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Effect of Plant Based Preservatives on Shelf Life and Quality of Mango Fruits (*Mangifera indica*) During Storage

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Authors' contributions

This work was carried out in collaboration among all authors. Author ASP performed labor experiment and the statistical analysis, managed the literature searches and wrote the first draft of the manuscript. Author JAN designed the study and wrote the protocol. Authors JAN and DG managed the analyses of the study and the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Mango is one of the main fruits grown in Chad. However, it is prone to high post-harvest losses due to lack of adequate distribution networks, appropriate harvesting and conservation methods. The objective of this study was to test the effectiveness of coatings based on extracts of *Allium sativum* (garlic), *Zingiber officinale* (ginger) and *Spirulina platensis* (spirulina) on their conservation. Shelf life, weight loss, firmness, pH and total soluble solids content of mangoes were evaluated. The coated mangoes had excellent brillance compared to control mangoes. The coatings based on the extracts of *A. sativum*, *S. platensis* and *Z. officinale* increased respectively the means shelf life of mangoes to 18, 19 and 24 days. Weight losses were 21% for control mangoes while they were 13% for mangoes coated using mixture containing extracts of *A. sativum* and *S. platensis* and 11% for

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mangoes coated with *Z. officinale*. Coatings based on extracts of *Z. officinale* and *S. platensis* had statistically comparable effects on the firmness of mangoes but significantly higher than those of *A. sativum* extracts and controls after the 10th day. pH values and total soluble solids content (TSSC) values of control mangoes were significantly higher than those of coated mangoes. On day 10 after treatment, chlorophylls were absent from the peel of control mangoes whereas they were still present in the peel of coated mangoes. The mangoes coated with extract of *Z. officinale* reached a shelf life of 24 days. This shelf life was significantly higher than that of mangoes coated with other types of extracts and control mangoes. The coating with *Z. officinale* extract slowed considerably the ripening of mangoes. It can be recommended for conservation of mangoes in fresh.

Keywords: Mangoes; coating; Allium sativum; Zingiber officinale; Spirulina platensis; conservation in fresh.

1. INTRODUCTION

Mango (*Mangifera indica*) is the fifth most produced fruit in the world with 43.9 million tons produced in 2013 [1]. According to the statistics of the Intergovernmental Group on Banana and Tropical Fruits of the FAO [2], the production of mangoes by Chad estimated at about 32600 tons in 2010 represents 2% of the production of the countries of ECOWAS. Mango is considered as one of the best fruits in the world thanks to its attractive color, delicious flavor and excellent nutritional characteristics [3]. It is a fruit rich in carbohydrate, β-carotene, vitamins C, B1, B2 and is an important source of polyphenols [4]. Indeed, mango *Mangifera indica* is a plant of Indo-Burmese origin belonging to the family Anacardiaceae [5]. In Chad, mango is grown mainly in the Sudanese Zone characterized by a dry tropical climate. Mango production generally starts in Chad in january and ends in july-august. This production, hitherto almost exclusively for local consumption, reached its peak in march, april and may [6]. During this period of high production, mangoes abound in orchards and markets of producing regions. The slump in sales of mangoes in the producing regions leads to huge post-harvest losses and an inestimable loss of profit for producers. Much of this production is lost due to lack of distribution networks, appropriate processing structures and methods of conservation in fresh. The main method of conservation mango used in Chad is the artisanal drying practiced by the women of producers. This process is considered like a feminine and accessory activity [6]. Indeed, most tropical agricultural products suffer from significant post-harvest losses for several reasons, including poor harvesting technical, pest attacks, product depreciation under the influence of microbiological agents, storage difficulties in the absence of appropriate infrastructure and the low technical achievement of the most appropriate [7]. In particular, post-harvest losses of mangoes are estimated at around 80% worldwide [8]. Currently one of the great challenges of fruit growing is the preservation of fruit quality after harvest and the minimization of post-harvest losses [9]. Coatings based on *Allium sativum* (garlic), *Zingiber officinale* (ginger), *Spirulina platensis* (spirulina) were used because of their multiple human health benefits [10]. They act as a barrier against external elements, prolonging the shelf life and reducing the risk of health [11]. To limit post-harvest losses and dispose of mangoes during a long period, the development of simple technical that slow down the ripening process and extend the shelf life of mangoes is essential. The objective of this work was to test the efficacy of edible coatings based on *Allium sativum*, *Zingiber officinale* and *Spirulina platensis* extracts on some mango conservation characteristics.

2. MATERIALS AND METHODS

2.1 Plant Material

The study was conducted on mango varieties grown in the Sudanese Zone of Chad. There were four varieties of local mangoes (Bangui, Kassai, Maiduguri and Mangotine) and nine varieties of improved mangoes (Cœur de Bœuf, Davis Haden, Eldon, Jose Tchad, Julie Kassawa, Keitt, Kent, Palmer, Smith and Valencia.). Mxtures containing extracts of *Allium sativum* (garlic), *Zingiber officinale* (ginger) and *Spirulina platensis* (spirulina) and gum arabic were used to coat these varieties of mangoes. The mangoes used collected during the 2017 mango harvest season in southern Chad. These fruits, free from defects such as sunburn and insect or disease damage, were harvested at approximately the same stage of maturity (mature green stage with a firmness $>$ 4 kgf). The work was carried out during the month July 2017 at the Applied Botany Research Unit of the Faculty of Science of Dschang University. Fruits were collected from 7 to 10 years old mango trees in 2017.

2.2 Methods

2.2.1 Preparation of extracts

To prepare the extracts, 1 kg each of *Allium sativum* L. of *Zingiber officinale* Roscoe and of *Spirulina platensis* were respectively macerated in a mixture of 500 ml of water and 500 ml of ethanol (95%) according to the method of Aghofack et al. [12]. The different mixtures were allowed to stand for 2 hours and then filtered with a polythene cloth. The residues from the first filtration were then macerated in a mixture consisting of 250 ml of water and 250 ml of ethanol. For the formulation of the coating based on extracts of *A. sativum*, *Z. officinale* and *S. platensis.* gum arabic (10%) and bleach (230 µl /l) were added to the different filtrates obtained. The dose of bleach recommended for consumption was used to disinfect the mixture. Gum arabic was used as a coating matrix to thicken the extracts and form an adhesive and transparent film on the surface of mangoes.

2.2.2 Coating of mangoes

Five mature mango fruits per variety were soaked during 5 minutes in the different coatings. For the controls, five fruits of each variety were immersed in water/ethanol (1/1, v/v) mixture containing 10% gum arabic and 0,023% natrium hypochlorite. Four batches of mangos were constituted: The controls, the mangoes treated with extract of *A. sativum*, the mango treated with extract of *Z. officinale* and the mango treated with extract of *S. platensis*. Each batch consisted of 65 mangoes, or 5 fruits per variety. The fruits thus coated were then dried at room temperature. The mean temperature and mean relative humidity measured during this conservation test were 24.97°C and 75.28%, respectively.

2.2.3 Evaluation of the effect of coatings

The effect of the coatings was evaluated by determining the shelf life, the loss of mass, the variation of the firmness, of the pH and of the total soluble solids content (TSSC) of the mangoes. Twenty fruits were analyzed every 5 days, that to say five fruits per treatment (control, *Allium sativum* L., *Zingiber officinale* Roscoe and *Spirulina platensis*).

2.2.4 Mass loss

Mangoes were weighed every 5 days. Mass loss was determined using the formula of Lepengue et al. [13]:

$$M (\%) = [(Mi-Mt) / Mt] \times 100$$

Where Mi corresponds to the initial mass of the mango and Mt, to the mass of the mango at the definite time.

2.2.5 Shelf life of mangoes

The shelf life of mangoes was defined as the time between the first day of coating and the day when the first symptoms of tissue necrosis appeared.

2.2.6 Firmness of the mango pulp

The firmness of fruits was measured using a GY-2 SAUTER GmbH type penetrometer every 5 days according to the method used by Mehinagic et al. [14]. A disc of peel of about 2 cm² was preleved from three places in the equatorial part of the fruit for this purpose. The firmness of the pulp was expressed in kilogram-force (kgf) or newtons (N) (1 kgf = 9.80665 N).

Table 1. Composition of the coatings used

Plant used	Matrix	Solvent	Composition of coatings
A. sativum	Gum arabic	Water + ethanol	1550 ml of *A. sativum* extract + 155 g of gum Arabic (10%) + 356,5µl of bleach
Z. officinale	Gum arabic	Water + ethanol	1800 ml of *Z. Officinale* extract + 180 g of gum Arabic (10%) + 414 µl of bleach
S. platensis	Gum arabic	Water + ethanol	1050 ml of *S. Platensis* extract + 105 g of gum Arabic (10%) + 241,5 µl of bleach

2.2.6.1 pH of mango pulp

The determination of the pH of the mango pulp was made using a Consort C533 pH meter every 5 days. The pH sensor was immersed in the undiluted mango juice obtained after grinding the pulp and filtration using a polythene cloth.

2.2.6.2 Determination of the total soluble solids content of mango pulp

The total soluble solids content (TSSC) was determined every 5 days using the Navarre & Navarre method [15]. One or two drops of mango juice free of bubbles and floating particles were deposited on the prism of a ATC brand refractometer and the reading was made in the presence of a incadescent lamp. The TSSC was determined in degree Brix, one of which corresponds to 1 g sucrose /100 g of sample [16].

2.3 Experimental Design

The design used in this experiment was a Complete Randomised Design (CRD) with 4 treatments (control, *Allium sativum* L., *Zingiber officinale* Roscoe and of *Spirulina platensis*), 13 factors (varieties) and 5 replications.

2.4 Statistical Analysis

The statistical analysis of the data was performed using the XLSTAT 2014.5.03 software (Kovach Computing Services, United Kingdom). The data obtained were subjected to analysis of variances (ANOVA) and the means of shelf life, physical and biochemical characteristics were compared using the Student-Newmann-keuls test at a probability threshold set at < 5%.

3. RESULTS AND DISCUSSION

3.1 Effects of Coatings Based on Extracts of *A. sativum*, *Z. officinale* and *S. platensis* on the Conservation of Mangoes at Ambient Temperatures

The appearance of coated mangoes was considerably improved by the three types of coating used compared to control mangoes (Fig. 1). The coated mangoes had excellent brillance. The best brillance of mangoes was observed after application of a coating based on extract of *A. sativum* (Fig. 1B) followed respectively by coatings based on extracts of *Z. officinale* (Fig. 1C) and *S. platensis* (Fig. 1D). The appearance of the fruits is essential, because the visual quality is a determining criterion to attract the consumer and constitutes one of the organoleptic qualities of the fruits. This brilliance resulted obviously from the activities of gum arabic and extracts used. It could be due on the one hand to the action of the main constituent of gum arabicogalactan and on the other hand to the action of allicin and gingerol which are respectively the constituents of *A. sativum*, *S platensis* and *Z. officinale*. According to Onias et al. [17], these constituents of *A. sativum, S. platensis and Z. officinale* act as adjuvants of the crystalline structure, and give a good appearance to coated fruits.The adhesive, gelling, thickening and whipping properties of gum arabic ultimately improve the texture of food products [18].

3.2 Effects of Coatings on the Shelf Life of Mangoes

Examination of results of effects of different coatings on the shelf life of coated mangoes showed that the coatings used increased the

Fig. 1. Brillance of control mangoes (A) and mangoes treated by applications of coatings based on extracts from *A. sativum* (B), *Z. officinale* (C) and *S. platensis* (D)

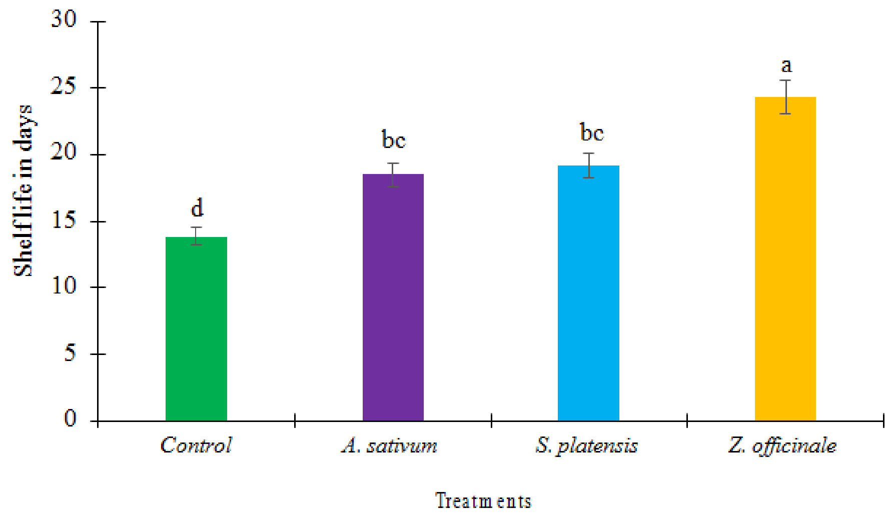

Fig. 2. Means shelf life of control mangoes and mangoes treated by applications of coatings based on extracts of *A. sativum*, *S. platensis* and *Z. officinale* (Bars followed by the same letters don't differ significantly at the 5% threshold)

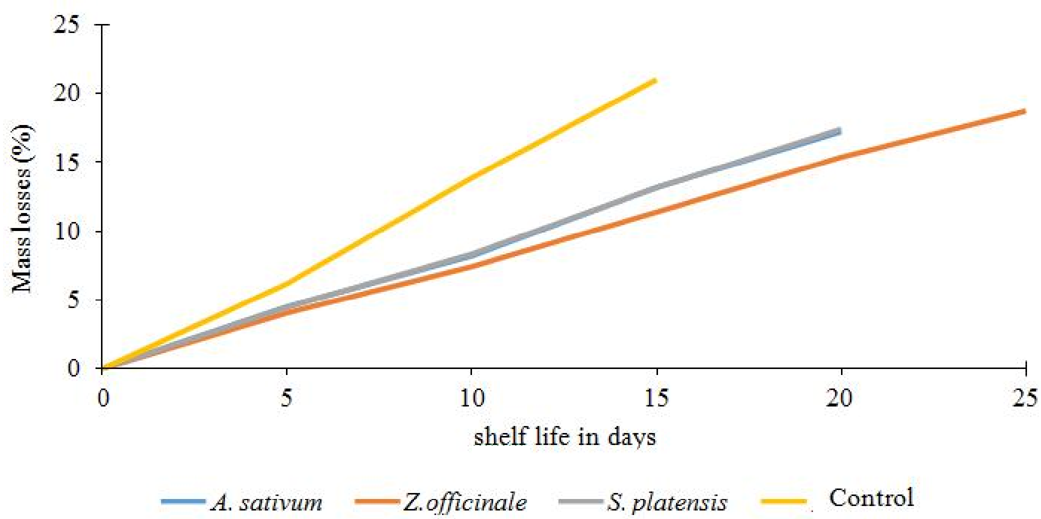

Fig. 3. Evolution of mass losses of control and coated mangoes during conservation

average shelf life of mangoes. The coatings based on the extracts of *A. sativum*, *S. platensis* and *Z. officinale* increased respectively the means shelf life of mangoes to 18, 19 and 24 days (Fig. 2). On the other hand, the mean shelf life of control mangoes was 14 days. The shelf life of *Z. officinale*-coated mangoes was significantly higher. These results corroborate, with regard to the *Z. officinale* extract coating, those of Thaithi [19] which had obtained a shelf life of mangoes of 24 days. On the other hand, coatings based on *Chlorella* sp. have achieved 28 days of storage without damaging the quality of bananas (*Musa* spp.) [20]. Generally, the ripening process of mangoes after harvest lasts 9 to 12 days [21]. This short period seriously limits its long-distance marketing [22]. The shelf life of fruits is related to their ripening speed. Maturing brings together a set of irreversible and inevitable physiological processes that modify the composition of the fruit [23]. The ripening of control mangos is revealed by the change of colors, because during this process the chlorophyll content decreases,

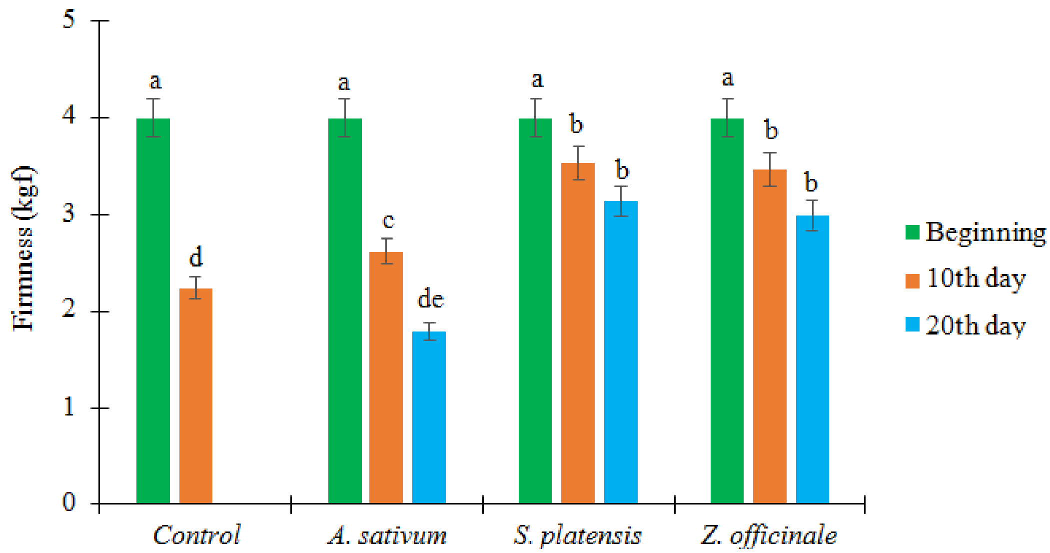

Fig. 4. Variation in the firmness of control and mangoes coated during conservation
(Bars followed by the same letters don't differ significantly at the 5% threshold)

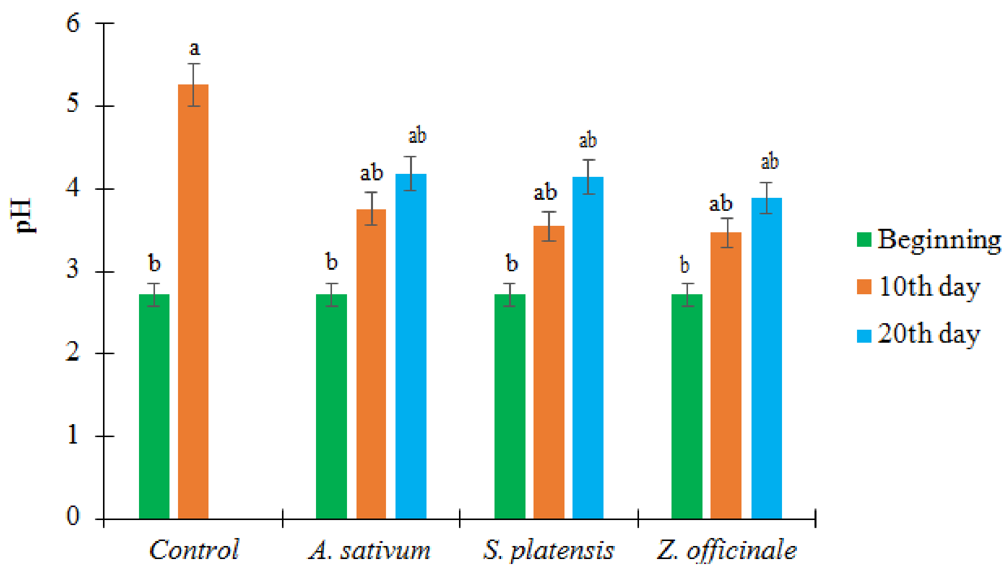

Fig. 5. pH variation of control and coated mangoes during conservation
(Bars followed by the same letters don't differ significantly at the 5% threshold)

while the concentration of carotenoid increases [24]. It appeared from the present work that the coatings used retarded the degradation of chlorophylls and limited the speed of ripening. The content of pigments such as chlorophyll is one of the main signatures of the physiological state of the fruits [25]. The increase in shelf life was probably a result of the action of the active biological compounds contained in *Z. officinale* including gingerol.

3.3 Effects of Coatings on the Loss of Mass of Mangoes

The results of weight showed that the mass losses of the mangoes coated using mixture containing extracts of *A. sativum* and *S. platensis* were almost identical, that's why their curves are confused (Fig. 3). Mass losses of control mangoes were significantly higher than those of coated mangoes. *Z. officinale*-based

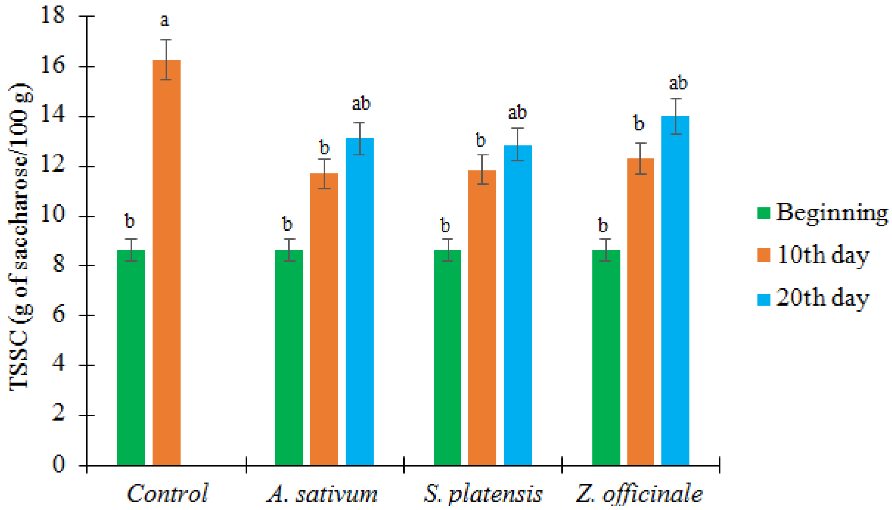

Fig. 6. Variation of Total Soluble Solids Content (TSSC) of control and coated mangoes during conservation

(Bars followed by the same letters don't differ significantly at the 5% threshold)

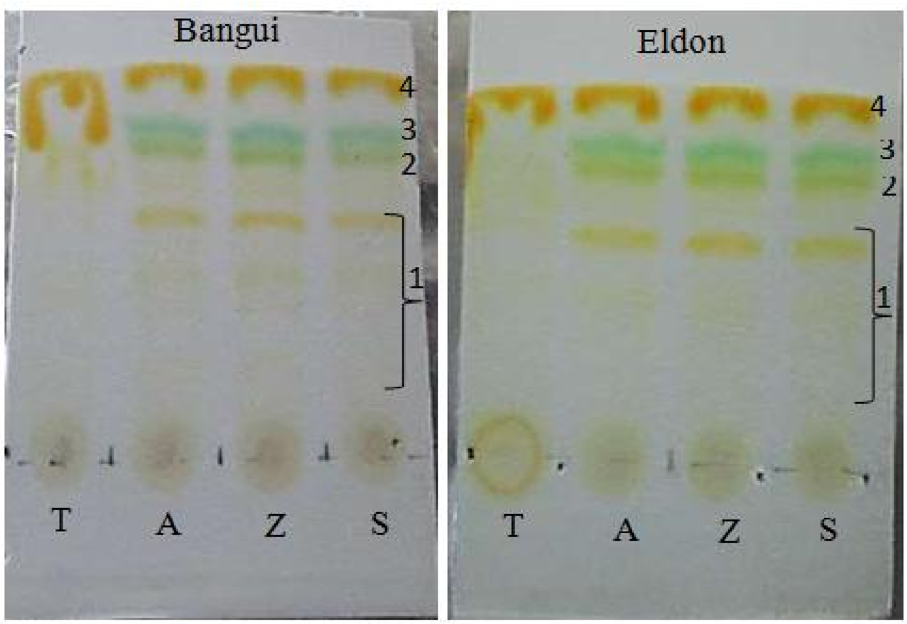

Fig. 7. Thin layer chromatographic profiles of pigment from the peel of control mangoes (T) and mangoes coated with extracts of *A. sativum* (A), *Z. officinale* (Z) and *S. platensis* (S) on the 10th day of storage. 1: xanthophylls, 2: chlorophyll b, 3: chlorophyll a and 4: carotenes

coating significantly reduced the loss of mango mass. On the 15th day of conservation, weight losses were 21% for control mangoes while they were 13% for mangoes coated using mixture containing extracts of *A. sativum* and *S. platensis* and 11% for mangoes coated with *Z. officinale*. *Z. officinale*-based coating significantly reduced mass losses during storage. It was more effective than the other two types of coating for the reduction of mass loss. These weight losses of coated mangoes were similar to those of Thaithi [19], but lower than those obtained by Lepengue et al. [13] with coated eggplant (30 to 80%). These coatings are responsible for the bioactive effects on fruits, mainly the regulation of transpiration and the reduction of mass loss [26]. In addition, the loss of mango mass increased with the shelf life regardless of the treatment, as also shown by Cissé [27]. The decrease in mass is due to a loss of water by transpiration, and causes a change in cell metabolism due to water stress [28]. However, the low weight loss of coated fruit can be attributed to the barrier properties to water loss of coatings [29] and in particular to the action of active biological compounds contained in gum arabic and *Z. officinale*. Several studies have shown that excessive losses of water cause the product to soften, reduce its shelf life and may lead to a significant degradation of the commercial quality of the fruit [19].

3.4 Effects of Coatings on the Firmness of Mangoes

The results of effects of coatings on the firmness of mangoes showed significant differences between the firmness values of the control and coated fruits (Fig. 4). Similarly, there were significant differences between the firmness values of fruits coated by a mixture containing *A. sativum* extract and those coated with extracts of *S. platensis* and *Z. officinale*. Coatings based on extracts of *Z. officinale* and *S. platensis* had statistically comparable effects on the firmness of mangoes but significantly higher than those of *A. sativum* extracts and controls after the 10th day (Fig. 5). The coatings based on the extracts of *Z. officinale* and *S. platensis* thus made it possible to stabilize the firmness during conservation. These coatings helped stabilize the firmness of mangoes. They therefore slowed the ripening process and consequently increased the shelf life. Reduced breathing and decreased water loss may be responsible for maintaining firmness. These factors minimize cell turgor loss and slow down the activity of lysing enzymes including polygalacturonase, pectic galactanase and beta-galacturosidase in fruit during conservation [30]. Indeed, changes in the cell wall involve polygalacturonases and cellulases that decrease the cohesion between cells. In this way, the wall becomes less rigid, resulting in changes in the texture of the flesh, which becomes melting [31]. Coatings based on *Z. officinale* and *S. platensis* extracts have stabilizing properties which would slow down the activity of the lysis enzymes and thus ensure the maintenance of firmness.

3.5 Effects of Coatings on the pH of Mangoes

Overall, the pH values of control mangoes were significantly higher than those of mango varieties coated before storage (Fig. 5). The pH of mangoes coated by mixture containing extracts of *A. sativum*, *S. platensis* and *Z. officinale* evolved moderately. The pH values of coated mangoes were statistically comparable. However, the pH values of control mangoes were significantly higher than those of coated mangoes. The pH increase in control mangoes was significantly higher and faster than that of coated mangoes. The pH of coated mangoes showed the smallest increases. Coatings based on extracts from *A. sativum*, *S. platensis* and *Z. officinale* thus significantly slowed the pH evolution in mangoes (Fig. 5). During fruits ripening, the pH increases and the acidity decreases due to conversion of acids to salts, the rapid loss of citric acid associated with a slight decrease in the amount of malic acid [32,33]. The coatings used would have a moderating effect on the pH increase by slowing the conversion and loss of organic acids.

3.6 Effects of Coatings on the Total Soluble Solids Content of Mangoes

The results of effects of coatings on the total soluble solids content (TSSC) of mangoes showed that there were significant differences between the total soluble solids content (TSSC) values of control mangoes and those of mangoes coated with extracts of *A. sativum*, *S. platensis* and *Z. officinale* (Fig. 6). The total soluble solids content (TSSC) values of control mangoes were significantly higher than those of mangoes coated with *A. sativum* extract at day 10. In contrast, TSSC values of mangoes coated using mixture containing extract of *A. sativum*, *S. platensis* and *Z. officinale* did not show significant differences during storage. The TSSC values of control mangoes evolved significantly from the beginning to the 10th day of conservation, thus translating faster ripening, whereas those of mangoes coated with extract of *A. sativum*, *S. platensis* and *Z officinale* evolved slowly resulting in slow ripening of coated mangoes (Fig. 6). Total soluble solids content increased sharply and more rapidly in control mangoes between days 1 and 10 and decreased towards the end of conservation. On the other hand, it increased slowly in coated mangoes during conservation. This showed that preformed sugars in coated fruit were reduced at a slower rate than in controls as Cissé [27] also suggested with Senegal mangoes. The total soluble solids content increased during ripening due to the degradation of the polysaccharides present in the fruits. During ripening, the hydrolysis of the starch into maltose and glucose naturally results in an increase in the soluble sugar content and a decrease in starch content in mangoes [27]. The coatings used would have slowed the hydrolysis of the starch to glucose and maltose in treated mangoes.

3.7 Effects of Coatings on Chromatographic Profiles of Peel Pigments

The analysis of the thin layer chromatographic profiles of the peel pigments of control mangoes (T) and mangoes coated with extracts of *A sativum* (A), *Z. officinale* (Z) and *S. platensis* (S) on day 10 after treatment showed that chlorophylls were absent from the peel of control mangoes whereas they were still present in the peel of coated mangoes. In the peel of control mangoes, there were only carotenoids (Fig. 7). The coatings used therefore retarded the degradation of chlorophylls a and b in the peel of mangoes between the beginning and the 10th day after treatment. In the peel of control fruits, there were only orange and pink pigments (β-carotene and lycopene) on the 10th day after treatment. Specific enzymatic activities are involved in the modification of the color of the fruit. Two mechanisms are involved simultaneously: chlorophyllase catalyses chlorophyll degradation [34] whereas phytoene synthase is one of the key enzymes that catalyse the synthesis of carotenoids [35]. During fruit ripening, chloroplasts are transformed into chromoplasts, with concomitant degradation of chlorophylls and synthesis of carotenoids [36]. The coatings used would have therefore retarded chlorophyll degradation by chlorophyllases.

4. CONCLUSION

Coatings based on extracts of *A sativum*, *Z. officinale* and *S. platensis* positively affected the ripening process of mangoes by slowing the loss of mass, the transformation of starch and pectic compounds, the conversion of acids and degradation of chlorophylls. The coating with *Z. officinale* extracts had the most significant effects and increased the shelf life of mangoes to 24 days. The coating with *Z. officinale* extracts can thus be used to prolong the shelf life of fresh mangoes. It is a simple and less expensive technique using local plant material.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gerbaud P. Dossier mangue. FruiTrop. French. 2015;230:26-70. French
2. GIBFT/FAO. Groupe Intergouvernemental sur la Banane et Fruits Tropicaux de la FAO. Résumé du rapport sur la situation des marchés des fruits tropicaux; 2011. French
3. Mitra SK, Baldwin EA. Mango. Postharvest physiology and storage of tropical and subtropical fruits. CAB International: New York; 1997.
4. Sawadogo-Lingani H, Traore AS. Composition chimique et valeur nutritive de la mangue Amélie (*Mangifera indica* L.) du Burkina Faso. Journal des Sciences. 2001;1:35-39. French
5. Mukherjee SK, Litz RE. Botany and importance: In botany, production and uses. 2nd Edition Litz Richard E CAB International: Wallingford; 2009.
6. Passannet AS, Aghofack-Nguemezi J, Gatsing D. Diversité des variétés, de production et de conservation de mangues au Tchad. International Journal of Biological and Chemical Sciences. 2017;11(3):1145-1164. French
7. FIRCA. Fonds interprofessionnel pour la recherche et le conseil agricole. Répertoire de technologies et de procédés de transformation de la mangue et de l'ananas. Abidjan; 2013. French
8. Kansci G, Koubala BB, Mbome LI. Effect of ripening on the composition and suitability for jam processing of different varieties of mango (*Mangifera indica*). African Journal of Biotechnology. 2003;2(9):301-306.
9. Botelho LNS, Rocha DA, Braga MA, Silva A, Abreu CMP. Quality of guava cv. 'Pedro Sato' treated with cassava starch and cinnamon essential oil. Scientia Horticulturae. 2016;209:214-220.
10. Michalak I, Chojnacka K, Saeid A. Plant growth biostimulants, dietary feed supplements and cosmetics formulated with supercritical CO2 algal extracts. Molecules. 2017;22(66):1-17.

11. Onias EA, Rocha RHC, Lima JF, Onias EA, Furtunato TCS. Organic ‘Tommy Atkins’ mango postharvest quality when treated with biofilms enriched by *Spirulina platensis*. Revista Científica. 2016;44(3): 286-293.
12. Aghofack NJ, Hoffmann H, Schwab W. Effects of bio-based coatings on the ripening and quality attributes of tomato (*Solanum lycopersicum*) fruits. Journal of Sciences Food and Agriculture. 2019;99: 1842–1849.
13. Lepengue AN, Mouaragajda I, Dick E, Mbatchi B, Ake S. Essai d’amélioration de la durée de conservation des aubergines aux températures ambiantes au Gabon. 2012;6(2):792-798. French
14. Mehinagic E, Royer G, Bertrand D, Symoneaux R, Laurens F, Jourjon F. Relationship between sensory analysis, penetrometry and visible-NIR spectroscopy of apples belonging to different cultivars. Food Quality and Preference. 2003;14:473-484.
15. Navarre JP, Navarre C. Manuel d’œnologie. Edition J.B. Baillière: Paris; 1986. French
16. Bradley RL. Moisture and total solid analysis: In compositional analysis of foods. S.S. Nielsen, Springer Science+Business Media; 2010.
17. Onias EA, Teodosio AEMM, Bomfim MP, Rocha RHC, Lima JF, Medeiros MLS. Revestimento biodegradável à base de *Spirulina platensis* na conservação pós-colheita de goiaba Paluma mantidas sob diferentes temperaturas de armazenamento. Revista de Ciências Agrárias. 2018;41(3):849-860. Portuguese
18. Saidou C. Propriétés physico-chimiques et fonctionnelles des gommes hydrocolloïdes des écorces de *Triumfetta cordifolia* et *Bridelia thermifolia*. Thèse de doctorat de l’Université de Grenoble; 2012. French
19. Thaithi H. Effet de différents enrobages sur les caractéristiques de la conservation a l’état frais de la mangue. Thèse de Master of science en génie agroalimentaire méditerranéen et tropical. CIRAD-FLHOR Montpellier; 2000. French
20. Oliveira AMF, et al. Postharvest quality of 'prata anã' bananas treated with microalgae coating. Journal of Experimental Agriculture International. 2018;27(2):1-11.
21. Herianus JD, Singh LZ, Tan SC. Aroma volatiles production during fruit ripening of Kensington Pride mango. Postharvest Biology Technology. 2003;27:323–336.
22. Gomez-Lim MA. Postharvest physiology: In botany, production and Uses. 2nd Edition Litz Richard E CAB International: Wallingford; 1997.
23. Nordey T. Analyse expérimentale et modélisation de l'hétérogénéité de la qualité et de la maturité des mangues. Thèse de Doctorat de l’Université d’Avignon et des pays de Vaucluse; 2010. French
24. Sitbon C. Etude de la diversité génétique des manguiers antillais (*Mangifera indica* L.), utilisation de marqueurs microsatellites. Diplôme d’Etudes Supérieures Spécialisées, Université Paris. 2004;7. French
25. Féret JB. Apport de la modélisation pour l’estimation de la teneur en pigments foliaires. Thèse de Doctorat de l’Université Pierre et Marie Curie Ile de France; 2009. French
26. Oliveira LM, Alves KA, Teodosio AEMM, Morais FA. Postharvest of “tommy atkins” mango submitted to coating of *Chlorella* sp. Journal of Agricultural Science. 2018;10(9):225-233.
27. Cissé M. Immobilisation d’un système lactoperoxydase dans un enrobage de chitosane dans le but de prolonger la conservation des mangues. Thèse de Doctorat, Centre de Coopération Internationale en Recherche Agronomique pour le Développement CIRAD. Montpellier; 2012. French
28. Ben-Yehoshua S. Transpiration, water stress, and gas exchange in postharvest physiology of vegetables. J. Weichman Edition: Marcel Dekker New York USA; 1987.
29. Diac-Sobac R, De La Cruz J, Alma VL, Beristain CI, Garcia HS. Evaluation of softening and associated enzyme activities during the ripening of coated ‘Manila’ mangoes. Journal of Horticulral Science. 1997;72(5):749-753.
30. Tasdelen Ö, Bayindirli L. Controlled atmosphere storage and edible coating effects on storage life and quality of tomatoes. Journal of food processing and preservation. 1998;22(4):303-320.
31. Huber DJ. Cell wall hydrolase and fruit softening. Horticultural Reviews. 1983;5: 169- 219.
32. Medlicott AP, Thompson AK. Analysis of sugars and organic acids in ripening

mango fruits (*Mangifera indica* L. var Keitt) by high performance liquid chromatography. Journal of the Science of Food and Agricultural. 1985;36:561-566.
33. Kumar R, Kaushik RA, Chharia AS. Effect of postharvest treatments on the quality of mango during storage. Journal of Horticulral Science. 1992;21(2):46-55.
34. Jacob-Wilk D, Holland D, Goldschmidt EE, Riov J, Eyal Y. Chlorophyll breakdown by chlorophyllase: Isolation and functional expression of the Chlase1 gene from ethylenetreated Citrus fruit and its regulation during development. Plant Journal. 1999;20(6):653-661.
35. Gray J, Picton S, Shabbeer J, Schuch W, Grierson D. Molecular biology of fruit ripening and its manipulation with antisense genes. Plant Molecular Biology. 1992;19(1):69-87.
36. Kane O, Marcellin P. Incidence of ripening an chilling injury on the oxidative activities and fatty acid compositions of the mithochondria form mango fruits. Plant Physiology. 1978;61:634-638.

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