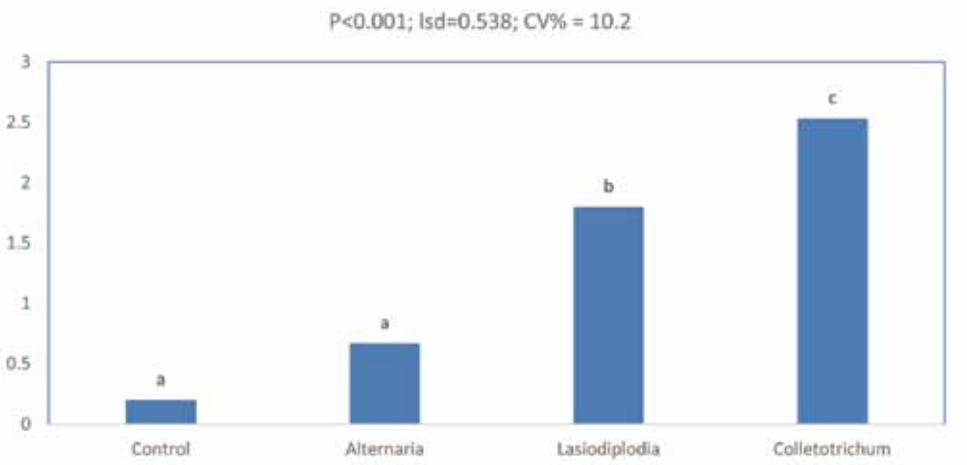


Figure 6. The recorded disease severity of three different isolates on avocado fruits after seven days of inoculation and their statistical parameters.

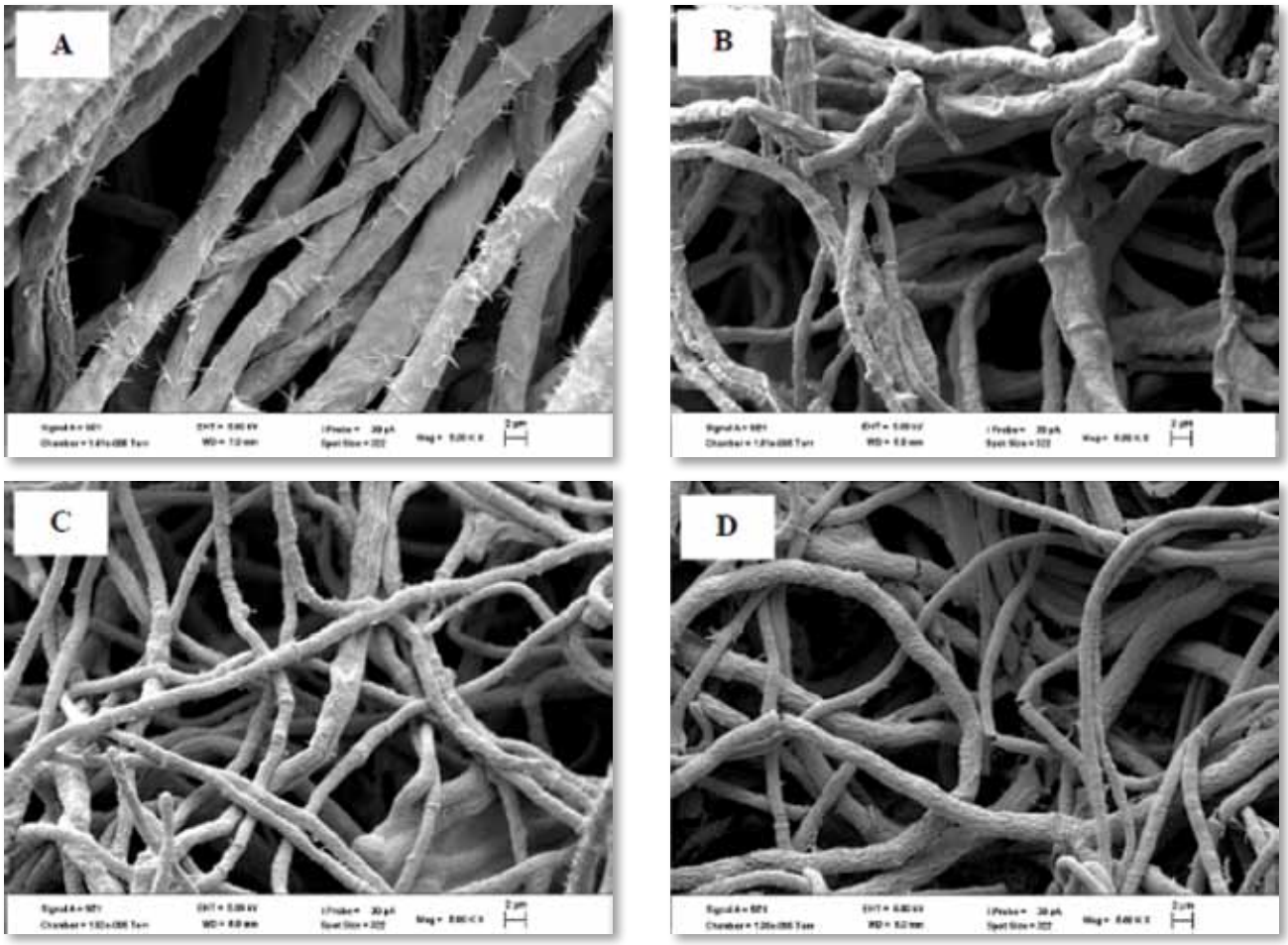


Figure 7. Scanning electron micrographs showing the effect of moringa extracts on the hyphal structure of the two isolates.

respectively, after ten days (Table 6 & 7). The ethanol (method 1) seed extracts were the second most effective extracts against *C. gloeosporioides* and *A. alternata* resulting in 30.1 and 31.6% inhibition, respectively, after ten days.

All methanol extractions were least effective against the isolates, except *L. theobromae* which was relatively inhibited (5%) by methanol extracted seed extracts after ten days (Table 8). This result is in agreement with the results obtained by Torres-Castillo *et al*. (2013) on *Phytopthora parasitica*, *Fusarium oxysporum* and *Alternaria solani* where leaf extracts showed highest antifungal activity against these pathogens. According to Torres-Castillo *et al*. (2013), the high antifungal activity of the leaf extracts can be associated with the high concentration of phenolic compounds in the tissue.

***In-vivo* test**

With the *in-vivo* test, simulating actual infection, fruit were dipped in suspension, the treatment had significant effect in the disease incidence and disease severity. The MLE and MSE+1% CMC reduced the disease incidence and severity respectively better than control (Table 6).

Scanning electron microscopy

The scanning electron microscopy also proved that the moringa extracts had an effect in inhibiting disease development by breaking down the fungi hyphal structures (Fig. 7). The plant extract ability to inhibition of the hyphal development may be associated with the plant biochemical compounds such as phenols. These results are in agreement with findings reported by Jabeen *et al*. (2008) where they observed a destruction of fungal hyphae by moringa extracts. According to Jabeen *et al*., 2008, the antimicrobial activity of moringa extracts can be associated with the occurrence of lipophilic compounds which may have bound to the cytoplasmic membrane, and permeabilise the fungal cell membrane thereby affecting its growth (Huang *et al*., 2000).

Overall, the study demonstrated that 'Hass' and 'Gem' avocado fruit coated with moringa leaf, seed extracts and 1% CMC, had lower rates of respiration and higher values of firmness compared with the uncoated control and this was observed consistently during the entire storage period. The results also showed that reduced rate of respiration, moisture and firmness loss, low disease incidence and less disease severity resulted in improved fruit quality and shelf-life. In conclusion, the study reported the potential of 1% CMC edible coating containing moringa leaf/and seed extracts to improve avocado fruit quality, reducing postharvest fruit loss due to pathogen during the storage period.

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