

Preservation of Mangoes (*Mangifera Indica* L. Variety “Kent”) by Edible Coating Based Cassava Starch, Coconut Microfiber and *Garcinia Kola* Oil

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Abstract The preservation of mangoes is limited by rapid ripening which leads to a change in the physicochemical and organoleptic properties of the fruit. In this study, edible coating was chosen as an alternative method to preserve the quality attributes of the "Kent" mango. The objective was to preserve the mango "Kent" with coatings based on cassava starch, coconut fibre and *Garcinia kola* oil. The mangoes after being collected and cleaned were subjected to coating and stored for 30 d with evaluations every 5 d at room temperature ($25 \pm 2^\circ\text{C}$) and under refrigeration at 13°C . The results showed that the coating significantly reduced the loss of mangoes during storage. There was no significant difference in the weight loss of coated and uncoated mangoes stored at 13°C during the 30 d of storage. The soluble solids content increased significantly during storage from 15.55 ± 0.25 on 5 d to 15.75 ± 0.62 on 15 d for coated mangoes stored at room temperature, while at 13°C it increased from 17 ± 0.13 on 5 d to 20 ± 0.56 on 30 d. The ascorbic acid (vitamin C) content decreased during the thirty days of storage. At 13°C , it decreased from 228.62 ± 2.12 mg/100g on 5 d to 142.5 mg g⁻¹ on 30 d in coated mangoes. The sensory profiles of the coated mangoes stored at room temperature and under refrigeration at 13°C showed good conservation of organoleptic properties with a sweet taste, good firmness, and good resistance to chewing. The coating technology used resulted in better preservation of most of the physicochemical and sensory characteristics of the mangoes "Kent" during the 30 d of storage.

Keywords: mango, starch, post-harvest losses, edible coatings, *Garcinia kola*, coconut fibre

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1. Introduction

The mango tree (*Mangifera indica* L.) is a plant of the Anacardiaceae family [1], widely cultivated in tropical countries for its fruit, which is of nutritional importance for humans [2]. Indeed, green mango fruits are rich in vitamin C and when ripe, they become a real source of vitamin A, thiamine, and niacin. They also contain sugar; this allows them to be a real source of energy [3].

In Côte d'Ivoire, the mango tree is cultivated throughout the country, but the areas where climatic conditions are favourable to its cultivation to produce good quality fruit are precisely in the savannah regions (Korhogo, Sinématiali, Ferkessedougou and Odienné) [4]. Mango provides food for the population and is their main source of income during the harvest period, which runs from April to June. Thus, it contributes to food security and the

fight against poverty. Indeed, with more than 150,000 tonnes produced annually [5], Côte d'Ivoire is the leading African country and the third country in the world, exporting mangoes to the European market after Brazil and Peru with a total export of 10,000 to 14,000 tonnes per year [6]. The mango sector generates more than 7 billion CFA francs in revenue (local sales and exports) and provides producers with around 1 billion CFA francs annually.

Despite its nutritional and economic importance, mango production in Côte d'Ivoire is faced with post-harvest losses estimated at 30-40% of national production [7]. This results in tens of tons of mangoes rotting in the orchards and interceptions of shipments to European markets. This situation leads to huge losses of earnings for producers, around CFA francs 3.3 billion per year. There are several causes of these losses, including rapid ripening, transpiration, mechanical injuries, post-harvest diseases,

respiration, and ethylene production [8]. However, fungal spoilage is one of the main constraints to fresh fruit quality in Côte d'Ivoire. According to Kouamé et al. [8], 20-25 % of fruit are decomposed by pathogens during post-harvest handling.

Many technologies are available to preserve mango quality. For example, the use of chemical fungicides to control post-harvest diseases in mango [9]. However, the use of chemical agents poses a real risk to consumer health. In addition, modified atmosphere packaging, low temperature, irradiation, and coating have been successfully used to extend the shelf life of many fruit such as table grapes [10], sweet cherries [11], nectarines [12]. Among these measures, edible coating is one of the promising methods to extend the shelf life of fruit and vegetables due to its properties, which prevent moisture and aroma loss, and inhibit oxygen penetration into plant tissues or microbial growth [13,14].

Edible coating could be a better alternative to extend the shelf life of mango. A preliminary study on the development of biodegradable packaging based on cassava starch revealed that the formulation of starch (4%) combined with 5% coconut fibre (*Cocos nucifera* L.) and 20% *Garcinia kola* oil had the required properties to be used for the preservation of fresh and perishable products. Thus, the objective of this work is to study the ability of this formulation to preserve the quality and extend the shelf life of the "Kent" mango variety exported extensively by Côte d'Ivoire.

2. Materials and Methods

2.1. Plant Material

Healthy mangoes (*Mangifera indica* L. cv. Kent) of class 1 and uniform size 9 were harvested from a commercial mango orchard located in Korhogo, Northern Côte d'Ivoire and delivered to Abidjan. The fruit were harvested at commercial maturity with intact pedicels of 1 cm in length. The fruit were then packed in cartons and sent to the Laboratoire de Biochimie Alimentaire et Technologie des Produits Tropicaux (LBATPT) of NANGUI ABROGOUA University. They were kept at 13 °C for 24 h to avoid the ripening of some mangoes.

2.2. Methods

2.2.1. Preparation of the Starch gel

2.2.1.1. Extraction and Obtaining of Native Starch

The cassava roots were peeled, washed, and cut into pods of about 10 cm length. The cylinders were then ground using an electric grinder. The resulting grind was weighed and mixed in equal proportions with water, macerated with a spatula. The mixture was filtered through a series of sieves with mesh sizes of 500, 250, 100 µm respectively. The resulting starch milk was alternately decanted and washed (at least 4 times). The product obtained was spread out on trays covered with aluminium foil and then dried in an oven at 45 °C for 48 h. The dry product was ground with a blender (Silver Crest, SC-9520)

and weighed. The starch was stored at room temperature with a relative humidity of 85 ± 2 %.

2.2.1.2. Oil Extraction from *Garcinia kola* Nut by Solvent Maceration

The oil contained in *Garcinia kola* seeds was extracted by maceration in hexane at room temperature according to the method described by Ungo-kore et al. [15]. In this process, *Garcinia kola* seeds were dried at 50 °C for 48 h in an oven (Biobase model BOV-T105F) and then coarsely ground using a blender (Silver crest blender). Approximately 1500 g of pulverised seeds were placed in a sealed container with 1000 mL of n hexane and allowed to stand at room temperature for a period of 3 d with intermittent agitation. The mixture was then filtered, and the oil was recovered from the mixture (oil and solvent) using a rotary evaporator at 40 °C. The oil was collected in a shaded glass vial and placed in a refrigerator (4 °C) to await analysis.

2.2.1.3. Extraction of Cellulosic Microfibres from Coir Fibres

The cellulosic coconut fibres were physico-chemically pre-treated. The cellulosic fibre samples were washed with distilled water to remove impurities. They were then dried in an oven (Biobase model BOV-T105F) for 72 h at 60 °C. This was followed by grinding with a blender (Silver crest blender) and then sieving with a 250 µm mesh screen. This was further followed by grinding with a laboratory mortar to crush the fibres without destroying the fibrils (Rokbi et al., 2011) [16]. The resulting fibres were then sieved with a 100 µm mesh sieve to de-agglomerate them and specially to obtain fine microfibres of very small sizes.

2.2.1.4. Preparation of the Coating Gel

The gel was prepared for coating the mangoes according to the method established by Adjouman [17]. The coating gel contained cassava starch of Olekanga variety, glycerol, *Garcinia kola* oil, soybean lecithin and *Cocos nucifera* L. (coconut) microfibres. The preparation of the gel was done in 3 steps. For the first step, *Cocos nucifera* L microfibres (5 %) by mass of starch were mixed with two thirds (2/3) of distilled water of the final mixture for 24 h under constant mechanical stirring at 300 rpm using a mechanical agitator (BIOBASE, Model: SK-0330-Pro, Chine). To this solution were added 4 g of powdered cassava starch of the Olékanga variety, glycerol (plasticizing agents) at 30 % (on a dry basis of the starch w/w). The resulting mixture was heated for 20 min from 30 to 75 °C with a heated magnetic stirrer (BIOBASE, Model: MS7-H550-S, Chine). The second step was to mix 20 % of the *Garcinia kola* oil (based on the weight of starch) and soy lecithin (5 % based on the weight of the oil) with one third of distilled water of the total mixture. The resulting mixture was also heated for 20 min from 30 to 75 °C with constant stirring at 750 rpm with a heated magnetic stirrer (BIOBASE, Model: MS7-H550-S, Chine). The solution of *Garcinia kola*, soy lecithin and distilled water was homogenised at 26,000 rpm for 1 min using the Ultra Turrax. In the third step, the homogenised solution was mixed with that of starch, microfibres and glycerol and then heated from 75 to 95 °C for 25 min at 750 rpm

with a heated magnetic stirrer (BIOBASE, Model: MS7-H550-S, China). The resulting gel was allowed to cool to 70 °C before use for coating.

2.2.1.5. Mango Coating Process

The selected mangoes were washed thoroughly with 50 L of tap water containing diluted bleach, followed by a tap water rinse. The mangoes were then air-dried before coating. Mangoes with a thread on the stem were immersed in the gel for 30 s. They were drained, dried with the aid of a dryer air stream, then immersed a second time in the gel for 30 s, drained before being dried again followed by the tests. The treated mangoes were split into 2 batches, one batch stored in a refrigerator at 13 °C relative humidity and the other batch at room temperature of 25 ± 2 °C and 83 ± 2 % relative humidity.

2.2.2. Physico-Chemical Properties of Mangoes

2.2.2.1. Determination of Mango Loss Rates

Seventeen mangoes per group were visually inspected for infection and deterioration to assess the effects of coating on post-harvest losses during the 30 d storage period at room temperature and cold storage at 13 °C. Post-harvest losses were defined as the ratio of the sum of infected fruits to the initial number of fruit [18]. Post-harvest loss rates were expressed as a percentage (%).

2.2.2.2. Determination of Weight Loss

Weight loss was determined according to the method described by Athmaselvi et al. [19]. Four (4) mangoes from each batch of treated and untreated mangoes stored at 13 °C and room temperature were weighed and the masses of coated and uncoated mangoes (Control) were recorded after coating (T0) at 5 d intervals for 4 weeks (D0, D5, D10, D15, D20, D25 and D30). Cumulative mass losses were calculated by the following formula:

$$M(\%) = (M_i - M_f / M_i) \times 100 \quad (1)$$

With:

M: Loss of mass;

M_i: Initial mass;

M_f: Final mass.

2.2.2.3. Determination of the water content of the mango pulp

The water content of the samples was determined according to the AFNOR method [20]. Five (5) g of the sample (P_e) were weighed into a quick crucible (P₀) and then placed in an oven at 105 °C for 24 h. The crucibles were then removed from the oven, cooled in a desiccator for 30 min, weighed and the final weight (P_f) was recorded. The moisture content was given by the following formula:

$$H(\%) = Pe - (Pf - P0) / Pe \times 100 \quad (2)$$

With:

H: Humidity (%);

P₀: Empty weight of crucibles;

Pe: Test weight;

P_f: Final weight.

2.2.2.4. Determination of Mango Firmness

Firmness (skin and flesh) was measured using a digital penetrometer (FC GAUGE PCE - FM 200, Milan, Italy) according to the manufacturer's instructions. For skin firmness, the tip (8 mm diameter) of the penetrometer equipped with an electronic force indicator was placed on the middle part of one cheek of each fruit. The force required to pierce the skin of the fruit was measured and expressed in Newton (N). The firmness of the pulp was measured at the middle of the inner side of the opposite cheek of the fruit after a longitudinal cut.

2.2.2.5. Determination of Soluble Solids Content (SSC) and Titratable Acidity

Mango pulp juice was extracted separately using a juice extractor (Kuvings D9900, Marseille, France). Soluble solids content (SSC) and titratable acidity were measured using a Brix-acid dual scale digital refractometer (PAL-BX-ACID91, ATAGO, Japan) at 25°C according to the manufacturer's instructions.

2.2.2.6. Determination of pH

The pH was determined using the potentiometric method. It was determined directly in the solution used to determine titratable acidity, using a pH meter (Consort multi-parameter analyser C3020, from Belgium).

2.2.2.7. Determination of Ascorbic Acid Content

The vitamin C content of mango pulp was determined by titration according to the method described by Pongracz et al. [21]. Ten (10) g of crushed pulp juice was soaked for 10 min in 40 mL of metaphosphoric acid-acetic acid solution (2 %, w v-1). The mixture was centrifuged at 1006,2 g for 20 min and the resulting supernatant was diluted and adjusted with 50 mL of distilled water. Ten (10) mL of this mixture was titrated to the end point with 0.5 g L⁻¹ dichlorophenol-indophenol (DCPIP).

$$\text{Ascorbic acid (mg g}^{-1}\text{)} = (C_{\text{DCPIP}} \times V_{\text{eq}}) \times 5 \times 10^2 / m_e \quad (3)$$

With:

V_{eq}: Volume (mL) of 2.6 DCPIP poured to equivalence.

C_{DCPIP}: DCPIP concentration (g/L): 0.5

Me: mass (g) of the fresh tomato sample.

2.2.3. Analysis of Sensory Characteristics

2.2.3.1. Sensory Evaluation test

During this study, the descriptive tests made it possible to monitor the evolution of the various organoleptic parameters of coated mangoes kept at room temperature and at low temperature, as well as the controls (uncoated). The panellists (15 members, including 7 boys and 6 girls) were trained before the sensory analysis according to Lateur et al. [22]. Panellists who regularly consume mango participated in the evaluation. The descriptors were: skin wilting, flesh colour, chewing resistance, acid taste and sweetness. The evaluation consisted of asking panellists to rate the intensity of these descriptors on a structured scale from 1 to 5. The intensity of these descriptors on a structured scale ranging from (1): no perception to (5): extremely intense. Disposable plates were used to serve the samples coded with two numbers

and the panellists were then asked to indicate the perceived intensity of the attributes by placing a cross on the appropriate point of the scale. Spring water was used to rinse the mouth and paper towels to clean the mouth between assessments. These attributes assessed on attributes were considered adequate to describe changes in mango quality during storage. The evaluation was conducted in a day light, well ventilated room in the laboratory.

2.2.4. Statistical Analyses

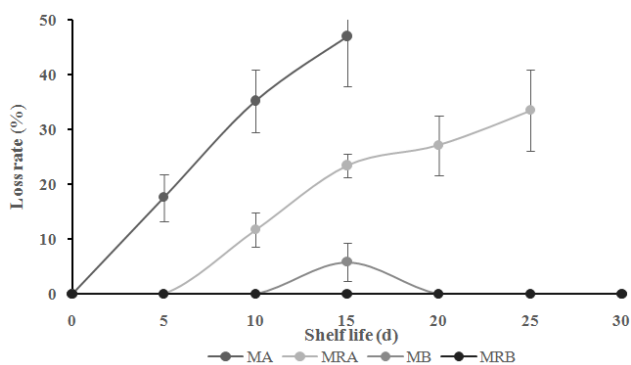
The physico-chemical analyses were carried out in trials of 3. The values are means \pm standard deviations. The results of the analyses were subjected to an analysis of variance (ANOVA) at a significance level of 0.05 with the STATISTICA 7.1 software. In case of significant differences in the samples, Tukey's Test was used to determine which samples differed from each other.

3. Results

3.1. Evaluation of some Physical Parameters of Mangoes

3.1.1. Evaluation of Mango Losses

The losses of uncoated and coated mango during storage at room temperature (25 ± 2 °C) and low temperature (13 °C) are presented in Figure 1. Losses were significantly ($p < 0.05$) higher for uncoated mango than for coated mango, regardless of storage temperature. At room temperature, losses of uncoated mangoes were recorded from the 5th to the 15th d of storage with a maximum of 47 % losses obtained at the 15th d. Unlike coated mangoes whose losses were recorded from the 10th to the 25th d with a maximum of 37 %. At low temperatures (13 °C), losses of uncoated mangoes were recorded on the 15th d with 5 % losses, unlike coated mangoes, for which no losses were recorded over 30 d.



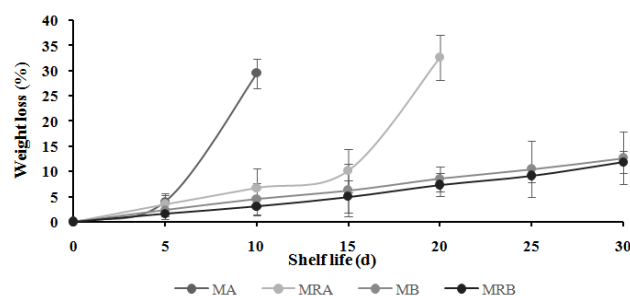
MA: uncoated mango stored at room temperature (25 ± 2 °C); MRA: coated mango stored at room temperature (25 ± 2 °C); MB: uncoated mango stored at low temperature (13 °C); MRB: coated mango stored at low temperature (13 °C).

Figure 1. Evolution of mango losses during storage

3.1.2. Weight Loss

Figure 2 shows the weight loss of coated and uncoated mangoes stored at room temperature and 13 °C for 30 d. The weight loss of the fruit increased with storage time,

regardless of the treatment. However, at 13 °C, no significant difference ($P \geq 0.05$) was recorded during the 30 d storage period. At room temperature, after five days of storage, weight loss was significantly ($p < 0.05$) higher for controls compared to coated mangoes.



MA: uncoated mango stored at room temperature (25 ± 2 °C); MRA: coated mango stored at room temperature (25 ± 2 °C); MB: uncoated mango stored at low temperature (13 °C); MRB: coated mango stored at low temperature (13 °C).

Figure 2. Evolution of weight loss of mangoes during storage

3.1.3. Firmness

Figures 3 and 4 show the firmness of the mango skin and pulp. It decreased significantly ($p < 0.05$) compared to the value of the control after 5 d of storage. However, it is better preserved by the application of coatings. The difference observed between coated and uncoated mangoes is significant in the case of skin firmness. The uncoated fruit have a lower firmness than the coated fruit.

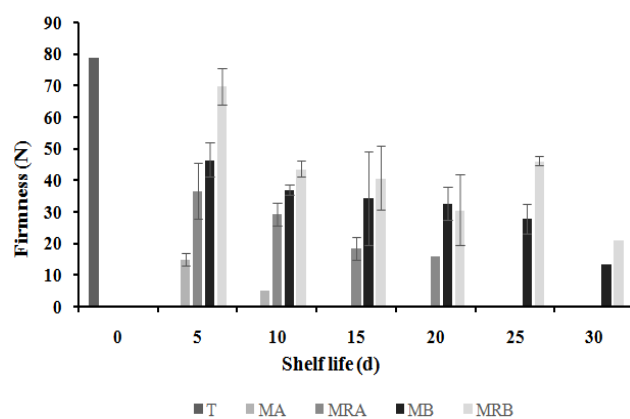
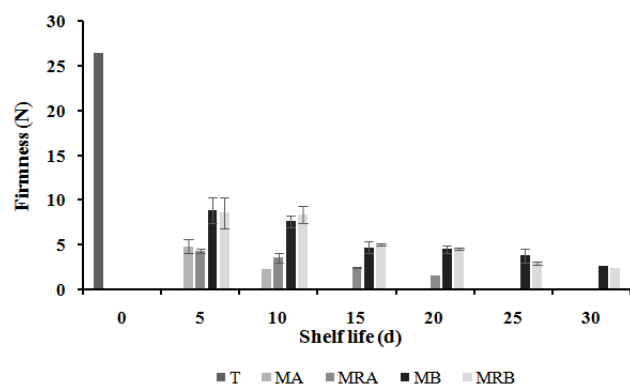


Figure 3. Evolution of mango skin firmness



MA: uncoated mango stored at room temperature (25 ± 2 °C); MRA: coated mango stored at room temperature (25 ± 2 °C); MB: uncoated mango stored at low temperature (13 °C); MRB: coated mango stored at low temperature (13 °C).

Figure 4. Evolution of mango flesh firmness

3.2. Evolution of Some Physical and Chemical Parameters

Some physical and chemical parameters of coated and uncoated mangoes stored at $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$ room temperature and at 13°C for 30 d are presented in Tables 1 and 2.

3.2.1. Water Content

The results showed significant differences ($p < 0.05$) in the moisture content during storage of control and coated mangoes stored at room temperature. The moisture content of the control (uncoated) mangoes increased on the 10th d of storage to $84.17 \pm 0.5\%$. The moisture content of coated mangoes stored at room temperature increased (80.59 ± 0.18 to $88.33 \pm 0.61\%$) from day five to day fifteen and then decreased to $86.51 \pm 0.80\%$ by day twenty of storage. For mangoes stored at low temperature, no significant difference ($P \geq 0.05$) in the percentage of moisture was recorded for control (uncoated) mangoes, but for coated mangoes, the percentage of moisture increased to $88.90 \pm 0.42\%$ on 25 d and then decreased to $82.2 \pm 0.28\%$ on 30 d of storage.

3.2.2. Soluble Solids Content

The soluble solids content of coated mangoes stored at room temperature did not differ significantly ($P \geq 0.05$). However, that of the control mangoes increased significantly ($P < 0.05$) after 5 d of storage to $18.95 \pm 0.35\%$ and then decreased to $16.15 \pm 0.21\%$ on 10 d. The soluble solids content of the control and coated mangoes stored at low temperature increased significantly over the 30 d of storage. Indeed, the soluble solids content of the control mangoes increased (13.83 ± 0.25 to $19.7 \pm 0.97\%$) and that of the coated mangoes also increased from 13.83 ± 0.25 to $20 \pm 0.56\%$.

3.2.3. Titratable Acidity

With regard to titratable acidity, there was no significant difference ($P \geq 0.05$) during the 10 d storage at room temperature of the control mangoes. However, there was a significant ($p < 0.05$) decrease (0.43 ± 0.01 to $0.38 \pm 0.02\%$) in titratable acidity from 15 d to 20 d of storage at room temperature for coated mangoes. In contrast to storage at room temperature, coated mangoes stored at 13°C , titratable acidity showed no significant difference ($P \geq 0.05$). Whereas that of control mangoes increased after 15 d to $0.55 \pm 0.09\%$ and decreased on 30 d of storage at 13°C to $0.31 \pm 0.04\%$.

3.2.4. Evolution of pH

During the 30 d storage period, the pH data differed significantly ($P < 0.05$) for both control and coated mangoes regardless of storage temperature. At $25 \pm 2^{\circ}\text{C}$, the pH of uncoated mangoes increased from 3.75 ± 0.3 to 4.67 ± 0.5 during the 10 d storage, while for coated mangoes the pH increase was at 10 d to 3.95 ± 0.1 and then a decrease in pH to 3.89 ± 0.01 was recorded until 20 d of storage. At 13°C , the pH increased from 3.75 ± 0.3 to 4.63 ± 0.01 during the 30 d storage period for uncoated mangoes. For the coated mangoes, the pH increased until 25 d to 4.25 ± 0.2 and then decreased to 4.13 ± 0.01 on 30 d of storage.

3.2.5. Ascorbic Acid

Regarding the ascorbic acid content of mangoes, the results showed a significant decrease ($P < 0.05$) for all types of treatments. At room temperature, the vitamin C content of the control and coated mangoes decreased from $235.62 \pm 8 \text{ mg g}^{-1}$ to $58.75 \pm 0.74 \text{ mg g}^{-1}$ and from $235.62 \pm 8 \text{ mg g}^{-1}$ to $111.25 \pm 2.66 \text{ mg g}^{-1}$ respectively. At low temperature, the ascorbic acid content of the control and coated mangoes decreased from $235.62 \pm 8 \text{ mg g}^{-1}$ to $87.5 \pm 3.76 \text{ mg g}^{-1}$ and $235.62 \pm 8 \text{ mg g}^{-1}$ to $142.5 \pm 4.24 \text{ mg g}^{-1}$ respectively.

Table 1. Evolution of physical and chemical parameters during storage at room temperature

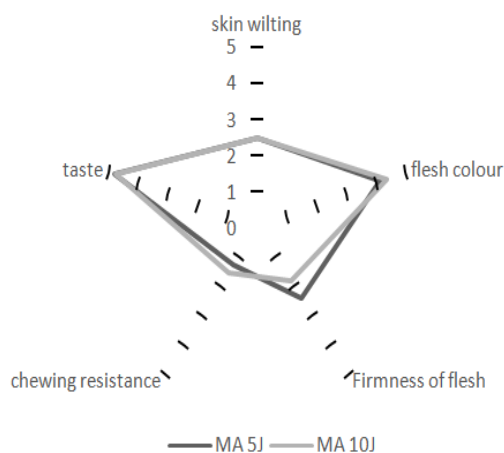
	Shelf life (d)	Parameters				
		Moisture content (%)	Brix value (%)	Titratable acidity (% acidity)	pH	Ascorbic acid (mg g^{-1})
MA	0	80.59 ± 0.18^a	13.83 ± 0.25^a	0.36 ± 0.04^a	3.75 ± 0.3^a	235.62 ± 8^a
	5	80.64 ± 0.38^a	18.95 ± 0.35^b	0.34 ± 0.01^a	4.46 ± 0.01^b	87.5 ± 2.74^b
	10	84.17 ± 0.5^b	16.15 ± 0.21^c	0.32 ± 0.05^a	4.67 ± 0.5^c	58.75 ± 0.74^c
	15	Nd	Nd	nd	Nd	Nd
	20	Nd	Nd	nd	Nd	Nd
	25	Nd	Nd	nd	Nd	Nd
	30	Nd	Nd	nd	Nd	Nd
	MRA	0	80.59 ± 0.18^a	13.83 ± 0.25^a	0.36 ± 0.04^a	3.75 ± 0.3^a
5		84.04 ± 0.17^{ab}	15.55 ± 0.63^a	0.34 ± 0.06^a	3.74 ± 0.1^a	188.75 ± 2.86^b
10		87.17 ± 0.16^b	15.05 ± 0.34^a	0.44 ± 0.07^a	3.95 ± 0.1^c	160 ± 3.53^c
15		88.33 ± 0.61^b	14.9 ± 0.97^a	0.43 ± 0.01^a	3.74 ± 0.02^a	135 ± 2.82^d
20		86.51 ± 0.80^{ab}	15.75 ± 0.62^a	0.38 ± 0.02^{ab}	3.89 ± 0.01^b	111.25 ± 2.66^e
25		Nd	Nd	nd	Nd	Nd
30		Nd	Nd	nd	Nd	Nd

The values in the table are the means of three trials, with standard deviations. Means with the same letter in the same column are not significantly different at the 5% probability level according to the Tukey test. MA: mango not coated at room temperature; MRA: mango coated at room temperature.

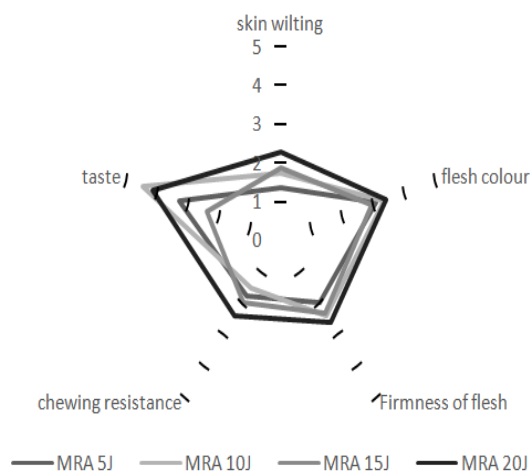
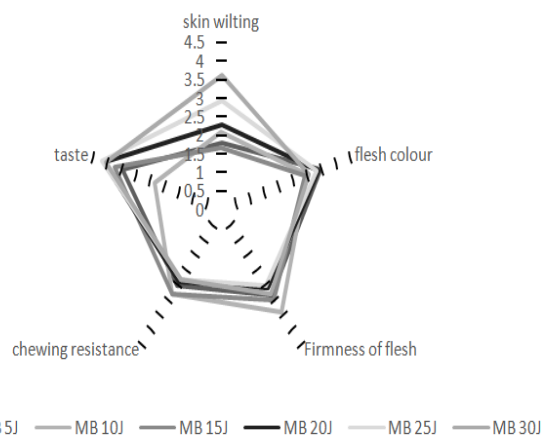
Table 2. Evolution of physical and chemical parameters during storage at refrigerator (13 °C)

	Shelf life (d)	Parameters				
		Moisture content (%)	Brix value (%)	Titratable acidity (% acidity)	pH	Ascorbic acid (mg g ⁻¹)
MB	0	80,59 ± 0,18 ^a	13,83 ± 0,25 ^a	0,36 ± 0,04 ^a	3,75 ± 0,3 ^a	235,62 ± 8 ^a
	5	82,07 ± 0,18 ^a	18,25 ± 0,6 ^{ab}	0,39 ± 0,04 ^a	3,95 ± 0,03 ^b	167,5 ± 1,41 ^b
	10	82,12 ± 0,75 ^a	18,3 ± 0,56 ^{ab}	0,39 ± 0,02 ^a	4,17 ± 0,01 ^{bc}	152,5 ± 2,82 ^{bc}
	15	82,64 ± 0,09 ^a	18 ± 0,69 ^{ab}	0,55 ± 0,09 ^b	4,36 ± 0,01 ^{cd}	145 ± 4 ^c
	20	82,35 ± 0,34 ^a	18,85 ± 0,34 ^b	0,40 ± 0,04 ^a	4,44 ± 0,2 ^d	126,25 ± 5,65 ^d
	25	85,86 ± 0,81 ^a	19,3 ± 0,42 ^b	0,33 ± 0,01 ^c	4,5 ± 0,14 ^d	103,75 ± 1,41 ^e
MRB	0	84,93 ± 0,38 ^a	19,7 ± 0,97 ^b	0,29 ± 0,01 ^c	4,63 ± 0,01 ^e	87,5 ± 3,76 ^f
	5	80,59 ± 0,18 ^a	13,83 ± 0,25 ^a	0,36 ± 0,04 ^a	3,75 ± 0,3 ^a	235,62 ± 8 ^a
	10	82,48 ± 0,83 ^a	17 ± 0,13 ^{ab}	0,39 ± 0,03 ^a	3,91 ± 0,01 ^b	228,75 ± 2,12 ^{ab}
	15	80,03 ± 0,5 ^a	18,15 ± 0,47 ^b	0,45 ± 0,03 ^a	4 ± 0,01 ^b	206,25 ± 4,24 ^{bc}
	20	83,07 ± 0,6 ^a	16,25 ± 0,49 ^{ab}	0,51 ± 0,02 ^a	3,91 ± 0,01 ^b	188,75 ± 3,16 ^c
	25	83,94 ± 0,02 ^a	17,15 ± 0,63 ^{ab}	0,32 ± 0,07 ^a	4,02 ± 0,02 ^c	163,75 ± 1,55 ^d
	30	88,90 ± 0,42 ^b	20,2 ± 0,56 ^b	0,49 ± 0,02 ^a	4,25 ± 0,2 ^e	150 ± 7,77 ^d
	30	82,2 ± 0,28 ^a	20 ± 0,56 ^b	0,42 ± 0,03 ^a	4,13 ± 0,01 ^d	142,5 ± 4,24 ^d

The values in the table are the means of three trials, with standard deviations. Means with the same letter in the same column are not significantly different at the 5% probability level according to the Tukey test. MB: mango not coated stored under refrigeration; MRB: coated mango stored in the refrigerator; nd: parameter not determined.



MA 5J: uncoated mango stored for 5 d at room temperature; MA 10J: uncoated mango stored for 10 d at room temperature.

Figure 5. Sensory profile of uncoated mangoes stored at 25°C**Figure 6.** Sensory profile of coated mangoes stored at 25°C

MB 5J: uncoated mango kept for 5 d at 13°C; MB 10J: uncoated mango kept for 10 d at 13°C; MB 15J: uncoated mango kept for 15 d at 13°C; MB 20J: uncoated mango kept for 20 d at 13°C; MB 25J: uncoated mango kept for 25 d at 13°C; MB 30J: uncoated mango kept for 30 d at 13°C

Figure 7. Sensory profile of uncoated mangoes stored at 13°C

3.3. Characterisation of Organoleptic Parameters of Mangoes

3.3.1. Uncoated Mango at Room Temperature (MA)

The evolution of the organoleptic parameters of uncoated mangoes kept at room temperature over 10 d is shown in Figure 5. The scores obtained after sensory analysis showed no significant difference ($P \geq 0.05$) in the parameters studied. The mangoes were moderately wilted, the flesh was orange-yellow in colour, moderately firm, not resistant to chewing and sweet in taste.

3.3.2. Mangoes Coated at Room Temperature (MRA)

The evolution of sensory characteristics of coated mangoes stored at room temperature for 20 d is shown in Figure 6. Skin wilt, flesh colour, chewing resistance and

MRA 5J: coated mango kept for 5 d at room temperature; MRA 10J: coated mango kept for 10 d at room temperature; MRA 15J: coated mango kept for 15 d at room temperature; MRA 20J: coated mango kept for 20 d at room temperature.

taste of the mangoes showed significant differences during the storage period. The wilting changed from day five to day twenty of storage. Flesh colour and chewing

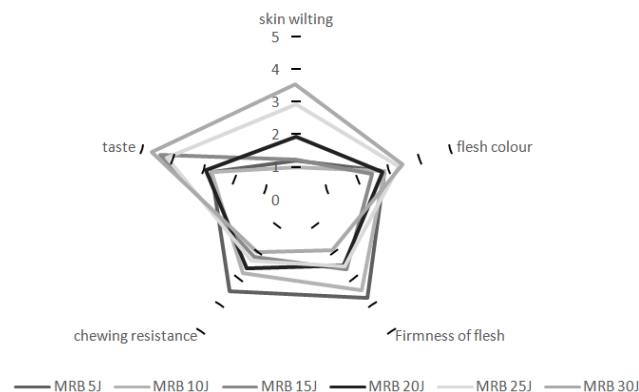
resistance were yellow-orange and not chewing resistant respectively on 20 d. Finally, the results showed that the mangoes were low in sugar between days five and fifteen of storage and neither acidic nor sweet after 20 d.

3.3.3. Uncoated Mango at Low Temperature (MB)

Figure 7 shows the evolution of organoleptic parameters of uncoated mangoes kept at low temperature for 30 d. The results showed only a significant difference in mango skin wilting. At 30 d, the data for skin wilting was between the wilted and very wilted descriptors.

3.3.4. Low Temperature Coated Mango (MRB)

The evolution of the sensory characteristics of coated mangoes preserved for 30 d at low temperature (13 °C) is shown in Figure 8. The statistical treatment of these characteristics allowed us to deduce a significant difference in the different sensory parameters evaluated during storage. The wilting of the mango skin evolved from medium to very wilted from 20 d to 30 d. The colour was between yellow and dark yellow from 25 d to 30 d. As for firmness, the data characterising it showed that firmness was between the descriptors medium firm and firm from 15 d to 30 d. Regarding resistance to chewing, it evolved from the 10th to the 30th d, with resistance to chewing being judged by the descriptors moderately resistant and resistant. The mangoes were slightly sweet and sweet from 15 d to 30 d.



MRB 5J: uncoated mango kept for 5 d at 13°C; MRB 10J: uncoated mango kept for 10 d at 13°C; MRB 15J: uncoated mango kept for 15 d at 13°C; MRB 20J: uncoated mango kept for 20 d at 13°C; MRB 25J: uncoated mango kept for 25 d at 13°C; MRB 30J: uncoated mango kept for 30 d at 13°C.

Figure 8. Sensory profile of uncoated mangoes stored at 13°C

4. Discussion

The storage losses of control mangoes were higher than those of coated mangoes. The reduction in storage losses of mangoes by the starch, coconut microfibre and *Garcinia kola* oil coating could be attributed to the ability of the coating gel to delay ripening and spoilage. This is because the coating delays ripening by protecting the integrity of the membrane (the fruit's natural barrier).

Ranjith et al. [23] in a study on the control of post-harvest fungal spoilage of mango (*Mangifera indica* L.) fruit reported that the edible coating produced by incorporating bioactive peptides into chitosan inhibited the growth of fungi that commonly infest mangoes.

The starch-based coating significantly reduced weight loss and limited water loss in mangoes at room temperature and at low temperatures. These results show a protective action of the coating system against water loss from the fruit [24,25]. Indeed, according to Chiumarelli et al. [26], the slowing down of water loss from cassava starch-coated fruits can be attributed to the additional barrier against diffusion through the stomata.

The loss of fruit firmness can be attributed to many reasons, including the degradation of cell wall pectin [27]. Post-harvest treatment of mangoes with a cassava starch formulation reduced the loss of fruit firmness compared to the control in the skin and pulp. The reduction in firmness loss by application of the coating could be explained by its ability to reduce water loss and reduce respiration [28]. According to Sapper et al. [29], starch-based coating reduces the loss of firmness in fruits and vegetables such as tomato and apple.

The soluble solids content (SSC) of mangoes increased regardless of processing and storage temperatures. This increase during storage may be due to hydrolysis of polysaccharides to soluble solids in the form of simple sugars such as glucose, fructose, and sucrose. This leads to significant changes in flavour (increased sweetness) [30,31].

In this study, a decrease in titratable acidity and an increase in pH of mangoes were observed. The decrease in titratable acidity of uncoated and coated fruit at some day of storage and the increase in pH are probably related to the use of acids as a carbon substrate in the respiratory process, as well as its conversion to sugars via gluconeogenesis [32,33]. On the other hand, an increase in acidity was observed on some days of storage at room temperature and refrigeration (13 °C). Silva et al. [31] showed similar results and reported that the increase in fruit acidity can be attributed to galacturonic acid, which is derived from the breakdown of pectin.

In addition, the progressive decrease in ascorbic acid (vitamin C) content can be attributed to the oxidation process. A similar behaviour was found for 'Pedro Sato' guavas that were coated with a formulation of hydroxypropyl methylcellulose and beeswax [34]. The difference in the reduction in ascorbic acid content observed between treatments could be due to the slowing down of the physiological process of fruit ripening by the coating [35].

For the sensory test, the results showed an increase in wilting of coated mangoes stored at 25 ± 2 and also of control and uncoated mangoes stored at 13 °C. The increase in mango skin wilting is related to the significant loss of fruit weight during storage. This result is like those of Vilvert et al. [36] who reported that high weight loss is associated with poor fruit appearance, which tends to wilt. Also, in coated mangoes stored at 13°C, firmness and chewing resistance decreased, but taste and colour increased during storage. The decrease in firmness and chewing resistance is related to the irreversible process that occurs due to cell wall carbohydrate metabolism, enzymatic activity, starch hydrolysis [36,37]. The increase

in flavour is closely related to the soluble solids content of mangoes, which increased progressively with all treatments during storage, due to the ripening of the fruit because of the degradation of starch to glucose with the inhibition of amylase and maltase activities [36]. The evolution of mango pulp colour would be due to the biosynthesis and accumulation of certain carotenoids that are regulated by the expression of genes of the carotenoid structural pathway during fruit ripening. These results agree with those of Ma et al. [38] who worked on carotenoid accumulation and carotenoid biosynthesis in mango flesh.

5. Conclusion

At the end of this study, it should be said that the coating treatment based on cassava starch, *Garcinia kola* oil and *Cocos nucifera* L. microfibre is an effective treatment for extending the shelf life of mangoes. Indeed, it slows down the loss of mangoes during storage, reduces the loss of weight and firmness of the fruit. In sum, the coating based on cassava starch, *Garcinia kola* oil and *Cocos nucifera* L. microfibre can therefore be proposed as an alternative and effective method to better preserve mangoes of the Kent variety. The deterioration of mangoes is linked to the attack of micro-organisms. It would be interesting to see the action of the coating gel in this study on mango spoilage micro-organisms.

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