Reducing Postharvest Losses in Plantain through Sodium Alginate/Essential oil coatings

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ABSTRACT

Matured plantain fruits undergo postharvest physiological deterioration in the food supply chain contributing to food loss/waste and economic losses. However, available plantain preservation techniques are ineffective, cost intensive and unsustainable. The aim of the study was to evaluate effective, low-cost, and sustainable plantain preservation techniques by harnessing the potential of sodium alginate and cellulose nanocrystals to produce a film blended with cinnamon essential oil in varying proportions (10%, 15%, and 20%) and to determine the extended shelf-life of fresh plantain under the tested treatment conditions. The film produced exhibited good molecular interaction and thermal stability as elucidated by the Fourier Transform and Infrared (FTIR) spectroscopy and thermogravimetric analysis respectively. The samples of plantain coated with film-forming solution and stored up to 8 days were examined for their physiochemical parameters (pulp moisture content, ^{o}Brix, weight loss, firmness, and colour changes) during eight-day storage at room temperature (25 ±1°C). There was a significant ($p<0.05$) reduction in moisture production, ^{o}Brix, weight loss rate, and softening rate for coated plantains relative to the uncoated samples. Increasing proportion of the essential oil in the film was effective in delaying the unset of ripening and deterioration by one week. Therefore, by optimizing the level of cinnamon essential oil in the film, this innovative technique can serve as an effective, sustainable and inexpensive way of preserving plantain to maintain it nutritional and functional qualities while enhancing its economic value in the food supply chain.

1.0 INTRODUCTION

The issue of Food Loss and Waste (FLW) has engendered significant interest worldwide. Estimate by FAO's State of Food and Agriculture (2019) report indicates that about 14% of the food produced get lost or wasted. This figure, in monetary terms, is nearly $400 billion dollars yearly. According to FAO projection, the food that is wasted and lost is enough to cater for 1.26 billion hungry people every year. Food losses are associated with the food supply chain, i.e., from the growing, harvesting, transportation, storage, processing, and retailing to the final consumer. Consequently, the Sustainable Development Goal (SDG) target 12.3, which seeks to to halve per capita global food waste at the consumer and retail levels and further cause a reduction of food losses along food supply chains, including post-harvest losses (UNEP Food Waste Index Report, 2021). In Ghana, food crops such as cereals, grains, and legumes rank high, with a predicted 30%-50% annual losses, whilst fruits, vegetables, roots, and tubers follow with an estimated yearly loss of 20-50%. These losses are mainly caused, among others, by lack of technical and/or financial capacity of the players along the food supply chain to preserve the food (Xue et al., 2019). Because of the huge economic losses associated with FLW, much attention and research are being focused on reducing food losses and waste in major food crops such as cereals, grains, and legumes and to some extent fruits and vegetables (Rutten & Verma, 2014) to the neglect of food crops such as plantain which ripens easily and if not quickly utilized get wasted posing economic losses to farmers and other actors in the food supply chain.

Plantain (genus *Musa*) falls under banana as a monocotyledonous perennial and important crop in the tropical and sub-tropical regions of the world (Baiyeri et al., 2011). Plantain is a staple crop with significant economic value based on its high nutritional value. In Africa, Cameroon leads in plantain production with 4.3 million tonnes, followed by Ghana (about 4 million tonnes) annually (Adi et al., 2019). In Ghana, the production approximates 13% of GDP, representing a unit annual consumption of about 100kg per person (Adi et al., 2019). Nutritionally, plantain is a major source of energy for the body and therefore utilized as food at every stage of its life cycle (immature to overripe). The main methods used in plantain processing in West and Central parts of Africa are boiling/steaming, frying, roasting or drying of plantain fruits. Food products such as fried plantain, roasted plantain, boiled plantain, pounded plantain and plantain chips in Ghana (Dadzie & Wainwright, 1995), Cameroon (Newilah et al., 2005), Ivory Coast (Kouamé et al., 2015), Nigeria (Akinyemi et al., 2008), Benin (Marcellin et al., 2018) and Democratic Republic of Congo (Ekesa et al., 2012). Despite the high nutritional and economic benefits obtainable from plantain utilization, it economic value reduces considerably along the fruit maturation cycle. The average shelf life of mature plantain after harvest is below two weeks (Adi et al., 2019) due to rapid ripening resulting in product deterioration and economic losses. The projected plantain loses in Ghana is between 10-30% representing 200-400 thousand tonnes of annual production (Adu-Amankwa & Boateng, 2011). These losses represents 100-300 million US dollars yearly (Dzomeku et al., 2011) and occur from production to consumption raising the need for effective post-harvest management strategies to preserve the fruit.
Plantain is mostly preserved to prolong its shelf-life and enhance freshness using various preservation strategies including cold refrigeration, using modified atmosphere packaging, and storage on counters or floors under room temperature and processing into plantain chips. However, these

available rudimentary methods often fail to enhance the shelf-life of plantain particularly during storage and distribution and still contributes to huge economic losses.

As a climacteric fruit, plantain produces ethylene gas at maturity that induces ripening. The process of ripening is characterized by distinctive color changes (green to pale yellow), texture changes (firm to soft), conversion of complex polysaccharides (starches) to simple sugars with sweet taste, and the development of a unique flavour compounds. Other noticeable changes include pulp-to- peel ratio, ethylene production, changes in ^{o}Brix, pulp moisture, pulp pH, total titratable acidity, dry matter content, and changes in respiration rate (Adi et al., 2019; Subedi & Walsh, 2009, 2011). Therefore, it is important to understand the physiological process involved in plantain ripening and adopt appropriate control strategy to slow down the processes and delay early ripening. Little attention has been paid to the use of active packaging system in extending the shelf-life and maintaining the freshness of plantain along the supply chain. Active packaging controls the respiration of fruit and vegetables, lipid oxidation, loss of moisture, and microbial activity (Youssef & El-Sayed, 2018). It also preserves the nutritional value of food and decrease the wastage of food. Therefore, the objectives of the study were to: 1) fabricate and characterize active packaging coatings from sodium alginate, cellulose nanocrystals blended with cinnamon essential oil using calcium chloride as a crosslinking agent, and 2) investigate the effect of the coatings on shelf-life extension of plantain. This active sustainable packaging technique is expected to have the potential to deliver fresh and nutritive plantain to the ever rapidly growing population in Ghana and beyond while enhancing its economic benefits in the food supply chain.

2.0 MATERIALS AND METHODS

2.1 Materials

Sodium alginate and glycerol (both extra pure) were obtained from Daejung Chemicals and Metals in Gyeonggi-do, Korea. Calcium chloride was purchased from Merck KGaA, Germany, the Cinnamon Essential Oil was sourced from Hemani Herbal LLC, USA, and Tween 80 obtained from Jinan Future Chemical company, China. Cellulose nanocrystals (CNC) (12.2wt% batch no-2015-FLP-71) was acquired from University of the Maine.

2.2 Film Preparation procedure

To investigate physical, mechanical, and thermal characteristics of the coats formed on the plantains, films were prepared using different coating solutions. The film-forming solution was prepared by using 4g of sodium alginate powder mixed in 200ml of distilled water.

Furthermore, 2g weight of glycerol, 1.68g of cellulose nanocrystals (CNCs), and 0.12g of $CaCl_2$ were added as plasticizers, reinforcement, and cross-linking agents. Following this process, an emulsion consisting of Cinnamon Essential Oil and Tween-80 were added at three varying concentrations (10%, 15%, and 20%). Stirring was done to the final solution to obtain a consistent mixture. Part of the final film-forming solution, 30.0g, was delivered into a 9cm diameter Petri Dish and made to dry in a 60°C in an oven for a period of 24 hrs. The fabricated films were cooled, peeled off from the Petri Dishes ready for characterization.

2.3 Thermal properties of the film

Analysis of the thermal properties were done using Differential Scanning Calorimeter (DSC, Q2000, TA Instruments, Delaware, USA) under a 30 mL/min nitrogen flow rate. Nearly 15mg of the fabricated films, in triplicates, was weighed in aluminum pans, sealed, and then heated from 20°C to 400°C at a heating rate of 5°C/min (Pankaj et al., 2014).

2.4 Thickness of film

Film thickness was measured using a Micrometer (Mitutoyo dial thickness gauge, Mitutoyo Co., Japan) at a 0.01-mm accuracy at five random position of the film. The mean of recorded data was found using statistical averages (Rhim, 2004).

2.5 Moisture content of films

The films were subjected to weighing using an electronic balance, and the values of the initial weight recorded as W1. The films were subsequently placed in an oven at constant temperature of 105°C for 24 hours. Second weighing was done almost immediately after the films were out from the oven to prevent the films reabsorbing moiture from the atmosphere (Cazón et al., 2020) and this weight represented as W2. The percentage moisture was estimated using the equation below.

$$\text{Moisture Content} = \frac{W1 - W2}{W2} \times 100\%$$

Where: W1 = Initial weight of the film

W2 =Second weigh of film (weight of film after it was dried in the oven)

2.6 Fourier Transform and Infrared Spectroscopy (FTIR)

Fourier Transform and Infrared Spectroscopy (FTIR) Analysis was done with the help of Perkin Elmer UATR Two Spectrometer with an attenuated total reflectance accessory. The measurement range was 450 – 4000 cm^{-1}, with a 4 cm^{-1} resolution. The process encompassed wiping the holding crystal with ethanol, after which films were arranged for spectral analysis. The analysis of the data was done using Origin Pro 2019 software, with which the FTIR spectra were obtained.

2.8 ºBrix of coated plantain

To determine the soluble solid contents of the plantain, samples pulp were first blended with distilled water to form a consistent solution. Following this, a drop of the solution was placed on an Abbey 60 Refractometer (Bellingham and Stanley Ltd, Kent, United Kingdom) with the aid of a pipette to determine the ºBrix. This experiment was done three times to obtain the statistical average value of the ºBrix.

2.9 Pulp moisture of coated plantains

Approximately 10g of each sample of plantain pulp was weighed and represented by P1. Afterward, the weighed samples were placed in an oven at a constant heat of 105°C for 24 hours and weighed again presenting P2. Finally, the moisture content of the samples was calculated as a percentage using the equation:

Moisture Content (MC) of plantain = $\frac{P1-P2}{P2}$ x 100%

2.10 Firmness of coated plantain pulp

The firmness of the pulp was determined using a Brookfield Texture Analyzer Model CT3 10K (Middleboro, MA 02346, U.S.A) operating in a normal mode. The experiment was conducted using a needle probe (1.0mm D, 43mm L) at a penetration depth of 20mm at three randomly selected positions of the plantain pulp and a speed of 2mm/s(Owolabi et al., 2021).

2.11 Pulp to peel ratio of coated plantain

This ratio was determined by weighing the pulp and peel separately on the third day, sixth and eighth day on an electronic scale. The experimental process was done in triplicate and the ratio of the pulp relative to the peel determined for each of the measure. The weight loss was also estimated from the measurements.

2.15 Visual observation of the coated and uncoated plantain

Visual images were taken using a high-resolution Digital Camera to detect visual variabilities of the plantains with time.

2.16 Statistical Analysis

The data gathered was analyzed using GraphPad Prism software Version 8.0.2 (263) for Windows (GraphPad Software, San Diego, CA, USA) for all descriptive and inferential statistics. One-way ANOVA inferential statistics was done to compare means between different groups of numerical continuous variables for at least 3 different groups at 5% significance level.

3.0 RESULTS AND DISCUSSION

3.1 Characterization of the Films

The characterization of the films included thermographic analysis, FTIR analysis, moisture adoption capacity, and film thickness.

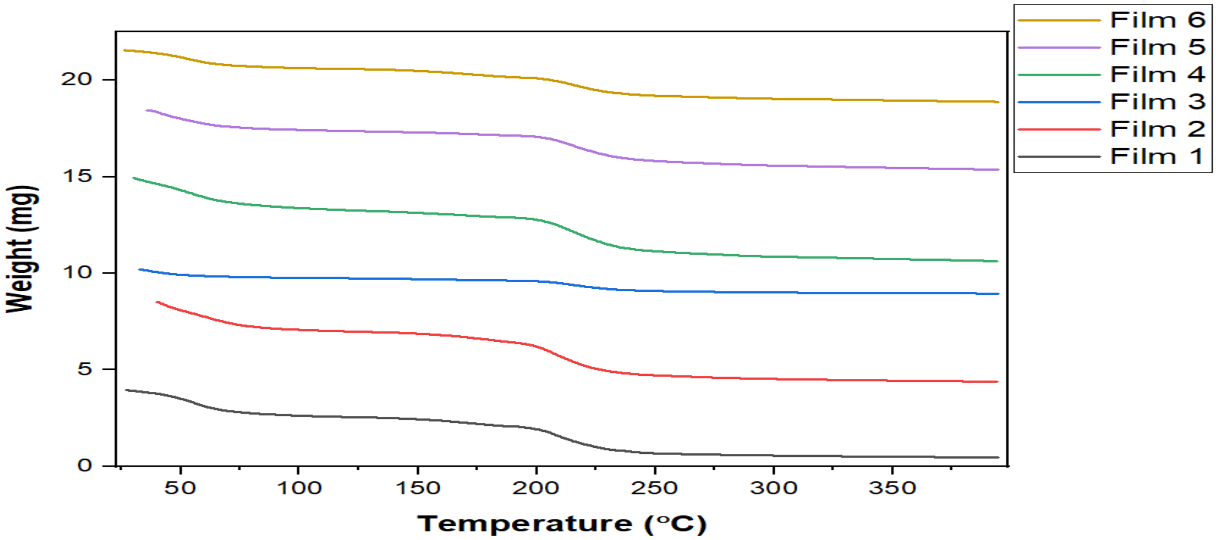
3.1.1 Thermogravimetric Analysis

The Thermogravimetric Analysis (TGA) was applied to detect variations in weight relative to temperature changes and to observe the impact of cinnamon essential oil (CEO) and other components of the film-forming solution, on the film's thermal stability. The TGA thermogram of the different films were studied, and the outcome signaled a multistage decomposition (three stages of weight loss) for films (Figure 1). The first change in the weight of the film depicts loss of free water and other low molecular weight volatile compounds from the films corresponding to temperatures of 50ºC and 75ºC. The second weight lost corresponds to temperature of 175ºC and 190ºC explaining thermal degradation of substance of low molecular weight like glycerol and bonded water. Furthermore, significant mass loss of the film was observed occasioned by thermal decomposition of the sodium alginate within the temperature range 200ºC and 250ºC, and then remain stable with temperature with no significant weight loss. In comparison, the control film (Film 1) showed higher weight loss as relative to the films containing cinnamon essential oil (Film 4, Film 5, and Film 6). It was observed that the essential oils caused an increase in the thermal stability of the film. However, the films with different cinnamon essential oil concentration gave different thermal stability on the basis of discontinuous structure formation resulting in a rise in free volume spaces and a less dense structure.

3.1.2 Fourier-transform Infrared Spectroscopy (FTIR) Analysis

The FTIR profile, Figure 2, presents the spectra of the different kinds of films showing the chemical and/or physical interactions between the participating compounds and bonding entities in the coatings or films. Usually, the films, regardless of their chemical makeup, show unique peaks. The high absorption peak at 3000-3683cm^{-1} is characteristic of stretching vibration of OH. The OH stretching absorption peak in all the films is broad ranging from 3000cm^{-1} to 3700cm^{-1} compare to free standing OH group which absorbs within 3200-3600cm^{-1} wavenumber. The increased intensity and broadening of OH stretching vibration is attributed to H-bonding. This may be due to strong intermolecular interactions between hydroxyl (OH) groups present in sodium alginate and cellulose nanocrystals or intramolecular interaction of molecules of the sample compounds. This is consistent with studies that indicated that H-bonding cause an increase in absorption peak intensity.

Figure 1: Thermogravimetric Analysis (TGA) profiles of the different films



Film 1 - Sodium alginate (SA)/Glycerol, Film 2 - SA/Glycerol, Cellulose Nano Crystals (CNC), Film3 -SA/Glycerol/CNC/Calcium Chloride (CC), Film 4-SA/Glycerol/CNC/CC/Tween 80 (T80)/10% Cinnamon Essential oil (CEO), Film 5- SA/Glycerol/CNC/CC/T80/15% CEO, Film 6 - SA/Glycerol/CNC/CC/ T80/20%CEO.

Figure 2B shows an overlap plot comparing individual components of the film with different fabricated films. The two prominent peaks at 2925cm−1 and 2857cm−1 shoulder to the OH peak are assignable to stretching vibration C-H bond in the film.

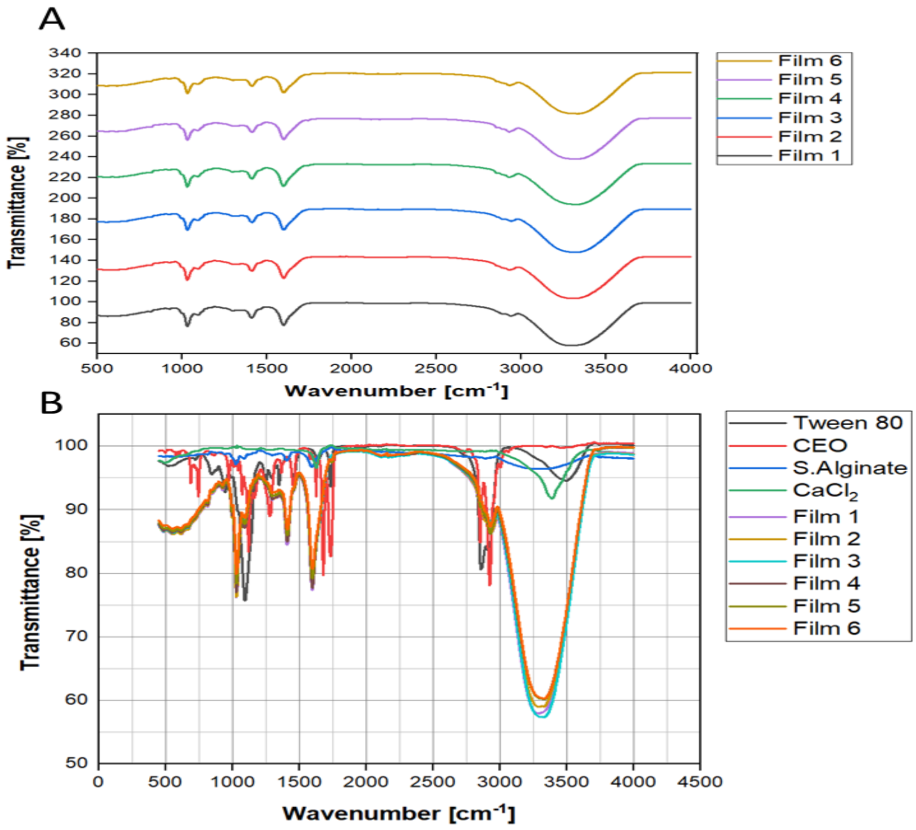
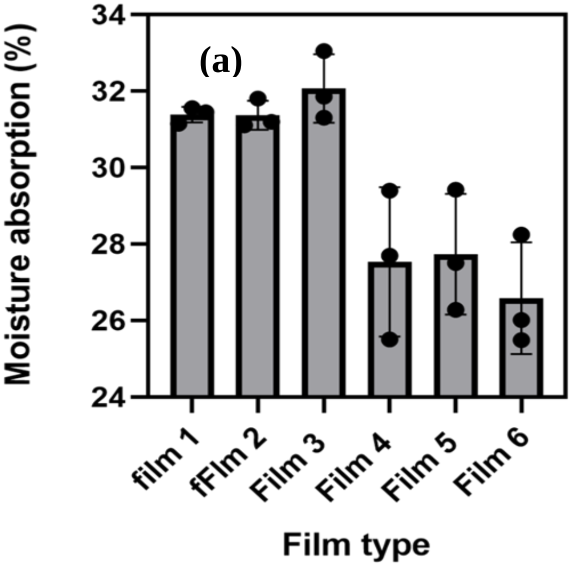


Figure 2: A: FTIR profile of Film 1, Film 2, Film 3, Film 4, Film 5, and Film 6.

The FT-IR spectra of Film 1-Sodium alginate (SA)/Glycerol, Film 2-SA/Glycerol, Cellulose Nano Crystals (CNC), Film 3-SA/Glycerol/CNC/Calcium Chloride (CC), Film 5-SA/Glycerol/CNC/CC/Tween 80 (T80)/10% Cinnamon Essential oil (CEO), Film 6- SA/Glycerol/CNC/CC/T80/15%CEO, Film 6-SA/Glycerol/CNC/CC/ T80/20% CEO, characterized as film 1 to 6 respectively.



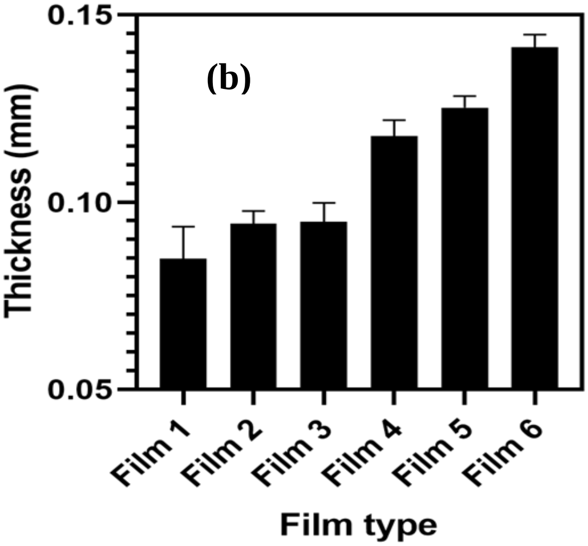


Figure 3a. Moisture absorption capacity film. **Figure 3b: Thickness of film**

Error bars indicate standard deviation at 95% Confidence interval

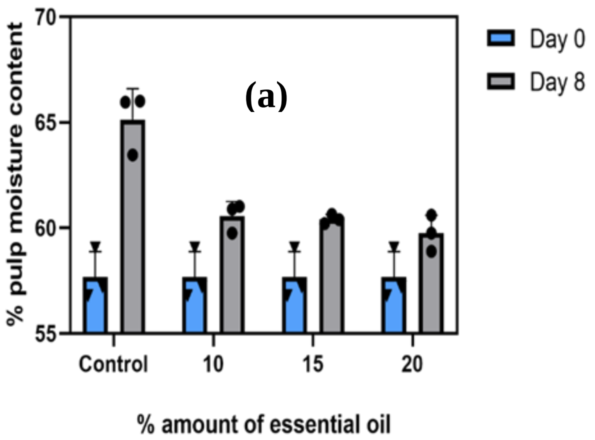
3.1.3 Moisture adoption capacity and thickness of the films

The moisture absorption capacity of the various films is shown in Fig. 3a. Film 1, 2 and 3, which did not contain the essential oil, absorbed moisture more than 30% of their dry weight. Whereas films 4, 5, and 6 which contain essential oil absorbed moisture of at least 27 % of their dry weight. The films without the essential oil had significant water absorption capacity than the films with essential oils ($p<0.05$). The presence of essential oil in the film therefore limited the water absorption capacity of the film. The thickness of the various films as presented in Figure 3b was largely influenced by variation in the amount of the cinnamon essential oils present in the film. The films with the essential oil had significant greater thickness than those with the film ($p<0.05$). Film 6 with 20% of the essential oil had significant higher thickness than both Film 5 (15% essential oil) and Film 4 (10% essential oil) but the two also had significant greater thickness than those without the essential oils ($p<0.05$). The essential oils decreased water adoption capacity of the films, rendering them denser (less volume of film per unit area) than the films without the essential oils which tended to absorb more moisture from the atmosphere leading to significant rise in volume of film per unit areas.

3.2 Preservation of plantain by films

The protective effect of the coating against plantain ripening and deterioration, was examined on pieces of plantain and the properties of the pulp such as moisture, ^{o}Brix, firmness, weight loss and visualization determined. The results of the pulp moisture of the plantains both coated and uncoated with initial moisture content of about 57% increased after the 8th day (Figure 4b) with the pulp of uncoated plantain (control) producing significant moisture content than coated plantains ($p<0.05$). For example, on day 8, the pulp of the uncoated plantain produced 65.0% moisture content, a significant increase of about 7% from its initial value whilst the plantains coated with 10% and 15% cinnamon essential oil also had significant rise in their pulp moisture content to about 62% each but significantly lower than that of the uncoated sample. The plantain coated with the 20% cinnamon essential oil with initial pulp moisture content of 57% produced insignificant increase in pulp moisture content to about 59% ($p>0.05$). The coating of the plantain with essential oils therefore helps to lower the pulp moisture content of the plantain pulp.

The coating controlled the rate of respiration of the plantain by limiting gas exchange (O_2 uptake, CO_2 and ethylene production) and reducing plantain ripening rate. Reduced rate of ripening could be due to the reduction in the rate of enzyme-catalyzed hydrolysis of starches (amylose and amylopectin) present in the plantain pulp into simple soluble sugars (sucrose, glucose, and fructose) used for cellular respiration to produce energy and water thereby increasing the moisture content of the pulp. This observation is in agreement with the results of the study conducted by (Sojinu et al., 2021) and found that ripening of plantain produces a higher pulp moisture content than unripe plantain with a recorded value of 50.66 ± 0.50 for unripe plantain and that of the naturally ripened plantain to be 62.53±0.20. ^{o}Brix is an estimated of total soluble solids (TSS) content of the pulp, which is indicative of the amount of sugars (fructose, glucose, sucrose) present, corresponding to the degree of ripeness and taste of fruits. Therefore, TSS represents nutritional constituents such as sugars, organic acids, and soluble amino acids present in the plantain fruit (Phan, Chaliha, Sultanbawa, & Netzel, 2019). The results showed that both coated (treated) uncoated plantain (control) showed a significant ($p<0.05$) increase in ^{o}Brix content from the initial value (1.03%) up to Day 8 with the uncoated plantain producing a significant higher ^{o}Brix (7.5%) than the coated samples, 10% CEO (4.12%), 15%CEO (3.82%) and 20% CEO (1.53%).



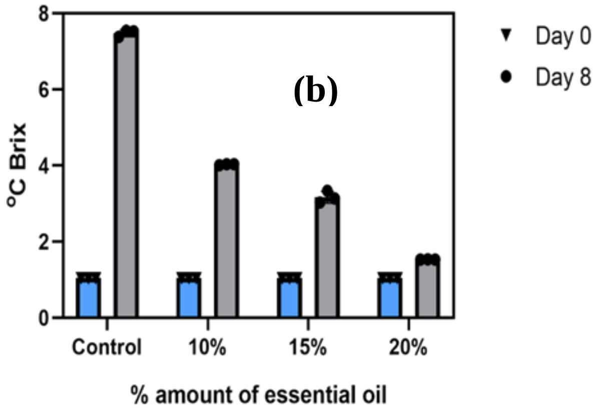
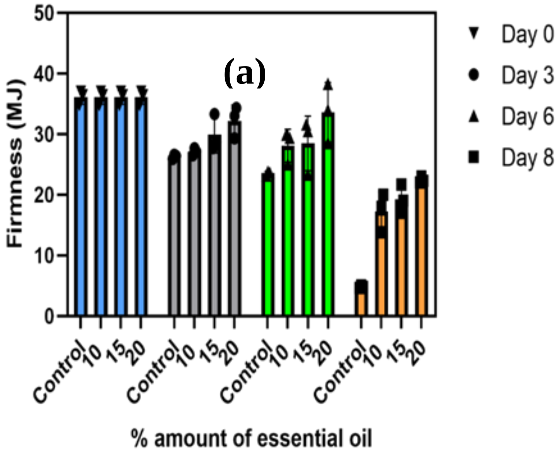


Figure 4 (a): Moisture content plantain pulp; **Figure 4 (b): ºBrix of plantain pulp**

Error bars indicate standard deviation at 95% Confidence interval



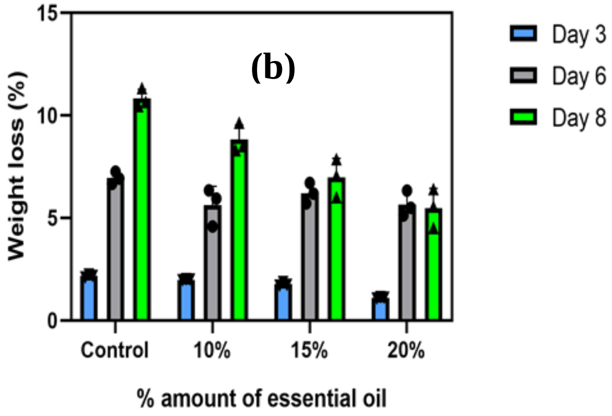


Figure 5 (a): Firmness of plantain pulp; **Figure 5 (b): Weight loss of plantain pulp**

Error bars indicate standard deviation at 95% Confidence interval

The plantains coated with cinnamon essential oils showed a slow rise in °Brix content. The result further showed that °Brix content decreased with increasing essential oil content in the coated plantain. Therefore, the presence of essential oil is effective in suppressing a rise in the °Brix content. The rise in °Brix content is attributable to enzyme-catalyzed hydrolysis of starch to sugars like sucrose, glucose, and fructose (Sojinu et al., 2021).

Firmness is one of the most important characteristics of fruit quality and softening is an indicator of fruit ripening and deterioration which is the main obstacle for long distant shipments of fruits like plantain. The results of the firmness of uncoated and coated plantains are depicted in figure 4.10. The results confirmed that, generally, firmness of plantains reduced as the number of days storage increased. The firmness of the uncoated plantain reduced from 36.07 MJ to 4.8 MJ on Day 8, whereas the firmness of the plantain coated with 10%, 15%, and 20% cinnamon essential oil reduced to 17.27 MJ, 19.23 MJ, and 22.4 MJ, respectively after the eighth day. Therefore, increasing proportion of cinnamon essential oil in the coasted samples caused a delay in the softening of the plantain. The softening of the plantain pulp can be ascribed to enzyme-catalyzed degradation of starches into simple sugars and the changes in cell wall polysaccharides. As previously explained, the fruit softening process is mainly caused by the disintegration of primary cell wall of the fruit causing a disentanglement of intercellular association (Shi et al., 2022; Wang & Seymour, 2022). Biomolecules such as cellulose, hemicelluloses, and pectin are the three main constituents of the primary cell wall in fruits, which undergo enzymatic hydrolysis and transformation during fruit ripening by a group of cell wall hydrolytic enzymes causing disintegration of the middle lamella, enhancing pectin solubilization, facilitating loss of pectin side chain neutral sugars, and engineering the depolymerization of polysaccharides of hemicellulose (Shi et al., 2022; Wang & Seymour, 2022). The enzyme-mediated degradation process of these biomolecules constitutes a vital source of carbon for the formation of sucrose and flavour-producing volatile molecules (Saraiva et al., 2013).

Fig 4b also present the results of the moisture loss from both coated (treated) and uncoated (control) samples of the plantain. Moisture loss in fruit is intricately linked to changes in firmness during storage (Moggia & Lobos, 2023). The outcome of the investigation showed that both the control and coasted samples of plantain produced significant weight losses during storage from the initial weighs equivalent of about 11% (uncoated), 8.5% (10% CEO), 7.0% (15% CEO) and 5% (20% CEO) on Day 8. Cinnamon essential oil had significant influence in reducing the weight of loss in the plantain. Weight loss during storage may be mainly due to water loss through transpiration process or weight loss could be due to carbon loss in respiration (Liu et al., 2003; Onwuka & Onwuka, 2005; Ranasinghe et al., 2019). Aerobic respiration contributes to overall fruit weigh loss by three main processes: (a) carbon loss in the form of carbon dioxide gas, (b) water generated during respiration getting lost as water vapour during transpiration, and (c) the heat energy produced during respiration becomes source of latent heat for more water vapourization. As observed by Xanthopoulos et al. (2017) respiratory water loss contributes to about 39% total water loss by transpiration in a study of pear.

3.3 Color Changes in Plantain

The changes in pigments are indicative of the development stage and the physiological condition of the fruit which are critical for optimal storage and postharvest management (Solovchenko et al., 2019) . Figure 5 shows colour changes associated with the coated and uncoated plantain peels during storage. Fruit color is indicative of its stage of maturity, freshness and quality, and provides the basis for classification (Wrolstad & Culver, 2012). From the results, no colour change in the peels of the plantain was observed for both coated and uncoated samples up to Day 2. The onset of colour change (green to light yellow) was observed in Day3 for only the uncoated sample. While the fourth day marked the beginning of colour change for the coasted samples particularly for the samples coated with 10% and 15% cinnamon essential oil, the colour change was almost completely dominant for the uncoated sample. The coasted samples did not show dominant colour change up to the 8th Day while the peels of the uncoated sample had dark patches signifying over-ripening and marking the unset of plantain deterioration. The results portray that the amount of cinnamon essential oil in the coated samples is influential in the delay of unset of colour changes associated with ripening of plantains.

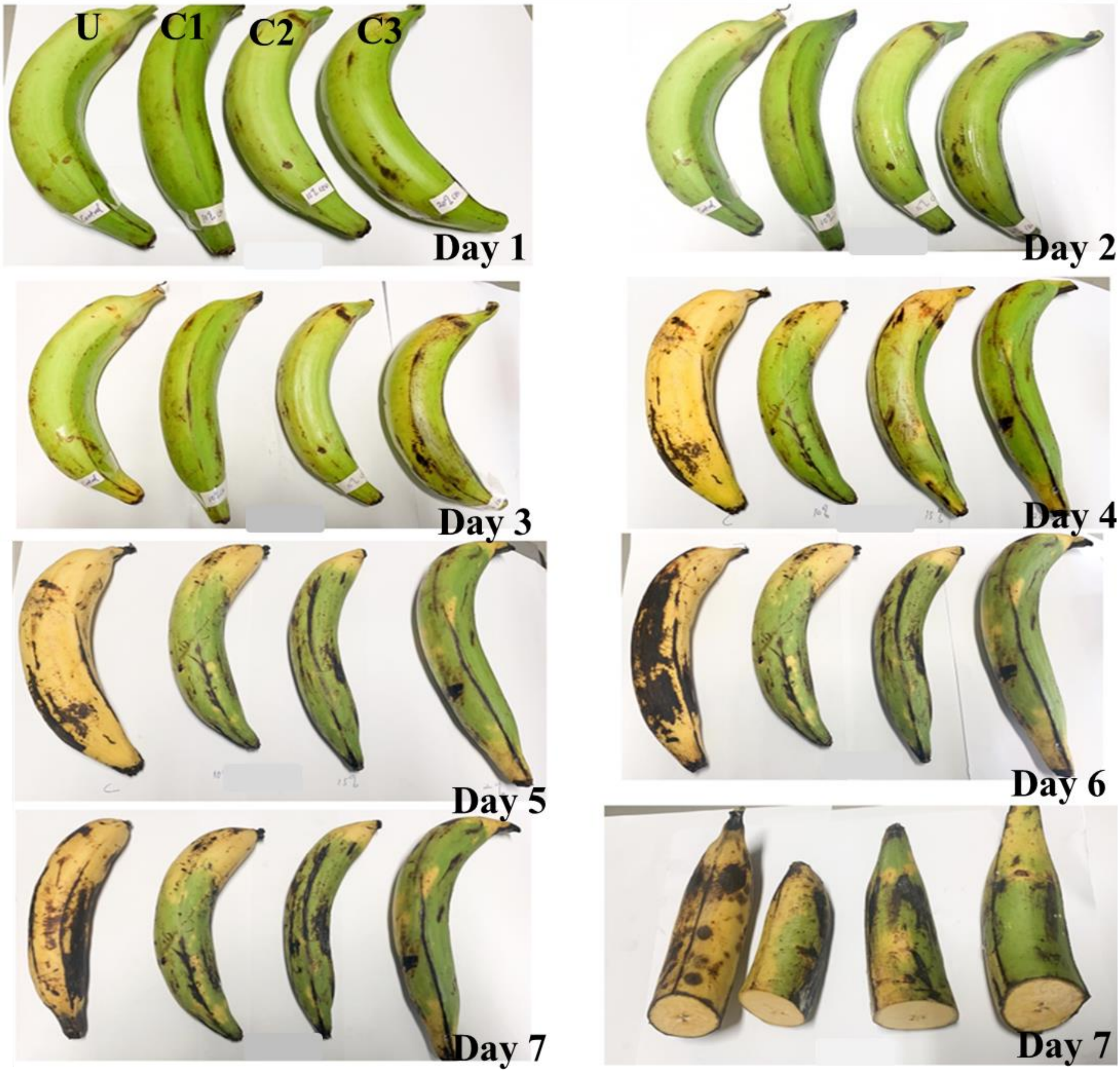


Figure 3: Images of coated and uncoated plantain during the storage for Day 1, 2,3,4,5,6,7 and 8

U=Uncoated, C1=Coated film (10% CEO), C2=Coated Film (15% CEO), and C3=Coated film (20% CEO)

The colour changes in fruit during ripening is caused by biosynthesis and degradation of pigments during the growth and maturation stages of the fruit. The buildup of pigments is influenced mostly by the various maturation stages, during fruit ripening, which is also influenced by biotic and abiotic factors as well as the genetic constitution of the plant species. In the process of maturation, various biochemical and physiological transformations take place in the fruit that tend to affect the type and composition of bioactive substances in the fruit (Belwal et al., 2019).

4.0 CONCLUSION

The study investigated the potential of harnessing sodium alginate and cellulose nanocrystals blended with cinnamon essential oil in varying proportions to produce an effective, low-cost, and sustainable film coatings to examine their suitability of preserving fresh plantains by extending shelf-life of the produce under the tested treatment conditions. Characteristically, the film coatings produced exhibited good molecular interaction and thermal stability based on the results of Fourier Transform and Infrared (FTIR) spectroscopy and thermogravimetric analysis respectively. The samples of plantain coated with film-forming solution and stored for 8 days were examined for their physiochemical parameters (pulp moisture content, ^{o}Brix, weight loss, firmness, and colour changes) during eight-days storage at room temperature (25 ±1°C). There was a significant ($p<0.05$) reduction in moisture production, ^{o}Brix, weight loss rate, and softening rate for coated plantains relative to the uncoated samples. Increasing proportion of the essential oil in the film was effective in delaying the unset of ripening and deterioration by one week. This investigation demonstrates that cinnamon essential oil incorporated in sodium alginate polymer and cellulose film is effective in delaying the postharvest physiological ripening and deterioration of fresh plantain and can contribute to extending the shelf life of fresh mature plantain in distribution and storage. Therefore, by optimizing the level of cinnamon essential oil in the film, this innovative technique can serve as an effective sustainable way of preserving plantain to maintain it nutritional and functional qualities while enhancing its economic value in the food supply chain.

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