Influence of postharvest treatments and storage conditions on the quality of Hass avocados

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ABSTRACT

The purpose of this study was to investigate the influence of postharvest treatments on the shelf life of avocado. The experimental design consists of pre-packaging (hot water and wax), packaging (low-density polyethylene and biodegradable films), and storage temperatures (ambient and cold storage), which was arranged in a randomized complete block design with three replications. The effects of combined postharvest treatments on the changes in the physical, chemical, and sensory quality of ‘Hass’ avocados during a 28-day cold chain simulation were evaluated. The quality parameters evaluated included puree viscosity, moisture content, dry matter, pH, total soluble solids, total titratable acid and subjective quality attributes. Storage conditions significantly (P ≤ 0.05) affected the measured parameters. Cold chain conditions (5.5 °C for two days, 5 °C for six days and 4.5 °C for 20 days at 95% relative humidity) offered the most significant benefit in maintaining higher fruit quality. The combination of a wax coating, low-density polyethylene packaging, and cold chain conditions was beneficial in delaying ripening by approximately two weeks with minimum changes in moisture content (9.5%) and TSS (19.0%) and viscosity. Cold storage is essential in improving the shelf life and maintaining the quality of avocado fruits during export.

1. Introduction

Perishable commodities such as the avocado (Persea americana Mill.) pose a challenge in their supply chain concerning their qualitative and quantitative perishability. This is of great ethical, environmental, and financial concern. The deterioration of perishable commodities, therefore, warrants the complexity of the cold chain management, with great emphasis being placed on controlling and regulating the desired storage conditions (Aiello et al., 2011). The South African avocado industry is primarily based on export, making fruit quality an essential factor (Vorster et al., 1990). The type of packaging that is used also contributes to the final fruit quality, as efficient packaging will allow for cold air to move uniformly around the fruit horizontally and vertically (Dodd et al., 2007). Studies have shown that the use of low-temperature storage, the application of wax, 1-methylcyclopropene and preventing breaks in the cold chain, were all beneficial in postharvest handling of avocados (Lutge et al., 2012). Based on the literature, it is apparent that numerous studies have been conducted in determining the quality of avocados during the supply chain, with a focus on storage temperature. However, a comparison of the integration of pre-packaging, packaging and storage conditions on the physical, chemical and sensory quality of avocados is deficient. The aim of this experiment is, therefore, to investigate the combined effect of postharvest treatments on the quality of avocados and to provide practical recommendations during avocado postharvest handling in South Africa.
2. Material and methods

2.1. Growing site description

Avocados (Persea americana Mill.), belonging to the ‘Hass’ cultivar, were obtained from the Everdon Estate located in the Karkloof Valley in Howick, KwaZulu-Natal (29° 27′ S, 30° 16′ E). The orchard is located in the Phillips’ Bioclimatic Group 3, characteristic of cold mesic conditions typical of ‘mist belt’ areas (Moore-Gordon et al., 1995; Moore-Gordon and Wolstenholme, 1996). The orchard experiences mean minimum temperatures of approximately 15 °C in January and approximately 6.7 °C in July, with corresponding mean maximum temperatures of approximately 26.1 °C and 19.4 °C (Moore-Gordon and Wolstenholme, 1996; Mazhawu et al., 2018). The area receives an average annual rainfall of 1 052 mm. Micro-jet irrigation systems supply water to the scheme that has been installed with tensiometers (Moore-Gordon and Wolstenholme, 1996). The predominant soil is a well-drained Hutton prepared by deep-ripping only once. Two mulch dressings are placed around trees annually, which have resulted in a marked improvement to the fruit. Due to the colder subtropical climate in Howick, the avocados grown in these orchards mature at a later stage compared to those grown in the Limpopo province. This enables the Everdon Estate to lengthen its export season, particularly in the case of ‘Hass’ which has a harvest season starting from early July and extending into October or early November each year.

2.2. Plant material

Green mature ‘Hass’ avocados were manually harvested by expert harvesters early in the morning to reduce field heat and minimise mechanical injury. Avocados within a mass range of 203–243 g were selected and packed into single layer standard count 18 corrugated cardboard boxes (18 avocados per box) with ventilation. A total of 222 avocados, amounting to approximately 50 kg, were acquired for this experiment. From the commercially harvested avocados, samples were selected based on their uniformity of weight, shape, colour, size and whether they were bruised and blemish-free to be used in the experiment (Mohammed et al., 1999; Maftoonazad and Ramaswamy, 2008; Getinet et al., 2011; Hassan and Dann, 2019). The selected samples were immediately transported to the University of KwaZulu-Natal Food Science and Agricultural Engineering laboratory, which is located 37 km from the packhouse, where sample preparation, treatment, and storage trials were carried out.

2.3. Experimental design

A factorial design consisting of three pre-packaging treatments (Avoshine® wax, hot water immersion, and no pre-packaging treatment), three packaging treatments (low-density polyethylene (LDPE), corn starch biodegradable films and no packaging), two temperature and relative humidity (RH) storage regimes (cold chain and ambient) and three replications were arranged in a randomised complete block design (Mohammed et al., 1999; Getinet et al., 2011). The samples were randomly treated and evaluated for their quality immediately after harvest.

2.4. Sample preparation and treatments

The avocado samples were visually inspected at the laboratory to ensure that they were not subjected to any damage during transportation and, if they were, the damaged avocados were excluded from the samples (Getinet et al., 2011). All work surfaces, tools, and utensils were cleaned and disinfected. Avocados were treated and tested for each of the two storage regimes on Days 0, 7, 14, 21, and 28.

2.5. Pre-packaging treatments

The use of wax (Kremer-Kohne and Duvenhage, 1997) and hot water pre-packaging treatments (Wu et al., 2011) were selected, as these are extensively used for avocados.

2.5.1. Wax coating

The liquid polyethylene wax emulsion, Avoshine®, was used to evenly coat the avocados as described by Hall (2011). Approximately 0.4 ml of Avoshine® wax was used per 250 g of avocado fruit (Blakey, 2012).

2.5.2. Hot water dipping

A hot water bath containing water was initially heated to 80 °C for 30 min to destroy most heat-sensitive micro-organisms and, after that,
reduced to 38 °C. The avocado samples were immersed in hot water for five minutes, then removed and dried.

2.5.3. Control
Avocado samples were not subjected to any pre-packaging treatments.

2.6. Packaging treatments

The selection of the packaging materials, LDPE, and biodegradable packaging films, were made based on previous findings, which showed their beneficial effects for avocados (Xiao and Kiyoto, 2001; Aguilar-Mendez et al., 2008).

2.6.1. LDPE bag
Soft, flexible, and strong LDPE bags with 20 μm thickness and 250 X 150 mm, high water vapour transmission rate (375–500 g m⁻² day⁻¹) and high ratio of CO₂ to O₂ permeability were used (Mangaraj et al., 2009). Micro-perforations (n = 4) at 30 mm intervals were made along the bottom of each bag in two rows, using a 1.13 X 10⁻³ m diameter needle to allow for the movement of gases and moisture between the micro-environment inside the bag and the surroundings.

2.6.2. Biodegradable cornstarch cellulose bag
Transparent biodegradable corn starch cellulose bags (30 μm thickness, 240 X 100 mm and 45 mm gussets) were used. These bags have a high barrier to air and micro-organisms, which is ideal for the packaging of food (Aguilar-Mendez et al., 2008). Two rows containing four micro-perforations (∅ = 1.13 X 10⁻³ m) at 20 mm intervals were made along the bottom of each bag. The interval spacing of the micro-perforations was smaller compared to the LDPE bags, due to the difference in width of the bags. Nine avocados from each of the packaging treatments.

2.7. Temperature and relative humidity

A total of 108 avocado samples were stored at 5.5 °C ± 0.01 °C for two days, then at 5 °C ± 0.01 °C for six days and then 4.5 °C ± 0.01 °C for 20 days, allat 95% relative humidity based on a typical Everdon Estate packhouse regime to depict a realistic cold chain. These conditions were controlled in a CTS Climate Test Chamber (Model C-40/100) with a temperature range of -40 °C to +180 °C and a humidity range of 10%–98%. Theoretical temperature and relative humidity fluctuations of the chamber for climatic testing are ± 0.3K and 1.5%, respectively. The total capacity of the testing chamber is 100 L (500 X 500 X 400 mm). Control samples were placed in six corrugated cardboard boxes in a single layer and exposed to ambient temperature (±25.14 °C) and relative humidity (±52.67%) conditions. Two HOBO data loggers (BoxCar® Pro 4.3 software) were used to record the control conditions.

2.8. Parameters analysed

Data were collected on Days 0, 7, 14, 21, and 28 during storage. The quality parameters that were analyzed included moisture content, dry matter, total titratable acid, total soluble solids, pH, puree viscosity, and subjective quality attributes.

2.9. Puree preparation

A Braun 300 W MR 400 hand blender was used to blend the diced avocados for two to three minutes until a fine paste was formed as described by Jacobo-Velazquez and Hernandez-Brenes (2011). The puree was sampled for moisture content, dry matter, total titratable acid, total soluble solids, pH, and viscosity.

2.10. Moisture content and dry matter

Moisture content (wet basis) and dry matter were determined using 3 g of avocado puree. The samples were dried in an oven at 70 °C for 48 h or until constant weight as described by Chen et al., 2009.

2.11. Total titratable acid, total soluble solids and pH

Approximately 25 g of the avocado puree was added to a beaker containing 25 g (25 ml) of distilled water. The samples were homogenized and filtered through muslin to collect the juice (Maftoonazad and Ramaswamy, 2008). An aliquot of 3 ml of juice was pipetted to a 50 ml beaker, into which two drops of phenolphthalein indicator solution was added. The juice aliquot was titrated with 0.1 N sodium hydroxide (NaOH) till a pink colour was formed and persisted for five seconds while the solution was being stirred, using a magnetic stirrer. Titratable acidity was calculated as the number of milliliters of 0.1 M sodium hydroxide multiplied by an appropriate conversion factor (Equation (1)). A conversion factor of 0.28 was selected, based on linoileic acid, a predominant acid in avocados, as used by Maftoonazad and Ramaswamy (2008).

\[ \text{TTA} = (0.1 \times \text{NaOH} \times 0.28 \times 1000)/ (\text{S}) \]  

(1)

where TTA is the total titratable acid, 0.1 is 0.1 mol of NaOH [N], NaOH is the amount of NaOH added [ml], 0.28 is the conversion factor, and S is the juice sample [ml].

The pH was measured using a standard pH meter, which was calibrated using pH 4 and pH 7 buffer solutions. The pH was determined according to methods by Getinet et al. (2008), Maftoonazad and Ramaswamy (2008), and Jacobo-Velazquez and Hernandez-Brenes (2011). The total soluble solids were determined using an ATAGO digital portable palette style refractometer (±0.1 % Brix) by placing one to two drops of the juice on the prism (Getinet et al., 2008; Maftoonazad and Ramaswamy, 2008).

2.12. Puree viscosity

Puree viscosity was measured using the Anton Paar Rheolab QC Rheometer basic unit (Model 13000) with Rheoplus V3.40 software. The viscosity was measured as a function of shear rate on approximately 16 g of puree samples, which was ramped from 0.01 s⁻¹ to 100 s⁻¹ for 250 s (Tabilo-Minizaga et al., 2005). A graphical representation of the shear stress (pa) and shear rate (s⁻¹) was plotted using the software. The experiment was carried out using the concentric cylinder and cup accessory. The puree samples were filled to the level mark inside the cup. All measurements were carried out at a room temperature of approximately 24 °C.

2.13. Subjective quality attributes

Once the avocados were removed from storage, they were inspected and examined visually for mould development or decay. The skin colour was perceived by the human eye in terms of green, purple or black, synonymous to degree of ripening (Hasan and Dann, 2019). Changes in the firmness was inspected by hand-feel for any soft spots (Hasan and Dann, 2019) Any other variances concerning the physical appearance were also observed and recorded such as dark spots or bruises. Based on this each fruit was assigned an overall rating of either ‘good’, ‘fair’ or ‘poor’.
The differences between treatments were determined by an analysis of variance (ANOVA) employing the MSTAT-C statistical software, Version 2.10 (MSTAT, Michigan State University). The means were separated using Duncan's Multiple Range Test, with a significance level of 0.05.

### 3. Results and discussion

#### 3.1. Moisture content and dry matter content

Table 1 displays the changes in the moisture content (MC) of avocados subjected to different pre-packaging, packaging, and storage conditions. The influence of storage conditions and storage period were...
effect was found to be significant ($P < 0.05$) on the changes in the MC. Under cold chain conditions, the LDPE maintained higher MC, as compared to biodegradable films. Control avocado samples devoid of pre-packaging and packaging treatments resulted in the highest MC loss at both cold chain and ambient storage conditions of 27.8% at Day 28 and 23.6% at Day 14, respectively. Higher temperatures contributed to a more significant loss in MC, as observed in the works of Ozdemir and Topuz (2004). The lowest reduction in the MC throughout the storage period of 9.5% at Day 28 was recorded for avocado samples pre-treated with wax, packaged in LDPE films and stored at cold chain conditions. Analysis of the MC trends emphasises the additional benefit of using pre-packaging and packaging in reducing the MC, under low-temperature storage. Several authors (Hofman and Jobin-Decor, 1999; Ozdemir and Topuz, 2004; Landahl et al., 2009; Obenland et al., 2012) have found the MC, dry matter (DM) and oil content of avocado fruit to be well correlated. These parameters are widely accepted as avocado fruit maturity indexes due to their consistency during fruit development (Shezi et al., 2020). A delay in the loss of the MC, therefore, implies a delay in the accumulation of oil and dry matter within the avocado, and hence, a delay in the ripening process.

The percentage of DM in avocado samples increased in both ambient and cold chain storage conditions (Table 2). Hofman and Jobin-Decor (1999) found that the storage of avocados at lower relative humidities of 40% and 60%, as opposed to 80% and 98%, resulted in an increase in the DM content by approximately 1% towards the end of the storage period at 22 °C. An increase in the dry matter is synonymous with avocado fruit maturation and the ripening process (Zauberman and Jobin-Decor, 1995; Hofman and Jobin-Decor, 1999; Shezi et al., 2020). Similar results have been observed in the present experiment, as the relative humidity (RH) of the cold chain conditions was higher (95%) than at ambient conditions ($P < 0.05$). The lower RH at ambient conditions increased the moisture loss from the fruit, thereby increasing the DM content. This was further exacerbated by the higher temperature under ambient conditions. Packaging films were found to be significant ($P < 0.05$) with LDPE and biodegradable packaged avocados having lower DM than unpackaged avocado samples, at both cold chain conditions and ambient conditions. Pre-packaged avocados displayed a lower DM, compared to control avocado samples without any pre-packaging. Control avocado samples devoid of any pre-packaging and packaging treatments resulted in the highest DM accumulation at both cold chain and ambient storage conditions of 32.8% on Day 28 and 28.9% on Day 14, respectively. The least increase in the DM throughout the storage period of 11.2% at Day 28, was observed for samples pre-treated with wax, packaged in LDPE films and stored at cold chain conditions ($P < 0.05$). It can be observed that on Day 28 from Tables 1 and 2, samples were no longer viable to be tested as they had long passed their shelf life and decayed.

### 3.2. Pure viscosity

The four-way interaction between pre-packaging, packaging, storage conditions, and storage period had a significant ($P < 0.05$) influence on the puree viscosity. A substantial increase in the viscosity was observed for avocado samples subjected to ambient storage conditions between Days 7 and 14. In contrast, storage at cold chain conditions maintained the viscosity level as determined at harvest during the first 21 days of storage for all treatments (Table 3). Sakurai and Nevins (1997) explained the decrease in the viscosity and elasticity of avocado tissue as a result of fruit ripening, which is mediated by the action of endo-type hydrolytic enzymes resulting in the breakdown of xyloglucan molecules in the cell wall (Sakurai and Nevins, 1997). This decrease in the elasticity could account for the increase in the viscosity of the puree avocado pulp as the ripening proceeds with time. Control avocado samples devoid of pre-packaging, packaging, and exposed to ambient storage conditions contributed to the greatest increase in the viscosity from 0.03 Pa.s on Day 0–7.11 Pa.s on Day 14. The combination treatment of wax and LDPE films with storage at cold chain conditions maintained the viscosity throughout the storage period. Unripened avocados have high moisture content (Table 1). Therefore, when passing the unripened puree through the muslin, the fluid was more easily separated from the solid components of the puree, which could also be attributed to higher levels of the carbohydrate propectin. Propectin can hold cells together in unripe fruits as determined in unripe guavas (Sanchez et al., 2009). In the present experiment, due to the higher moisture content of the unripe avocado, the puree had larger particles, as opposed to the ripe avocado puree, which had a smooth buttery texture and higher viscosity. A higher
viscosity is, therefore, synonymous with fruit ripening, which is accelerated by high ambient temperatures.

3.3. pH value

Aguirre-Joya et al. (2017) stated that Hass avocado fruit have a characteristic pH near neutrality, as can be seen in Table 4. Storage conditions and storage periods significantly (P < 0.05) influenced the avocado pH value. A general decline in the pH value was observed for avocado samples subjected to the different postharvest treatments, specifically those stored under ambient conditions. This trend is in agreement with the findings of Maftoonazad and Ramaswamy (2008), Jacobo-Velazquez and Hernandez-Brenes (2011), and Aguirre-Joya et al. (2017). Pre-packaging treatments had a higher significance (P < 0.05) than packaging films. Wax-coated avocado samples had higher pH values when stored under both cold chain and ambient conditions. Jacobo-Velazquez and Hernandez-Brenes (2011) reported the decline in the pH value to be attributed to the movement of organic acids from intercellular...
locations to the avocado puree. Besides, the increase in acidity could be due to the increase in concentration of free fatty acids as a result of triglyceride lipolysis (Jacobo-Velazquez and Hernandez-Brenes, 2011). An increase in the acidity can be one of the changes associated with avocado deterioration. Avocado samples devoid of pre-packaging and packaging treatments displayed the lowest pH values. However, it should be highlighted that hot water pre-treated samples, packaged in biodegradable films and stored under ambient conditions, exhibited a decrease in pH values over a 14-day storage period by 10.8%, compared to a decrease by 9.9% in control avocado samples. The lower pH values of hot water treated avocado samples can be attributed to tissue damage. The pH values of hot water treated samples without packaging and stored under cold chain conditions fluctuated during the 28-day storage. While cold storage proved to be highly beneficial for avocados, the use of hot water treatments appeared to have reduced the pH more than in the control samples, which is not desirable.

Table 6. Changes in the total titratable acid (mg.ml⁻¹) of avocados subjected to pre-packaging, packaging and different storage conditions for 28 days.

| Treatment | Packaging | Storage Conditions | 0 | 7 | 14 | 21 | 28 |
|-----------|-----------|--------------------|---|---|----|----|----|
| Pre-packaging | LDPE | CC                | 1.9* | 3.6** | 3.9* | 3.7** | 5.0** |
|             | HWT     | Bio               | 1.7* | 4.9** | 8.4** | -    | -    |
|             | NP      | CC                | 1.9* | 3.1** | 3.1** | 2.3** | 2.3** |
|             |         | AT, ARH           | 1.3* | 3.8** | 8.1** | -    | -    |
|             | LDPE    | CC                | 1.9* | 3.4** | 4.1** | 3.6** | 4.2** |
|             |         | AT, ARH           | 1.7* | 2.0** | 8.4** | -    | -    |
|             | NP      | CC                | 1.9* | 3.1** | 3.2** | 3.4** | 3.7** |
|             |         | AT, ARH           | 1.7* | 1.4** | 5.1** | -    | -    |
| Avoshine®   | Bio     | CC                | 1.9* | 3.4** | 3.4** | 4.4** | 7.0** |
|             |         | AT, ARH           | 1.7* | 1.9** | 6.2** | -    | -    |
|             | NP      | CC                | 1.9* | 3.1** | 3.8** | 4.4** | 5.8** |
|             |         | AT, ARH           | 1.7* | 5.8** | 6.5** | -    | -    |
|             | LDPE    | CC                | 1.9* | 2.2** | 3.0** | 4.4** | 6.2** |
|             |         | AT, ARH           | 1.7* | 4.5** | 5.3** | -    | -    |
|             | NPP     | Bio               | 1.9* | 2.6** | 2.6** | 8.7** | 8.1** |
|             |         | AT, ARH           | 1.7* | 4.5** | 4.3** | -    | -    |
|             | NP      | CC                | 1.9* | 2.9** | 2.7** | 8.4** | 11.5* |
|             |         | AT, ARH           | 1.7* | 5.0** | 7.5** | -    | -    |

Means within a column followed by the same letter/s are not significantly different from each other, according to Duncan’s Multiple Range Test (P < 0.05). HWT, hot water treatment; NPP, no pre-packaging; Bio, biodegradable corn starch packaging; LDPE, low-density polyethylene packaging; NP, no packaging; CC, cold chain; AT, ambient temperature; ARH, ambient relative humidity.

Table 7. Changes in the subjective quality attributes subjected to different postharvest treatments.

| Treatment | Final state of avocado | Rating |
|-----------|------------------------|--------|
| LDPE      | Dull exterior, remained firm and green | Good |
| AT, ARH   | Dull exterior, soft, darkening of the skin, mould development, shrivelling | Poor |
| HWT       | Dull exterior, remained firm and green | Good |
| Bio       | Dull exterior, soft, darkening of the skin, mould development, shrivelling | Poor |
| NP        | Dull exterior, remained firm and green | Fair |
| AT, ARH   | Dull exterior, soft, darkening of the skin, high degree of shrivelling | Poor |
| LDPE      | Shiny exterior, slight softening and darkening of the skin | Excellent |
| AT, ARH   | Shiny exterior, softening and darkening of the skin, slight mould development | Fair |
| Avoshine® | Shiny exterior, remained firm and green | Excellent |
| AT, ARH   | Shiny exterior, softening and darkening of the skin, slight mould development | Fair |
| NP        | Shiny exterior, slight softening and darkening of the skin | Very good |
| AT, ARH   | Shiny exterior, softening and darkening of the skin, slight mould development | Poor |
| LDPE      | Dull exterior, slight softening and skin darkening | Fair |
| AT, ARH   | Dull exterior, excessive softening, darkening of the skin, mould development, shrivelling, condensation within packaging | Poor |
| NPP       | Dull exterior, slight softening and skin darkening | Fair |
| AT, ARH   | Dull exterior, excessive softening, darkening of the skin, mould development, shrivelling, condensation within packaging | Poor |
| NP        | Dull exterior, softening and skin darkening | Poor |
| AT, ARH   | Dull exterior, most excessive softening, darkening of the skin, mould development, shrivelling | Very bad |

HWT, hot water treatment; NPP, no pre-packaging; Bio, biodegradable corn starch packaging; LDPE, low-density polyethylene packaging; NP, no packaging; CC, cold chain; AT, ambient temperature; ARH, ambient relative humidity.
compared to the cold chain storage conditions. The increased temperature and reduced RH under ambient storage conditions may have contributed to the increased hydrolysis of carbohydrates stored within the avocado fruit into soluble sugars. This results in a higher TSS and a reduction in the avocado shelf life, which is undesirable. Packaging treatments displayed a higher significance (P ≤ 0.05), compared to pre-packaging on the avocado TSS. Packaged avocado samples, generally demonstrated lower TSS values, compared to unpackaged control samples at both cold chain conditions and ambient conditions. This is in agreement with Tefera et al. (2007) and Workneh et al. (2011). However, Aguirre-Joya et al. (2017) found no distinct change in the TSS of avocado fruit in both refrigerated and room storage conditions but rather a general increase in the TSS values during storage. Avocados treated with wax, LDPE, and control storage conditions showed the lowest rate of increase in the TSS of only 19.0% from Day 0 to Day 28 indicative of slower senescence and ripening and a longer shelf life.

3.5. Total titratable acid

Table 6 presents the changes in the total titratable acid (TTA) of the avocado pulp. The storage conditions and the storage period were highly significant (P ≤ 0.05) in terms of the avocado TTA. A general increase in the TTA was observed for all treatment conditions. The increase in the TTA was observed to occur at a faster rate under ambient conditions for a 14-day storage period, compared to cold chain conditions for a 28-day storage period. This shows that the avocado samples at cold chain conditions had an additional 14 day shelf life compared to those at ambient conditions. Mattoonazad and Ramaswamy (2008) observed a similar trend of a more rapid rise in the TTA at higher temperatures of avocado samples. Pre-packaging and packaging were found to have a significant (P ≤ 0.05) influence on the changes of the avocado TTA. Pre-packaged avocados displayed lower TTA values, compared to pre-packed samples. Similarly, packaged samples demonstrated lower TTA values than unpackaged samples. The four-way interaction between pre-packaging, packaging, storage conditions, and the storage period was found to significantly (P ≤ 0.05) effect the avocado TSS. The increase in the TTA corresponds to a decrease in the pH. The lowest rate of increase in the TTA from 1.9 to 3.7 occurred in samples coated with Avoshine®, packaged in LDPE film and stored at cold chain conditions for 28 days. In contrast, the highest rates of increase in the TTA from 1.9 to 11.5 and from 1.7 to 7.5 were observed for control samples stored at the cold chain and ambient storage conditions, respectively. This, therefore, illustrates the benefit of pre-packaging and packaging treatments in maintaining the quality of avocado fruit.

3.6. Subjective quality attributes

Avocado samples stored at ambient conditions succumbed to more mould development, especially in the packaged treatment. The micro-environment within the packaging was conducive for the proliferation of mould development, especially in the packaged treatment. The micro-environment within the packaging was conducive for the proliferation of mould development, especially in the packaged treatment. The micro-environment within the packaging was conducive for the proliferation of mould development, especially in the packaged treatment. The micro-environment within the packaging was conducive for the proliferation of mould development, especially in the packaged treatment.
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