Evaluating the Efficacy of Edible Coatings Incorporated with Moringa Leaf Extract on Postharvest of ‘Maluma’ Avocado Fruit Quality and Its Biofungicidal Effect

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Abstract. This study investigated the efficacy of edible gum arabic (GA) and carboxymethyl cellulose (CMC) containing moringa (M) leaf extract as postharvest treatments for maintaining organoleptic quality and controlling *Colletotrichum gloeosporioides* on ‘Maluma’ avocado fruit. For the quality study, after the fruit was dipped into the treatments: GA 10%, GA 15%, GA 10% + M, GA 15% + M, and CMC 1% + M and uncoated fruit served as control, the fruit were then stored at 5.5 °C [95% relative humidity (RH)] for 21 days, and moved to ambient conditions at 21 ± 1 °C (60% RH) for 7 days to simulate retail condition. Quality parameters that were evaluated include mass loss, firmness, and color changes (L^* , a^* , b^* , respectively), and sensory quality attributes, such as taste, color, mouthfeel, odor, and overall acceptability. Fruit quality study results showed fruit coated with GA 15% + M and CMC 1% + M had lower mass loss (3.66%), retained firmness (62.37 N), and color changes [L^* (30.85), a^* (−2.33) and b^* (7.14)] compared with other treatments. In this biofungicidal study on antimicrobial properties of extracts, treatments against fungi strains using an in vitro test were investigated, which showed treatments of moringa leaf extract, GA 10% + M, and GA 15% + M suppressed radial mycelial growth of *C. gloeosporioides* by 30%, 28%, and 33%, respectively. In conclusion, our study demonstrated that GA 15% + M and CMC 1% + M retained fruit firmness and lowered weight loss and suppressed mycelial growth of *C. gloeosporioides* on ‘Maluma’ avocado fruit. These edible coatings could therefore be an alternative organic postharvest coating treatment and could potentially be commercialized as a new organic biofungicide for the avocado fruit industry.

Avocado fruit is highly perishable, mainly because of its characteristically high metabolic rates, resulting in short postharvest life. High metabolic rates are associated with high respiration rates and high endogenous production of ethylene, which accelerates fruit ripening (Maftoonazad and Ramaswamy, 2005; Tesfay and Magwaza, 2017). Avocado

is also considered to have high mass loss, which can have a negative consequence on fruit quality, such as the fruit experiences shrivelling due to excessive moisture loss, leading to significant economic loss as the value of fresh produce is often determined by its mass (Tefay and Magwaza, 2017). Economic losses also caused by postharvest diseases represent one of the main problems of the fruit industry worldwide. Postharvest losses of fresh produce do not only result in major economic losses but have a negative impact on climate and environment, as for every ton of food wasted ≈4.2 t of carbon dioxide is emitted (Opara and Mditshwa 2013; Qusted et al., 2011).

Commercially, avocados are generally waxed to enhance appearance and reduce moisture loss. Exported fruit treated with synthetic wax products are prohibited to the European Union market, resulting in major economic losses due to water loss and short

shelf life (Kruger, 2013). Edible coatings have recently emerged as an innovative, effective, and sustainable technique for prolonging the postharvest life of fresh horticultural produce. Edible coatings are biodegradable soluble formations that are applied on the fruit surface and can be consumed with the coated product (Embuscado and Huber, 2009; Zhang et al., 2014). Coatings must form a continuous film around the surface for better functionality. Coatings have been reported to improve the postharvest life of fresh produce and maintain postharvest quality by acting as a barrier against gases, moisture, and solute movement (Ncama et al., 2018; Park, 1999). This is achieved by the semipermeable layer formed by coating on the fruit surface. Importantly, edible coatings also can act as carriers for active ingredients, such as colorants, antimicrobials, and flavors, among others that can enhance their functionality (Azarakhsh et al., 2014).

Hussain et al. (2012) reported that CMC and GA have been studied as postharvest treatments for fresh produce. Reduced moisture loss, gaseous movement, and decay incidence, coupled with high firmness and ascorbic acid retention, have been reported in CMC-treated strawberries. Ali et al. (2010) also reported that compared with control treatment, GA delayed color development and improved organoleptic properties in tomatoes.

Moringa oleifera is known for its high phytochemical content that can be used in the pharmaceutical, agricultural, and food industries. Leaves, seeds, flowers, and bark have all been reported to have a high content of proteins, β -carotene, vitamins, phenolics, flavonoids, fatty acids, and other bioactive compounds (Saucedo-Pompa et al., 2018; Tesfay et al., 2016). Various studies have demonstrated the potential of moringa leaves as a functional additive for food products and food application (Adetunji et al., 2012). Moringa leaves are rich in phenolic acids, flavonoids, glucosinolates, and isothiocyanates.

Hot water or methanolic extracts are reported to have high chlorogenic acid, quercetin, and kaempferol content (Cuellar-Núñez et al., 2018).

Over the years, synthetic fungicides have been applied to reduce decay in various fruit (Oregel-Zamudio et al., 2017). For instance, in avocado, copper-based fungicides, such as copper hydrochloride and copper oxychloride, have been extensively used to control anthracnose, whereas stem-end rot has been effectively controlled by postharvest application of prochloraz (Bill et al., 2014; Tesfay et al., 2017). Prochloraz is another common postharvest fungicide used to control postharvest fruit fungal diseases with regulatory conditions restricted from very low maximum residual limits to none to ship the fruit to international export markets (Pérez-Jiménez, 2008). However, with persistent use of these chemical treatments, pathogens develop resistance against fungicides. In addition, the increase in human health concerns regarding chemical residues on treated fruit and the negative impact on the environment has

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resulted in synthetic fungicides becoming unfavorable (Maqbool et al., 2010). Consumer preference toward postharvest treatments that are free from chemicals and environmentally friendly have spurred a considerable interest among researchers to develop edible, natural, and food-safe coatings and plant extracts for avocado fruit.

Therefore, the aim of this study was to investigate the effect of polysaccharide-based coatings incorporated with moringa leaf extract for maintaining postharvest quality attributes and suppressing mycelial growth of *C. gloeosporioides* in 'Maluma' avocado fruit.

Materials and Methods

Fruit samples, treatment, and storage

A total of 180 avocado fruit (Maluma cultivar) used in this study were procured from a commercial orchard at ZZZ (Pty) LTD (lat. 23.6536°S, long. 30.2167°E) in Limpopo Province, South Africa. Using dry matter as maturity index, 'Maluma' avocado fruit were harvested at commercial maturity when the mean dry matter content was 30% (Magwaza and Tesfay, 2015). Harvested fruit were packed in open display boxes and transported overnight in a ventilated vehicle to the Postharvest Laboratory of the Department of Horticulture, the University of KwaZulu-Natal, and Pietermaritzburg campus.

On arrival at the laboratory, fruit were handled according to Tesfay et al. (2017), with slight modifications. Fruit were washed with distilled water. They were then assigned to six postharvest treatments: Control (untreated), GA 10%, GA 15%, GA 10% + moringa 10%, GA 15% + moringa 10%, and CMC 1% + moringa 10%. Each treatment had three replicates of 10 fruit per replicate. Fruit were dipped in treatment solutions, and air-dried on a laboratory bench at room temperature (21 ± 1 °C) for 30 to 45 min. After drying, fruit were packed into commercial boxes and transferred to a cold room which had a delivery air temperature set at 5.5 °C and RH set at $90\% \pm 2\%$ for 3 weeks, simulating shipping conditions. After 3 weeks of cold storage, fruit were transferred to ambient conditions (21 ± 1 °C, RH 60%) for 7 d, simulating ripening and retail conditions. Data on fruit quality parameters and organoleptic properties were collected.

Moringa tissue extraction process

Ten grams of moringa plant tissue was extracted with 1 L of ethanol 70% (v/v) for 2 h with constant agitation at 4 °C. Extracts were concentrated in a rotary evaporator, and 20 mL distilled water was added. Finally, crude extract was subjected to sequential liquid-liquid extraction with hexane, chloroform, and finally ethyl acetate. The extracts were thereafter kept in cold storage for amending GA and CMC 1% for treating fruit (Tesfay et al., 2017).

Fruit quality attributes and sensory evaluation

Mass loss. The fruit mass was measured according to Tesfay et al. (2017) using a RADWAG (Wagi Electronic Inc., Toruńska, Poland) digital balance (± 0.01 g) and was

reported as percentage loss in moisture using Eq. [1].

$$\text{Weight loss (\%)} = [(W_i - W_f) / W_i] \times 100 \quad [1]$$

where W_i = weight of fruit before postharvest storage, and W_f = weight of fruit at a specific ripening day.

Firmness. Firmness was done according to a method described by Tesfay and Magwaza (2017), with slight modification. Four readings were taken at an equatorial region of opposite sides of the avocado and the average was recorded. The hand-held densimeter measures fruit firmness by means of a metal ball (diameter 5 mm) that is pressed onto the fruit. The scale ranges from 100 (hard) to 0 (soft) (Köhne et al., 1998).

Peel color. For each replicate, four individual fruits were marked on the equatorial region (three regions per fruit) and the color was recorded on the same spot every time sampling was done. Color was determined according to McGuire (1992) using the Hunter Laboratory System with Minolta Chroma Meter CR-2000 (Chroma Meter; Konica Minolta Sensing, Inc., Osaka, Japan). The Chroma meter was calibrated with a white standard tile ($Y = 87.0$, $X = 0.3146$, and $y = 0.3215$) before fruit scanning at 30-min intervals. Values were recorded as L^* (white = 100, black = 0), a^* (green-red), and b^* (yellow-blue scale).

Sensory evaluation. Sensory evaluation was carried out according to Arpaia et al. (2015), with slight modifications. Sensory panelists were 37 students, 25 females and 12 males, with average age range of 22 to 26 years, at the University of KwaZulu-Natal, Pietermaritzburg campus. Most panelists had never performed a sensory evaluation of avocado. Each panelist was provided training on the meaning of the sensory characteristic and on how to use the hedonic scale. Carrots and water were used to cleanse the palate after each sample was evaluated. Panelists rated each sample for overall liking using a 5-point hedonic scale in which 1 = dislike extremely and 5 = like extremely. All samples were rated for the degree of color, taste, mouthfeel, odor, and overall acceptability.

Testing antifungal properties of treatments

Media preparation and pathogen isolation. Approximately 19.8 g of potato dextrose agar (PDA) was weighed and poured in 500 mL of distilled water. The PDA media was autoclaved for 15 min at 121 °C and cooled to 50 °C in a water bath. Prepared media were supplemented with 100 mg of chloramphenicol dissolved in 20 mL ethanol and poured into 90-mm petri dishes. Pathogen isolation was done according to Xoca-Orozco et al. (2017), with slight modifications. Briefly, pieces (5 mm) showing symptoms of *C. gloeosporioides* were aseptically isolated from infected avocado fruit showing symptoms of either anthracnose or stem-end rot. Pathogens were identified on the basis of their cultural and morphological characteristics, such as color, hyphae orientation, and spore shape by using light microscopy.

Moringa extracts and GA preparation. Moringa leaf was extracted as described by Tesfay et al. (2017), with slight modification. Briefly, 10 g of moringa leaf powder was dissolved in 1 L of 70% ethanol for 4 h with constant agitation at 4 °C. The extract was filtered into a clean glass container using Whatman no. 1 filter paper. The extract was then kept in cold storage for amending growing media and for preparation of GA coatings for in vitro screening. GA solutions in water alone and in moringa extracts were dissolved at two concentration levels: 10% and 15%.

In vitro evaluation of the fungicidal activity of GA, CMC, and moringa leaf extract. The effect of GA, moringa leaf extract, and GA in moringa leaf extract on the radial growth of *C. gloeosporioides* and *Lasiodiplodia theobromae* were studied using PDA (Tesfay et al., 2017), with slight modification. The amended PDA was poured into petri dishes (20 mL/plate) and control treatment, amendment of PDA was achieved by adding equal amounts of sterilized distilled water to the PDA. Discs of mycelium (5-mm diameter) were removed from the edge of 7-d-old cultures of the isolates, transferred, and placed at the center of the amended PDA media. The inoculated petri dish plates were then incubated at 28 °C for 10 d. Radial growth of cultures was measured using a ruler. The mean growth values were converted into inhibition percentage of mycelial growth in relation to control treatment according to Eq. [2].

$$GI (\%) = \left(\frac{x - y}{x} \right) \times 100 \quad [2]$$

where $GI (\%)$ = growth inhibition percentage, x = mycelial growth diameter in control, and y = mycelial growth diameter in treatment.

Statistical analysis. The collected data were subjected to analysis of variance using GenStat statistical software (GenStat, 18.1 edition; VSN International, UK) 17. Standard error values were calculated when a significant standard deviation was found at $P \leq 0.05$ between individual values.

Results and Discussion

Fruit mass loss. The postharvest mass loss in fresh horticultural produce such as fruit and vegetables results in loss of quality and freshness, and subsequently economic loss, as their market value is mainly determined by their mass (Maalekuu et al., 2006). Reducing mass loss does not only ensure good economic gains but plays a significant role in improving the shelf life of fresh produce. Mass loss with storage time is shown in Fig. 1. In this study, mass loss was significantly ($P \leq 0.01$) influenced by the interaction between storage time and coatings.

GA 15% + moringa (M) (3.66%) was the most effective treatment in reducing mass loss, followed by CMC 1% + M (6.19%) and GA 10% + M (8.30%). These results are in agreement with Tesfay and Magwaza (2017)

and Tesfay et al. (2017), who demonstrated that polysaccharide coatings such as chitosan and carboxymethyl cellulose were able to retard mass loss in avocados. Also, Al-Juhaimi et al. (2012) reported that GA was able to reduce mass loss in cucumbers. In our results, it can clearly be seen that GA 15% with or without moringa outperformed GA 10% throughout the study. For both uncoated and coated fruit, the highest mass loss occurred during the last week (week 4) of the storage period. This is inconsistent with previous reports that mass loss is predominantly driven by temperature and vapor pressure difference between the fruit surface and the environment (Bower, 2005; Thakur et al., 2018), thus major mass loss occurred at ambient conditions compared with cold storage. Fruit at ambient environment faces a potentially deleterious temperature effect to water loss. Moisture loss through the fruit surface is a natural aspect of the fruit metabolic aspect process that occurs through stomatal openings and skin cracks. Tesfay et al. (2017) further explained that loss of membrane integrity in avocado fruit results in an increase in stomatal opening, which subsequently increases mass loss. Loss of membrane integrity is correlated with membrane permeability, which subsequently increases metabolic activities, such as lipid peroxidation, resulting in an increased mass loss (Song et al., 2009).

Firmness. The firmness of 'Maluma' avocado fruit was significantly ($P \leq 0.01$) affected by the interaction between storage time and coatings. This could be explained by the sharp decline of firmness in control fruit in comparison with the steady decline in coated fruit. Loss of firmness gradually increased with storage time for both coated and control fruit (Fig. 2). At the end of storage time, uncoated fruit clearly had the lowest firmness (22.20 N). On the other hand, GA 15% + M (62.37 N), CMC 1% + M (59.93 N), and GA 10% + M (59.48 N) maintained higher firmness throughout the study. A similar trend was also observed in mass loss, in which minimal change was observed in fruit coated with the previously mentioned coatings. It can be argued that the restriction of moisture loss was the major factor why coatings retained higher firmness than uncoated fruit. This argument is in agreement with Aguirre-Joya et al. (2017), who demonstrated that moisture loss is not only related to mass loss, but also correlates with fruit softening.

Avocado softening is a result of the loss of membrane integrity caused by mass loss and enzymatic activity that hydrolyzes the cell wall structure and solute leakage (Pesis et al., 1978). Avocado membrane structure is made up of mainly cellulose and hemicellulose, as well as pectins; hydrolysis and depolymerization of these structures by enzymes such as polygalacturonase and pectin methylesterase results in fruit softening (Bower and Cutting, 1988). Dhalsamant et al. (2017) reported that the use of modified atmosphere packaging with O_2 (2%) and CO_2 (10%) delayed ripening and softening in mango fruit. In this study, it could

Fig. 1. Effect of edible coatings on mass loss of 'Maluma' avocados stored at 5.5 °C for 3 weeks and then transferred to ambient temperature (21 ± 1 °C) for 1 week. Vertical bars represent SE at $n = 4$. GA = gum arabic; CMC = carboxymethyl cellulose.

Fig. 2. Effect of edible coatings on 'Maluma' avocado firmness stored at 5.5 °C for 3 weeks and then transferred to ambient temperature (21 ± 1 °C) for 1 week. Vertical bars represent SE at $n = 4$. GA = gum arabic; CMC = carboxymethyl cellulose.

be argued that coating fruit with GA 15% + M, CMC 1% + M, and GA 10% + M resulted in a modified atmosphere with reduced O_2 and increased CO_2 levels, causing a reduction of enzymatic activities in coated avocados compared with uncoated avocados. In agreement with this finding, Bill et al. (2014) also reported that chitosan and aloe vera-based coatings in combination with thyme oil retained 'Hass' avocado firmness.

Color. Fruit color is the primary and most used perception parameter in determining the quality of fresh horticultural produce. Changes in L^* , a^* , and b^* values of avocado skin color are shown in Fig. 3. The lightness (L^*) gradually decreased during storage in both coated and uncoated fruit. The highest decrease in lightness was observed in uncoated fruit followed by GA 10% coated fruit, whereas the fruit coated with 15%, 10% GA + M, and CMC 1% + M retained their lightness values at the end of the experiment. This observation has been anticipated in avocado fruit tissues, which

accumulate high oil content that has a lipophilic functional property that exhibits resistance to water loss (Kruger, 2013). Thus, the performance of the coating may be improved because of its good adherence and compatibility with fruit peel of high lipid content, as bilayer, enhances the fruit appearance and attractiveness. Similarly, GA is a polysaccharide, it has hydrophilic functional properties, which display mechanical strength, and it slows gas exchange. The results observed in the current study are also in agreement with Maftoonazad and Ramaswamy (2005) and Magwaza et al. (2013), who showed that methyl cellulose and natural glossiness of avocado fruit retards moisture loss and gas exchange.

In this study, an interaction between edible coatings and storage time had a significant ($P < 0.001$) effect on the increase in a^* values. There were significant differences in performance among edible coatings, with GA 15% + M being the most effective coating followed by CMC 1% + M and GA 10% + M. Changes in a^* values

Fig. 3. Effect of edible coatings on fruit color of 'Maluma' avocados stored at 5.5 °C for 3 weeks and then transferred to ambient temperature (21 ± 1 °C) for 1 week. Vertical bars represent SE at n = 4. GA = gum arabic; CMC = carboxymethyl cellulose; M = moringa.

Fig. 4. Sensory evaluation scores of color, taste, mouthfeel, odor, and overall acceptability of 'Maluma' avocados treated with different edible coatings after 3 weeks at cold storage (5.5 °C) and further stored 1 week at ambient conditions (21 ± 1 °C). Mean of 37 panelists for each sample used the following hedonic scale: 1 = disliked extremely; 2 = disliked slightly; 3 = neutral; 4 = liked slightly; 5 = liked extremely. GA = gum arabic; CMC = carboxymethyl cellulose.

ranged from -10.2 to +1.8, -9.9 to +0.8, -9.8 to -1.5, -9.9 to -1.9, -9.8 to -1.9, and -9.8 to -2.5 for control, GA 10%, GA 15%, GA 10% + M, GA 15% + M, and CMC + M, respectively. The increase was common in dark-skinned avocados, as this indicates the degradation of chlorophyll and synthesis of anthocyanin pigments, which increase with avocado ripening (Cox et al., 2004). This result corroborates the findings of Adjouman et al. (2018), who reported that polysaccharide coatings delayed a* value increase in tomatoes compared with control. The ability of these coatings to retain avocado green color suggest that coatings were able to delay fruit ripening. This can be supported by the findings of Jeong et al. (2003) and Cox et al. (2004), who reported that any postharvest treatment that can delay color change from green to dark purple can prolong the shelf life of dark-skinned cultivars. Conversely, the results showed there were sharp declines in b* values in control than coated fruit with storage time. Changes in b* values ranged from 14.08 to 3.19, 14.08 to 3.75, 14.08 to 4.13, 14.08 to 5.48, 14.08 to 7.17, and 14.08 to 5.53 for control, GA 10%, GA 15%, GA 10% + M, GA 15% + M, and CMC + M, respectively. According to Maftoonazad et al. (2007), reduction in b* values in avocado is an indication of a decrease in yellowness and increase toward a darker chroma. The color change in uncoated fruit was enhanced and they attained purple to black color during shelf life compared with the coated fruit. Although the fruit coated with GA 15% + M, GA 10% + M, and CMC 1% + M remained green even after 28 d of storage, it is possible that GA and CMC provided a thick barrier against ethylene production and gas exchange between inner and outer environments, and therefore delayed the ripening of the fruit during storage. Furthermore, Ali and his group (2010) also reported similar results that GA had significant effect in the physical appearance of tomatoes. Similar results were observed by Park et al. (1994) when they stored tomatoes coated with a corn-zein film at 21 °C. During ripening, the green chlorophyll pigment is degraded and there is accumulation of carotenoids, particularly lycopene, giving the red color to the ripe tomato (Khudairi, 1972). During ripening of tomatoes, high CO₂ levels decrease ethylene synthesis, which can delay color changes (Buescher, 1979). In this study, coating of avocados with GA and CMC delayed color change, which was probably due to an increase in CO₂ and decrease in O₂ levels.

Sensory evaluation. Consumer acceptability of produce coated with surface coating is still a major concern, as coatings may change the organoleptic properties of coated produce (Guerreiro et al., 2015). This makes sensory evaluation an important factor in the development of edible coatings. Figure 4 shows the sensory evaluation scores of color, taste, mouthfeel, odor, and overall acceptability of each treatment. Statistical analysis demonstrated that the edible coating significantly ($P \leq 0.01$) influenced all tested parameters.

Sensory evaluation of coated and uncoated fruit at the end of the storage period revealed significant ($P \leq 0.05$) differences in

pulp color, taste, mouthfeel, odor, and overall acceptability (Fig. 4). The fruit coated with GA 10% + M, GA 15% + M, or CMC 1% + M had the highest scores in all parameters after 28 d of storage, whereas those coated with control and GA 15% developed poor taste, mouthfeel, and odor and had lower scores of overall acceptability. GA 15% + M was the least effective treatment in sensory fruit quality, as the treatment attained lower scores during sensory evaluation. This might suggest that the coating was too thick to allow gaseous movement, resulting in the development of anaerobic conditions. This argument is supported by Ali et al. (2010), who reported that an increase in GA concentration to 15% and 20% resulted in tomatoes developing poor pulp color, inferior texture, and off flavors. Overall, the results suggest that GA 10% + M, GA 15% + M, and CMC 1% + M can be used successfully as an edible coating for prolonging the shelf life and improving avocado fruit quality. Similar results were observed by Ali et al. (2010) when they treated tomatoes with GA coating to improve fruit quality.

In vitro screening of moringa plant extracts against the isolates. The effect of GA, moringa leaf extract, or GA incorporated with moringa leaf extract on radial mycelial growth of *C. gloeosporioides* after 10 d

during *in vitro* experiment is illustrated in Fig. 5. It can be observed that GA edible coatings as a standalone treatment showed a significantly lower ($P \leq 0.5$) inhibition effect on the radial mycelial growth of *C. gloeosporioides* than other treatments. As standalone treatments, GA 10% and GA 15% had similar mycelial growth, showing little inhibition like the control treatment during the 10-d incubation period. Our findings are in agreement with Cheong and Zahid (2014), who reported that GA had zero inhibition against anthracnose of papaya.

Moringa leaf extract treatment, significantly ($P \leq 0.05$) inhibited (30%) radial mycelial growth of the pathogen as the combination of GA edible coatings with moringa leaf extract. However, a maximum inhibition (33%) in mycelial growth was observed in GA 15% + M. It is evident from our results that the incorporation of moringa leaf extract with edible coatings improved the antimicrobial activity. This could be corroborated by the findings of Maqbool et al. (2010) and Ali et al. (2016), who reported that incorporation of plant-based active ingredients, such as essential oils and plant extracts, significantly improves the antimicrobial activity of edible coatings against postharvest pathogen that causes major economic losses. In fact, Tesfay et al. (2017)

demonstrated that moringa leaf extract inhibited the growth of *C. gloeosporioides* *in vitro*. Similarly, Chiejina and Onaebi (2016) reported that ethanolic moringa leaf extract showed 100% inhibition of *Geotrichum candidum* and significantly reduced mycelial growth of *Mucor micheli* and *Rhizopus stolonifera*. The inhibitory effect of plant extract on mycelial growth of various pathogens has been largely attributed to the high phytochemical constituents, which include phenols, alkaloids, and tannins among the few others (Anyasor et al., 2011; Tesfay et al., 2017).

In conclusion, the results showed that GA 15% + M, followed by GA 10% + M and CMC 1% + M, were the most effective treatments in reducing mass loss and firmness loss, delaying color changes as well as in inhibiting the growth of *C. gloeosporioides* (33%). Overall, the study demonstrated that edible coatings incorporated with moringa leaf extract reduced mass loss, retained firmness, and delayed color changes, as well as antifungal properties against *C. gloeosporioides* compared with the control in 'Maluma' avocado. These edible coatings could therefore be an alternative organic postharvest treatment to be used by avocado industries in future.

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Fig. 5. Effect of gum arabic (GA) coatings, moringa (M) leaf extract, or the incorporation of GA into moringa extract on mycelial growth rate of *C. gloeosporioides* incubated at 28 °C for 10 d. Means followed by the same letter within a clustered column are not significantly different according to Fisher's least significant difference test at $P \leq 0.05$. CMC = carboxymethyl cellulose.

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