Harvest and Postharvest Technologies for Fresh Fruits and Vegetables

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APPLICATION OF POSTHARVEST COATINGS TO FRESH CASSAVA ROOTS (*Manihot esculenta*, Crantz) FOR REDUCTION OF VASCULAR STREAKING

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ABSTRACT

Cassava root is consumed by more than 300 million people worldwide, but suffers postharvest losses up to 70% due to development of a physiological disorder, vascular streaking (VS), 48 to 96 hours from harvest. Although many methods have been tested for alleviation of VS, the only commercial application has been paraffin wax, which permits shipping under refrigeration for more than 20 days with minimal occurrence of VS. However, paraffin, a petroleum derivative, has been banned by several countries for direct contact with food.

Two studies were undertaken to determine the efficacy of several coatings as alternatives to paraffin wax. The first test compared paraffin wax (100%), carnauba wax (100%), two USDA microemulsions: M91A (an oxidized polyethylene/petroleum emulsion), M97B (a carnauba wax/petroleum wax emulsion), and xanthan gum (1%). Roots were obtained on the day of harvest near Rio de Janeiro, washed, dried, coated, stored at 5°C or 25°, RH 90%, and evaluated periodically for 30 days. For paraffin-treated roots stored at 25°, VS and decay were absent for 14 days longer than the untreated control, emulsion waxes and xanthan gum (total=16 days). Carnauba wax delayed these symptoms for 5 days longer than the other coatings (total=7 days). Storage at 5° maintained the roots free from VS for 7 days and from decay for 16 to 30 days, irrespective of coating.

The second test compared paraffin wax with two carnauba emulsions and a vegetable oil emulsion, and was set up similarly to Test 1, except all roots were stored at 25°. Water-soluble carnauba emulsion maintained root quality equivalent to paraffin wax, showing potential as a natural wax substitute for paraffin. There were no significant differences between treatments in either experiment regarding cooking time, pulp color or moisture content.

Keywords: Storage, waxing, tropical root crop, export

RESUMEN

La raiz de la yuca es consumida por mas de 300 millones de personas en el mundo entero. Durante el proceso de distribución, este producto sufre de pérdidas de hasta del 70%, las cuales son causadas principalmente por un desorden fisiológico - decoloración vascular (DV) - que ocurre entre las primeras 48 a 96 horas después de la cosecha. A pesar de que existen varios métodos para reducir DV en la yuca, el único proceso disponible comercialmente es la aplicación de la cera de parafina. Sin embargo recientamente, algunos paises europeos han prohibido el uso de productos derivados del petróleo, como la parafina, que tengan un contacto directo con los alimentos.

En la presente investigación, se muestran los resultados de dos estudios con yuca disenados para identificar coberturas alternativas a parafina. En los dos experimentos las raices fueron obtenidas cerca de la cuidad de Rio de Janeiro, Brasil. En el primer experimento las raices de yuca fueron lavadas, secadas y tratadas inmediatamente después de la cosecha con una de las seguientes ceras:

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parafina (100%), carnauba (100%), dos microemulsiones hechas por el USDA (M91A y M97B) y la goma xantana (1%). Las raíces fueron almacenadas durante 30 días a 5°C ó 25° y 90% de humedad relativa. Aquellas raíces almacenadas a 25° y tratadas con parafina se mantuvieron sin mostrar DV o pudrición por 14 días mas que aquellas sin tratamiento o aquellas aplicadas con las dos microemulsiones o la goma de xantana (16 días en total). La carnauba retrasó la aparición de síntomas por 5 días mas que las demás coberturas evaluadas. Las raíces almacenadas a 5° se mantuvieron libres de DV por 7 días y de pudrición entre 16 y 30 días sin importar el tratamiento.

En el segundo experimento la parafina fue comparada con dos emulsiones de carnauba e aceite vegetal, bajo las mismas condiciones del primer experimento, pero almacenando las raíces unicamente a 25°. Las emulsiones de carnauba (solubles en agua) mantuvieran la calidad de la yuca por 7 días en una forma similar al tratamiento con parafina. Esto señala el potencial de la carnauba como un substituto de cera natural para la parafina.

Palabras claves: Almacenamiento, cera, exportación

INTRODUCTION

Cassava is a staple food worldwide, being consumed by more than 300 million people. Brazil is the major producer with significant production in other tropical and subtropical regions in Indonesia, Thailand, Zaire and Nigeria (FAO, 1979). A root, cassava is consumed in many forms. Varieties which contain significant amounts of cyanogenic glucoside, (known as bitter types), are generally processed into flour to release the cyanide; those varieties with low amounts of this compound, (the sweet types) (Yamaguchi, 1983), are sold as a fresh market item and are boiled prior to consumption. This latter type is marketed as a fresh, whole root and suffers up to 70% postharvest losses due to development of a physiological disorder known as vascular streaking (VS). Postharvest life under nonrefrigerated handling conditions is limited to as little as 48 hr due to the rapid development of VS. Cassava processing quality is also negatively affected during handling. During this time starches convert to sugars, lowering culinary quality, and the roots became more fibrous, lengthening cooking time (Booth, et al., 1976). As root age increased over 12 months, root starch decreased and annual growth rings became apparent (O'Hair, 1989). For commercial operations high quality roots should be harvested in 10 to 12 months from planting and should require no longer than 20 minutes cooking time (Personal communication, H. Shuto, MAHA Industria e Comércio de Gêneros Alimentícios, Ltda., Campo Grande, MS, Brazil).

Vascular streaking appears as blue or purple spots when the root is cut transversely and is a result of an oxidative process in the vascular bundles. The development of VS typically occurs at wound sites, such as the apical end where the root is detached at harvest, or under breaks in the peel which can occur during careless handling. The biosynthesis of VS is related to the oxidation of scopoletin, a phenolic compound (Wheatley and Schwabe, 1985). Aracena (1993) speculated that the immediate cause of VS is ethylene, which is produced by the root as a direct response to wounding or water stress at injury sites.

Although many methods have been tested to reduce incidence of VS (Booth, 1976), the current commercial procedure for export is the application of paraffin wax, which, in conjunction with refrigeration, extends shipping time to more than 20 days with minimal occurrence of VS. However, paraffin, a petroleum-based wax, has been banned by several European countries for direct contact with food and may become a problem in the future for fresh cassava. This study was undertaken to identify coatings composed of compounds which are approved by the U.S. Food and Drug Administration with potential to substitute for paraffin wax on fresh cassava roots.

MATERIALS & METHODS

Test 1

Fresh cassava roots (cv. Saracura) were harvested on 27 October 1993, about 12 months after planting, in Santa Cruz, near the city of Rio de Janeiro, Brazil. The same day of harvest the roots were taken to the laboratory at EMBRAPA/CTAA where they were sorted for minimal mechanical injury and then washed, air-dried, trimmed to about 17 cm length, dip-coated, air-dried and stored at 5° or 25°C and about 92-95% relative humidity. The treatments (n=5 roots) were: paraffin wax (100%), carnauba wax (100%), two microemulsions: M91A and M97B (from Dr. R.D. Hagenmaier, U.S. Department of Agriculture Tropical and Subtropical Products Laboratory, Winter Haven, Florida), Xanthan gum (1% solution) and no coating. The compositions of the water emulsions from the USDA were:

M91A	M97B
Oxidized polyethylene (8.5%)	Carnauba wax (11.9%)
Petroleum wax (8.5%)	Petroleum wax (5.1%)
Oleic acid (3.0%)	Oleic acid (3.0%)
Morpholine (2.6%)	Morpholine (2.6%)

Paraffin and carnauba waxes were maintained at 150° during the dip treatment.

Quality evaluations were performed regularly during the subsequent 30-day storage period, namely, incidences of VS and decay (as observed by a transverse cut 5 mm below the trimmed end), crude fiber content and moisture content (wet weight basis). Pulp color was measured in L, a, and b values (S & M Colour Computer) and converted to hue angle and chroma using the following formulae:

1) Hue angle($\tan^{-1}b/a$) 2) Chroma $(a^2+b^2)^{1/2}$

Ease of peel removal was determined by removing about 1 cm of the peel adjacent to the cut end using a sharp paring knife, according to the following scale of 1-5 (1=very easy separation; 5=very difficult). Peeled pieces from the root median were boiled and considered cooked when a toothpick was easily inserted into the pulp.

Test 2

Paraffin wax was compared with three commercially available emulsions, two made from carnauba wax and one from vegetable oil. Roots of the same cultivar and age were obtained on the day of harvest (27 June 1994) from the same grower. The treatment procedure was similar to that of Test 1, with the exceptions that, after washing the roots (n=8) were immersed for about 10 minutes in water containing about 200 ppm free chlorine (to reduce storage decay) and were left intact (untrimmed) 15 to 30 cm in length. Upon drying the roots were coated with paraffin wax, FMC Sta-Fresh 819F (1 wax:1 water, FMC, Lakeland FL USA), Brogdex 559 Britex carnauba emulsion (3 wax:1 water, Brogdex Company, Pomona, CA USA) and Brogdex 522 vegetable oil emulsion (1 wax:1 water). Coatings were allowed to dry overnight at about 22° (about 16 hr) after which time roots were stored at 25° and about 95% relative humidity and evaluated as described for Test 1 at 0, 2, 4 and 7 days storage.

RESULTS & DISCUSSION

Development of VS was correlated with the vapor barrier qualities of the coatings in both tests, those coatings that were the most impermeable to water vapor had the lowest incidence of VS

Test 1

Of the coatings used in Test 1, paraffin wax was the most effective in retarding the development of VS. Paraffin-coated roots stored under ambient conditions (25°) were free of VS after 16 days storage, however, the core was very fibrous (Table 1). Carnauba wax delayed onset of these symptoms for 7 days. The other coatings were less effective than the control, in that between Days 2 and 7 these treatments developed 100% VS and 100% decay (40% for the control). Carnauba wax apparently delayed development of VS due to the very low water transmissivity rate. In the pure form, however, carnauba wax is very brittle and during the coating process in this present study, it cracked upon solidification, while paraffin wax maintained a uniform, semi-glossy transparent coating.

Storage at 5° delayed development of VS for 7 days (with the exception of USDA 2) (Table 1). After 16 days VS ranged from 0 to 40%, at which time paraffin-coated roots showed slight VS underneath the peel, roots from the other treatments had a prominent fibrous core surrounded by softening pulp. Despite relative humidity in excess of 92%, roots from all treatments (except paraffin) showed severe dehydration after 30 days storage.

Cassava roots from all treatments were free from decay after 7 days storage at 25° ; after 16 days storage those roots coated with paraffin or carnauba remained decay-free, while those from the other treatments had partial or complete softening of the pulp due to decay (Table 1). Coated roots stored at 5° had no decay until 30 days storage, while uncoated roots were decayed after 16 days. After 30 days storage principal decay organisms were identified as yeasts, Torula spp. and Penicilium spp (Dr. Charles F. Robbs, EMBRAPA/CTAA).

Peel removal was most difficult for roots coated with 100% carnauba wax, due to the strong adherance of this hard, brittle coating to the peel (Table 2). Other coatings were rated as fair (not objectionable) in removal force.

There were no treatment differences during storage for moisture content, fiber content and pulp color (data not shown). Moisture content ranged from 57% to 61% and fiber content was from 0.9% to 1.5% (fresh weight basis). Initial pulp color was L = 73.3, hue angle = -87.07, chroma = 17.00. After 30 days storage, these values were almost identical for the control and paraffin treatments.

There were no trends for cooking time due to significant variability between roots within the same treatment, illustrating the difficulty of objective determination of cassava root quality. The initial cooking time for four subsamples averaged 23 minutes, whereas subsequent measurements made after 2, 7, 16 and 30 days storage varied from 16 to 27 minutes (data not shown).

Based on the results of Test 1, none of the coatings were found suitable as a substitute for paraffin wax. Pure carnauba wax did not form a uniform barrier on the root, was very fragile during handling and caused the peel to be extremely difficult to remove. USDA 1 (M91A) imparted an attractive, shiny surface to the roots, while those coated with USDA 2 (M97B) had a darkened, water-soaked appearance. Although the latter two coatings retarded decay during storage at 5°, they did not delay the development of VS after 7 days. Xanthan gum also imparted a water-soaked appearance to the roots and, for storage at 5° had only 20% VS after 16 days and no decay after 30 days. However, when stored at 25° roots coated with xanthan gum had 100% VS and decay after 7 days.

Test 2

Roots in Test 2 were stored only at 25° to rigorously test the performance of the coatings. After 7 days storage roots with the highest quality were those coated with the two carnauba emulsions or paraffin. Only 25% of the roots in these treatments had VS (Table 3). Roots coated with vegetable oil or the control had 40% and 50% VS, respectively. The former coatings also had the least amount of decayed tissue, from 0 to 25%; however, roots from all treatments, except for those coated with paraffin, had superficial mold growth under the high relative humidity conditions of this test.

Roots coated with the Brogdex carnauba emulsion were noticeably easier to peel than the other treatments, although the latter coatings were still rated as easy and there was no difference between them. The vegetable oil emulsion was least able to maintain quality during storage, most likely due to poor vapor barrier qualities of this coating.

There were no other treatment differences in the remaining quality parameters which were measured after 7 days storage. The initial moisture content for all treatments averaged 60%, decreasing to about 56% (similar to Test 1). Fiber content was lower than Test 1, averaging 0.73%, and starch content had a mean of 20.3%, (fresh weight basis) (Table 4). Cooking times were very acceptable, averaging 12.1 min and were quite lower than Test 1, despite being of the same ccultivar and age at harvest. The pulp remained white during storage; values for L, hue angle and chroma averaged 88.24, -87.44 and 13.2, respectively. The 200 ppm free chlorine immersion appeared to aid in reducing decay. Booth (1976) obtained a 7-day delay in decay by dipping roots in a 2000 ppm chlorine solution after washing.

CONCLUSIONS

Paraffin wax is effective in delaying development of VS because it creates an impermeable barrier to water vapor, thus reducing stress on the tissue caused by harvest and handling injuries. Carnauba wax shows potential as a natural wax substitute for paraffin, however, in the pure form it is too brittle and, therefore, should be formulated as a water-soluble emulsion, such as was used in this study. Carnauba emulsion is also applied at room temperature, which simplifies application and eliminates heating costs required for paraffin wax.

For cassava coated with paraffin or the two carnauba emulsions, shippers could anticipate 7 to 16 days shipping life with 25% VS and about 25% decay when handled under ambient temperatures (25°). Shipping under refrigeration at 5° should extend the quality of cassava roots for 30 days, similar to that obtained with paraffin wax in Test 1 in which there was 40% VS and 25% decay.

Although not directly tested in this work, immersion of washed cassava roots in chlorinated water prior to application of the coating may aid in reducing subsequent storage decay, as has been demonstrated for several other crops.

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Table 1. Incidence of vascular streaking and decay (%) as affected by coating, storage length and storage temperature[z] (Test 1).

	VASCULAR STREAKING					DECAY				
	Days Storage					Days Storage				
Coating	Initial	2	7	16	30	Initial	2	7	16	30
25°C										
None	0	0	80	---		0	0	40	---	---
Paraffin	0	0	20	0	---	0	0	0	0	---
Carnauba	0	20	0	100	---	0	0	0	---	---
USDA 1	0	60	100	---	---	0	0	100	---	---
USDA 2	0	20	100	---	---	0	0	100	---	---
Xanthan	0	20	100	---	---	0	0	100	---	---
5°C										
None	0	---	0	20	0	0	---	0	100[y]	20
Paraffin	0		0	20	40	0	---	0	0	20
Carnauba	0		0	40	60	0	---	0	0	20
USDA 1	0	---	0	0	80	0	---	0	0	0
USDA 2	0	---	60	20	60	0	---	0	0	0
Xanthan	0	---	0	20	0	0	---	0	0	0

[z]Percent of roots with VS or decay (n=5 roots).

[y]After 16 days, untreated roots had pulp softening due to decay; after 30 days, roots from all treatments were very dehydrated, with the exception of those coated with paraffin.

Table 2. Ease of cassava peel removal as affected by coating, storage length and storage temperature (Test 1).

	PEEL REMOVAL RATING[z]							
	Days Storage (25°C)				Days Storage (5°C)			
Coating	Initial	2	7	30	Initial	2	7	30
None	1.0	1.0	2.4	---	1.0	---	2.1	2.4
Paraffin	1.0	1.0	2.3	---	1.0	---	2.7	3.0
Carnauba	1.0	4.4	3.7	---	1.0	---	4.0	5.0
USDA 1	1.0	3.1	---	---	1.0	---	2.2	2.8
USDA 2	1.0	1.8	---	---	1.0	---	2.3	3.0
Xanthan	1.0	2.3	---	---	1.0	---	2.2	3.0

[z]Peel removal rating: 1=very easy separation, 2=easy, 3=fair; 4=difficult, 5=extremely difficult. (n=5 roots)

Table 3. Incidence of vascular streaking and decay (%), and ease of peel removal as affected by coatings during storage at 25° (Test 2).

	DAYS STORAGE			
Vascular Streaking'				
Coating	Initial	2	4	7
Carnauba (Brog.)	0.0	25.0	37.5	25.0
None	0.0	0.0	12.5	50.0
Paraffin	0.0	0.0	12.5	25.0
Carnauba (FMC)	0.0	0.0	0.0	25.0
Vegetable Oil (Brog.)	0.0	0.0	12.5	40.0
Decay'				
Coating	Initial	2	4	7
Carnauba (Brog.)	0.0	0.0	12.5	25.0
None	0.0	0.0	12.5	37.5
Paraffin	0.0	0.0	0.0	12.5
Carnauba (FMC)	0.0	0.0	0.0	0.0
Vegetable Oil (Brog.)	0.0	0.0	0.0	37.5
Ease of Peel Removal'				
Coating	Initial	2	4	7
Carnauba (Brog.)	1.0	1.0	1.0	1.4
None	1.0	2.0	1.7	2.1
Paraffin	1.0	2.6	2.3	2.4
Carnauba (FMC)	1.0	1.1	1.3	2.0
Vegetable Oil (Brog.)	1.0	1.0	1.3	2.3

'Percent of roots with VS or decay (n=8 roots).
'Peel removal rating 1=very easy separation; 2=easy; 3=fair; 4=difficult; 5=extremely difficult.

Table 4. Overall treatment means for selected quality parameters for cassava stored at 25° for 7 days (Test 2).'

	MEAN	STD. DEVIATION
Moisture Content (%)	56.3	0.78
Fiber (%)	0.73	0.02
Starch (%)	20.3	0.81
Cooking Time (min)	12.3	0.83
Pulp Color		
L	88.2	1.26
Hue Angle($tan^{-1}b/a$)	-87.44	0.61
Chroma $(a^2+b^2)^{1/2}$	13.22	0.28

n=40 roots (five treatments with eight roots/treatment)

REDUCTION OF WATER LOSS AND CONDENSATION USING PERFORATED FILM PACKAGES FOR FRESH FRUITS AND VEGETABLES

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ABSTRACT

In this work, ten types of perforated films were tested to determine water vapor transmission resistance coefficient. Three of these films were used to pack eleven horticultural products in order to study water loss, condensation formation and overall quality of the product. Products were stored under controlled conditions (2°C and 95 % RH for seven days and 10°C and 95 % RH in alternate 12 hours cycles for two days). Perforated films reduce significantly water loss and formation of condensation. Perforated films also showed promising future for extending the marketability of fresh fruits and vegetables in terms of days in the display. However, more work is needed in order to determine the right "product weight / film area" ratio for optimal conservation.

Keywords: Water loss, moisture, condensation, fruits, vegetables, perforated films, packaging

RESUMEN

En el presente trabajo se han examinado diez tipos de films perforados a fin de determinar el coeficiente de resistencia a la transmisión del vapor de agua. Con objeto de estudiar las pérdidas de agua, la formación de condensación y la calidad del producto, tres de estos fims se utilizaron para embalar once productos hortícolas. Los productos fueron almacenados bajo condiciones controladas (2°C y 95% de HR durante siete días y 10°C y 95% de HR en ciclos alternados de 12 horas durante dos días). Los films perforados reducen significativamente las pérdidas hídricas y la formación de condensación. Los films perforados mostraron también un futuro prometedor en la extensión y comerciabilidad de frutas y verduras frescas en términos de días de exposición en el mercado. Sin embargo, son necesarias más investigaciones a fin de determinar el cociente "peso del producto/área del film" correcto para la óptima conservación.

Palabras claves: Pérdidas de agua, humedad, condensación, frutas, verduras, films perforados, envasado

INTRODUCTION

Market production of Quebec's fresh fruits and vegetables is often restricted due to their relatively short shelf-life. Packaging of fresh horticultural products using plastic films is more and more used for extending their shelf life. However, products like broccoli, spinach and various berries stored in conventional packages in cold storage (commonly found in retail markets) have a limited shelf-life due to desiccation, decay or injury problems caused by excessive moisture.

Plastic film reduces water loss, which is one of the most important cause of deterioration, and may supply a "modified" atmosphere well suited for each commodity. Although these protective packaging films can reduce water loss from the stored commodity, condensation problems may occur on the inside surface of the film. In extreme cases, the condensed moisture wets the surface of the product and favors mold growth.

Perforated films may offer a simple solution to condensation problems. In fact, the permeability to water vapor is increased by holes in the film. The main advantages of such films are that they prevent anaerobic conditions, reduce water loss and let the excess of water leave the package without dehydrating the product.

LITTERATURE REVIEW

Water loss

Water loss is one of the major conservation problem. Kader (1991) mentions that even in high humidity conditions, water loss can be as high as 1 % of initial weight per day for products with high transpiration rate like lettuce and carrots. Effects of water loss are weight loss, shrivelling, wilting, loss of nutritional quality and softening of the tissues (Kader, 1991). Hardenburg et al.