EFFECT OF SHEA BUTTER AND PALM OIL WAXING ON THE KEEPING AND SENSORY QUALITIES OF FOUR PLANTAIN (*MUSA* AAB) VARIETIES

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Abstract
The effect of shea butter and palm oil waxing on the pre-climacteric life and sensory qualities of four plantain varieties (*Apem*, *Apentu*, *Asamienu* and *Oniaba*) was studied. Waxing was achieved by brushing shea butter and palm oil on fruits surfaces. Parameters assessed were the uniformity of ripening, gloss quality and incidence of off-flavours and disorders. The fruit diameter before waxing (d_1) and after waxing (d_2) was measured and the difference (d_2-d_1) taken as the waxing thickness. Shea butter and palm oil waxing thickness of 0.5 and 1mm resulted in irregular ripening, green-soft disorder and off-flavours. However, thin layer waxing (<0.05mm) using shea butter prolonged the pre-climacteric life to 22, 20, 17, and 15 days in *Apem*, *Apentu*, *Oniaba* and *Asamienu* respectively. Shea butter waxing resulted in significant decrease ($P<0.001$) in physiological weight loss of 9.46% by 22 days after storage compared to control which had 21.25% by 10 days of storage. The incidence of migration of palm oil from peel to pulp was noticeable. The use of shea butter and palm oil as edible waxes to extend shelf life can be further explored since no safety or residual effect are foreseeable.

1. Introduction
Plantains (*Musa* spp. AAB and ABB) are an important cash and subsistence crop, and together with banana provide up to 25% of the energy requirement in the developing world (Robinson, 1996; Dadzie and Orchard, 1997; Ferris, 1997; Frison *et al*., 1999). The plantain fruits are consumed as main meals and snack at all stages of ripeness; green (unripe), yellow-green, ripe or over-ripe. However, plantains have a short pre-climacteric period of less than one week and a shelf life of about 11 days after harvest. Alternative storage is therefore necessary where there is a need to extend the shelf life beyond this period. Research on alternative methods of storage such as cold storage, hypobaric storage, irradiation, modified atmosphere and postharvest chemicals have been investigated (Olorunda and Aworh, 1984; Sholburg and Conway, 2005; Yahia, 2006; Kader, 1999). However, these methods are quite complex and beyond the technical and economic capacities of the small-scale handlers. In addition, there are widespread negative public perception and health lobby against the use of postharvest treatments; and such misconceptions among consumers and regulatory agencies have caused much confusion. But, there is little reason at the moment to believe that the use of approved postharvest treatments is hazardous to human health. Currently, the use of edible or non synthetic waxes to prolong postharvest shelf life where the potential exist is advocated. The objective of this study was therefore to evaluate the effect of shea butter and palm oil waxing on the pre-climacteric life and sensory qualities of four plantain varieties (*Apem*, *Apentu*, *Asamienu* and *Oniaba*).

Materials and Methods
2.1 Plantain samples
Uniformly ¾ mature green fruits of four plantain varieties were obtained from an arranged supplier in a local market in Accra for the study. The varieties were: two French plantains (*Apem*

and *Oniaba*), a False horn plantain (*Apentu*) and True Horn (*Asamienu*). *Apem*, *Apentu* and *Asamienu* are triploid land races, while *Oniaba* is an intermediate variety. These varieties are most populous in local markets in Ghana. The fruits were pre-cooled with a mist of water upon arrival at the storage room. Fingers were randomly selected for the treatments and incubated under ambient tropical conditions.

2.2 Procedure for waxing

Waxing was done by brushing the shea butter and palm oil on fruit surfaces to achieve a uniform smear of three thicknesses: 0.05mm, 0.5mm and 1mm. Wax thickness was determined using a Mitituyo micrometer screw gauge (0.01 – 150mm range). The fruit thickness (diameter) before waxing (d_1) and after waxing (d_2) was measured. The difference in diameter (d_2-d_1) was taken as the wax thickness.

2.3 Analysis of chemical properties

Data on chemical characteristics such as pulp pH, total soluble solids (TSS) and total titratable acidity (TTA) were determined at stages 1, 4 and 6 of ripening using standard laboratory procedures (AOAC, 1990).

2.4 Physiological weight loss

Weight loss in waxed fruits compared to fruits stored at room temperature was determined daily. The total weight loss (TWL) was expressed as percentage of the original weight lost during the storage period. Weight loss percentage per day (WL/D) was calculated by dividing total weight loss by the number days to reach stage 6 (Ahmed *et al.*, 2006).

2.5 Sensory analysis

A five-point Hedonic scale was used to score samples for taste, colour, flavour, texture, mouth feel and overall acceptability (Table 1). Plantain samples were roasted in an oven with the temperature set at medium to high. Coded samples per treatment were served to each member of 13 trained panelists for the sensory evaluation.

3.6 Estimation of storage Life

The storage life was expressed as the time between storage and when fruits become unacceptable for consumption. Daily observation for colour changes was made throughout the period of storage. Peel colour was measured using a colour chart. The criteria for determining the three stages are based on the pattern of colour change during ripening. This has been divided into ten stages; each stage has a characteristic peel colour, physico-chemical properties and forms of utilization (Baiyeri, 2001) (in Table 2).

Table 1: Description of quality attributes for sensory evaluation

Scale	Taste (sweetness)	Flavour (characteristic smell and aroma)	Mouth feel	Colour	Texture (hardness or softness)	Overall acceptability
5	Extremely sweet	Extremely strong	Excellent	Very yellow	Very hard	Excellent
4	Very sweet	Very strong	Very good	Yellow	Hard	Very good
3	Sweet	Strong	Good	Pale yellow	Slightly hard	Good
2	Slightly sweet	Slightly strong	Fair	Slightly yellow	Soft	Fair
1	No sweetness	Off-flavours	Dislike	Almost white	Very soft	Dislike

Table 2: Peel colour changes of plantain at various stages of ripening

*Physiological phases	Ripening stage (colour score)	Description of peel colour
1	1	Green
1	2	Pale green
2	3	Pale green with yellow tips
2	4	50% yellow 50% green
2	5	More yellow than green
2	6	All yellow
3	7	Yellow flecked with brown
3	8	50% black 50% yellow
3	9	More black than yellow
3	10	Pure black.

*Physiological phases: 1: pre-climacteric, 2: climacteric, 3: senescence

2.6 Data Analysis

The design was a 4 x 3 x 2 factorial experiment in a completely randomized design with six replications. Data were subjected to analysis of variance (ANOVA) using Genstat (Release 3:22), statistical package. Test of significance between means was by Fisher's Least Significance Difference (F-LSD) at 5% probability level.

Results

3.1 Effect on pre-climacteric life

The effect of shea butter waxing (SBW) on the pre-climacteric and storage life are shown in Figures 1 and 2 respectively. The pre-climacteric (green life) is the period in which the fruits remain green and firm. Thin layer shea butter waxing (<0.05mm) significantly ($P< 0.001$) prolonged the pre-climacteric life up to 22, 20, 17, and 15 days in *Apem*, *Apentu*, *Oniaba* and *Asamienu* respectively. The post-climacteric life of plantain is divided into the climacteric and senescence phases. Ripening commences when there is a trace of yellow colouration in the peel and completed when the entire peel attains full yellow. A prolonged post-climacteric life from 4 to 6 days across varieties in addition to firm texture at senescence was recorded. The shelf life expressed as the number of days between harvest and when fruits become unacceptable for consumption was extended from 11 to 26, 24, 21 and 19 days in *Apem*, *Apentu*, *Oniaba* and *Asamienu* respectively.

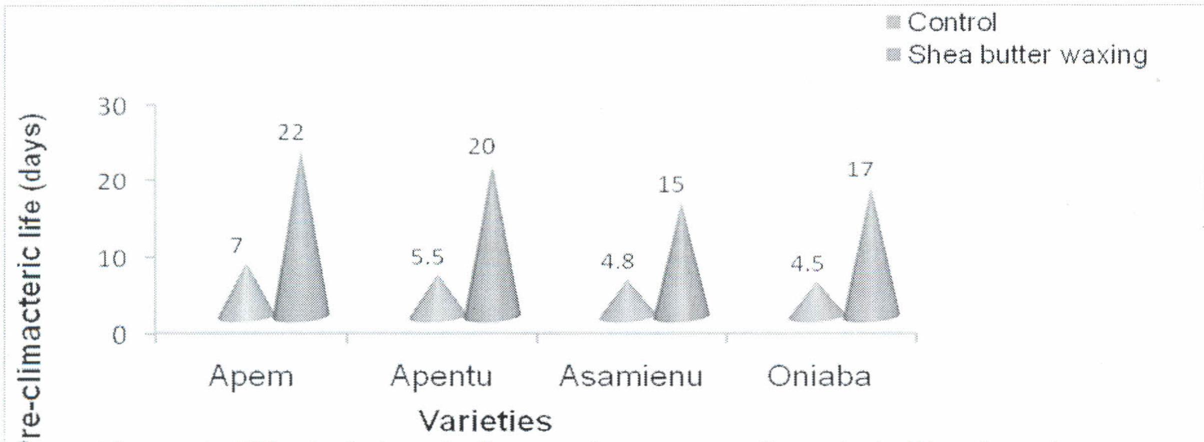

Figure 1: Effect of shea butter waxing on pre-climacteric life of four plantain varieties

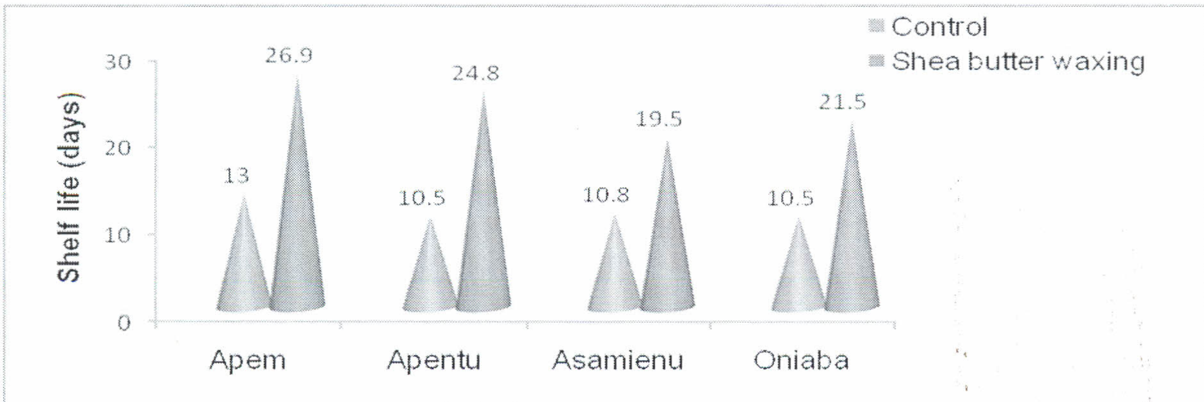

Figure 2: Effect of shea butter waxing on shelf life of four plantain varieties

3.2 Effect on physiological weight loss

Physiological weight loss was significantly ($P < 0.001$) less severe in both shea butter and palm oil waxed treatment compared to the control. Shea butter waxing reduced weight loss by 9.46% (by 22 days of storage) and a daily weight loss of 0.043% compared to control (21.25% by 10 days of storage) and a daily weight loss of 2.13% (Table 3).

Table 3: Effect of shea butter waxing on daily weight loss of four plantain varieties (%)

Days after storage	Control[b]					Shea-coated[a]				
	Varieties				Total	Varieties				Total
	Apem	*Apantu*	*Asamienu*	*Oniaba*		*Apem*	*Apantu*	*Asamienu*	*Oniaba*	
2	3.40	6.40	6.47	5.13	5.35	1.04	1.71	1.90	1.70	1.59
4	8.13	12.30	12.67	10.33	10.86	3.23	4.44	6.33	4.57	4.64
6	16.10	21.63	24.33	20.00	20.52	5.97	7.67	8.23	8.00	7.47
8	23.23	30.33	30.33	28..0	27.98	7.67	8.30	9.27	8.63	8.47
10	37.00	38.00	*	0	35.47	8.90	9.57	10.33	10.47	9.82
12	*	*	*	*	*	11.30	12.67	14.37	12.00	12.58
14	*	*	*	*	*	13.27	14.63	15.50	12.80	14.05
16	*	*	*	*	*	13.83	14.99	16.56	13.97	15.04
18	*	*	*	*	*	15.23	15.73	16.63	15.47	15.92
20	*	*	*	*	*	16.00	16.30	17.27	16.13	16.07
22	*	*	*	*	*	16.69	18.00	18.97	16.57	17.56
Variety	19.97	22.64	22.43	19.96	21.25	8.55	9.51	10.46	9.31	9.46

* Means fruits had ripened

%Weight loss of shea-waxed fruits is significantly($P<0.001$) lower than non-waxed fruits

3.3 Effect on sensory qualities

Analysis of variance showed that for all four varieties, both waxes received comparable scores ($P < 0.05$) for texture, flavour, mouth feel, taste and overall acceptability, except for colour. Palm oil waxed-fruits received marginally high scores for colour; an indication of possible migration from the peel to pulp. But, for any sensory attribute, significant difference between varieties existed. Fruit flavour, taste, mouth feel and colour were positively correlated. A range of scores for flavour (2.17 to 3.67), taste (2.50 to 4.50) and mouth feel (2.33 to 4.50) across treatments suggest that no off-flavours or astringent taste was noticeable according to panelists' evaluation.

3.4 Effect on chemical properties

Both waxes did not significantly ($P<0.05$) influence pulp pH, total titratable acidity (TTA) and total soluble solids (TSS), but significant difference ($P< 0.001$) between varieties existed at the three stages of ripening. There was a general decrease in pulp pH (increased acidity) as fruits ripen. Pulp pH of green *Apentu*, *Apem*, *Asamienu* and *Oniaba* were 6.12, 6.01, 5.98 and 5.90, and by full ripe the pH decreased to 4.52, 4.41, 4.42 and 4.48 respectively (Fig. 3). A dramatic rise in TSS and TTA with ripening was noticed. By full ripe, the TTA of *Apem*, *Apentu*, *Asamienu* and *Oniaba* were 9.72, 10.56, 8.8 and 9.91 g/l respectively (Fig.5). The TSS at the green stage did not vary among varieties and averaged at about 3% brix (Fig. 4). At full ripe, *Apentu* recorded the highest TSS values of up to 21% brix compared to 18.04, 15.84 and 14.92 %brix for *Oniaba*, *Apem* and *Asamienu* respectively.

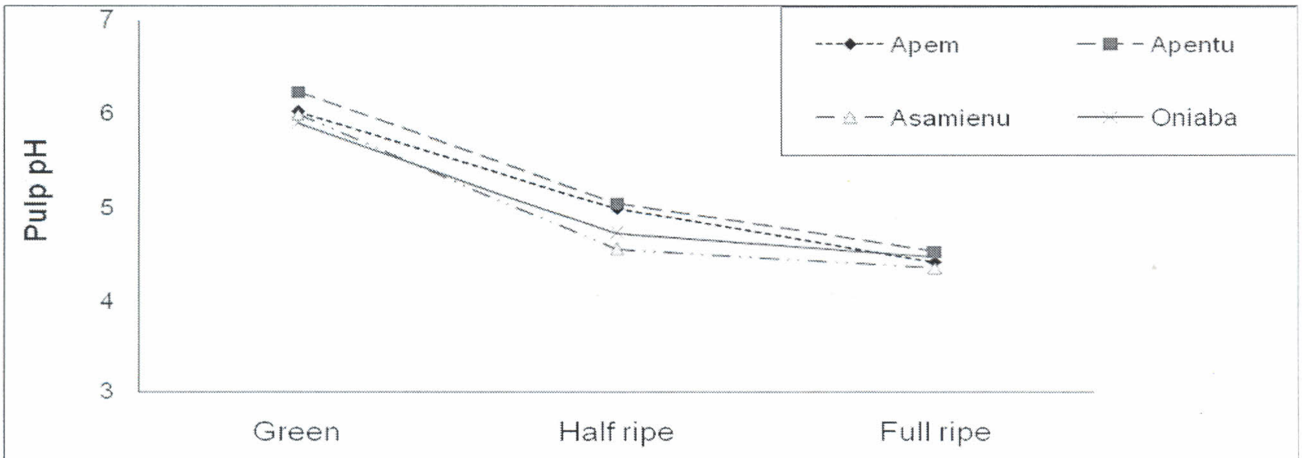

Figure 3: Changes in pulp pH at three stages of ripening

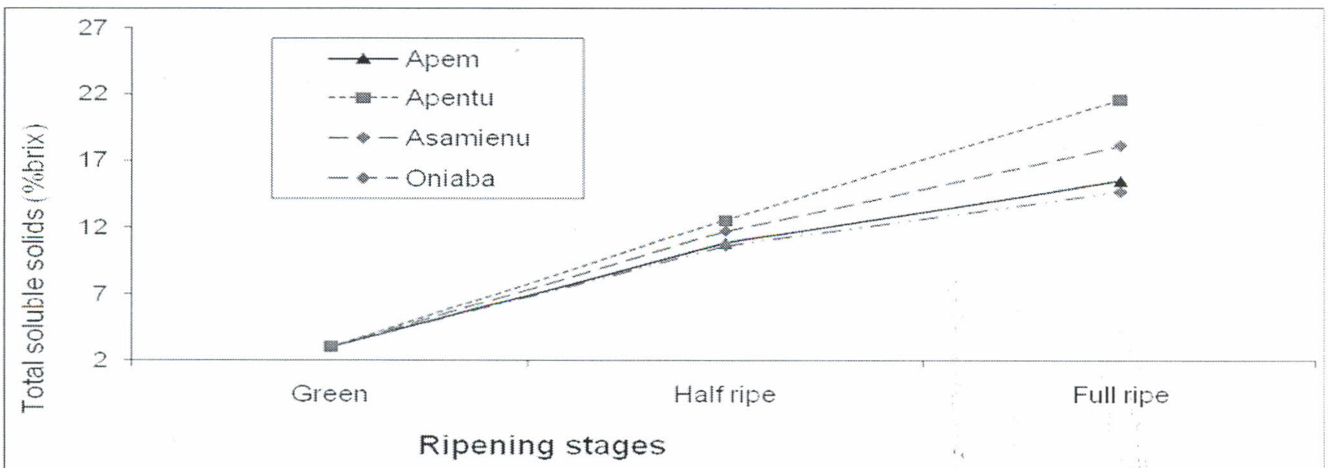

Figure 4: Changes in total soluble solids at three stages of repining

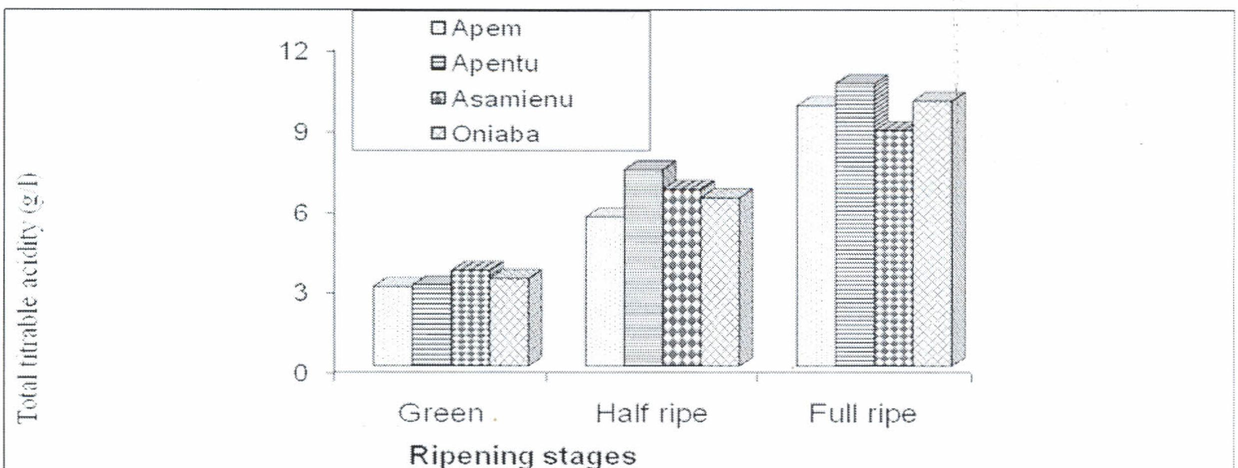

Figure 5: Changes in total titrable acidity at three stages of repening

Discussion

The postharvest life of plantains is typical of the perishable crops and highly climacteric. Even after harvesting, the fruits continue to live in the same way as in the mother plant (Wills *et al.*, 1981; Wills *et al.*, 1998; Ferris, 1997). Normal metabolism continues in order to maintain and repair the cells, as though the fruits were not cut off from their normal supplies of water, minerals, and other simple organic products for metabolism; which normally would be translocated to them from other parts of the plant. This explains why quality deterioration and senescence can be very rapid in most fruits and vegetables after harvest. Generally, the extent of prolonged shelf life depends on the pre-harvest growth conditions, type and maturity of variety and conditions of handling (Goldman *et al.*, 1999; Kader, 1999). The interplay of these factors determines rate of respiration and transpiration, the deteriorating agents of fruit quality in the postharvest period.

The extended pre-climacteric and shelf life (Figures 1 and 2) in this study show the immense potential of shea butter and palm oil as edible waxes for plantains and other high-value fruits. This prolonged pre-climacteric life is attributed to the extent to which ethylene biosynthesis was inhibited (Alexander and Grierson, 2002; de Wild *et al.*, 2003). Plantains are highly climacteric showing a sudden rise in respiration and a concomitant burst in ethylene production rates coincident with ripening. Once this process has commenced, ethylene production is autocatalytic with rapid production of ethylene and the fruits will ripe in few days (Baiyeri, 2001; Alexander and Grierson, 2002). Both shea butter and palm oil waxes provided a microfilm coating on the fruit surface which exerted little effect on water movement, but restricted gaseous exchange through the fruit skin, thus slowing down the rate of respiration (Wills *et al.*, 1998). The fruits showed reduced physiological weight loss, fresh appearance and firm texture at full ripe; indicative that the rate of physiological breakdown and hence senescence were significantly impeded. Both waxes are readily available in local markets in Ghana and the procedure of storage is less sophisticated for use by beneficiaries.

Generally, ethylene (C_2H_4) is implicated in the ripening of climacteric fruits. The gas is produced naturally by climacteric fruits during ripening and plays a key role in the subsequent ripening process (Feris, 1997; Alexander and Grierson, 2002). Substance that can remove or neutralize the activity of ethylene in storage would be valuable in lengthening the storage life of harvested fruits and vegetables. The gas is formed from methionine via *S*-adenosyl-L-methionine (AdoMet) and the cyclic non-protein amino acid 1-aminocyclopropane-1-carboxylic acid (ACC). ACC is formed from AdoMet by the action of ACC synthase (ACS) and the conversion of ACC to C_2H_4 is carried out by ACC oxidase (ACO) (Kende, 1993; Alexander and Grierson, 2002). CO_2 is an essential cofactor in ACC oxidaze (de Wild *et al.*, 2003). Therefore, elevated CO_2 atmosphere inhibits the activity of ACC synthase, while ACC oxidase activity is stimulated at low CO_2 and inhibited at high CO_2 concentrations and/or low O_2 levels. This implies that ethylene biosynthesis and action are also inhibited at elevated CO_2 and/ or low O_2 levels. This consequently inhibits respiration resulting in conditions that help to prolong the pre-climacteric phase (Ferris, 1997; Baiyeri, 2001). In this study, waxing thickness greater than 0.05mm resulted in irregular ripening, green soft disorder and occurrence of off-flavours. This can be attributed to anaerobic respiration as a result of restricted gaseous exchange between fruits and external environment (Wills *et al.*, 1981, Wills *et al.*, 1998; Yahia, 2006). It may also be difficult to achieve uniform fruit ripening, but this is not a critical limitation since traditional and chemical methods are available to induce uniform ripening.

The prolonged pre-climacteric life above two weeks across varieties was of critical significance as this connotes extended food supply, reduced postharvest losses and favourable price for both traders and consumers. In plantain marketing, the number of days fruits remain green is the most critical since several methods of utilization and processing options can be explored. At this stage, industrial and commercial processing into products such as flour and chips are feasible, but as fruits ripen only traditional dishes can be made (Baiyeri *et al.*, 1999). In Ghana, stages 4 to 5 fruits are mostly roasted by women as snack usually eaten warm with fried groundnut on the street, whiles stages 6 to 8 fruits are suitable for frying into *red-red* and *kelewele*, both are delicacies in Ghana. After stage 10, there is complete softening, microbial spoilage, sour taste and development of off-flavours. Subsequently fruits become unfit for human consumption. According to Shewfelt (1993), the mechanism of senescence is due to physical changes such as peel browning due the breakdown of photosynthetic apparatus, loss of pulp firmness due to breakdown of starch and other non-pectic polysaccharides to sugar and the solubilization of pectic substances in the cell wall and middle lamella resulting in reduced cohesion in the middle lamella.

Conclusion

The use of chemicals as preservatives and anti-microbial food additives operate within certain regulatory controls. Prior to using any chemical as postharvest treatment to improve shelf life, safety requirements must be satisfied. Such chemical must achieve standards as Generally Recognized As Safe (GRAS) food storage or processing aide. Precisely, such chemical must show to pose no hazard to consumers' health, operators and environment. Due to this requirement, most chemicals previously used as postharvest treatments are no longer permitted due to concerns on toxicity and residual effects. The study showed that as part of broad interventions to reduce postharvest losses, commercial exploration of shea butter and palm oil waxing can be considered to integrate them into the list of existing edible coatings, since they pose no safety or residue concern. Commercial exploration should consider among others dispersability; to provide a microfilm coating of less than 0.05mm on fruit surface. This will improve gaseous exchange and luster quality. In addition, consumer perception and acceptability issues should be considered.

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