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Introduction

External appearance is an important attribute of overall fruit and vegetable quality. It is the first attribute that buyers notice. Although there may not always be a correlation between external appearance and edible quality, visual appeal of the product is a powerful characteristic in determining market acceptance. Many consumers prefer produce with a shiny or glossy appearance. Various types of waxes and edible surface coatings may be applied to fruits and vegetables to improve the cosmetic features (shine, color) of the product.

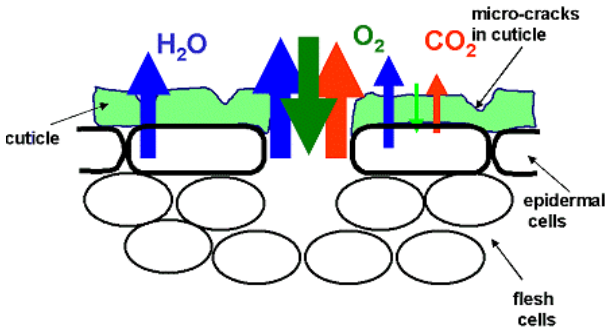
Waxing is recommended only for good quality products because it does not improve the quality of inferior ones. This is done to supplement or replace the natural wax on the surface of a commodity, which may be removed during cleaning and packing. Waxing consists of applying a thin layer of edible wax to the outer surface of the product. The benefits obtained by the product from waxing include an improved appearance, less moisture loss and shriveling, reduced postharvest decay, and a longer shelf-life. However, waxing of fruits and vegetables is not done in Guyana. This may be attributed to several factors, including the lack of awareness of the beneficial effects of waxing, lack of availability of food-grade waxes, lack of appropriate information on the technology of waxing, and the additional cost of application.

Benefits of Waxing

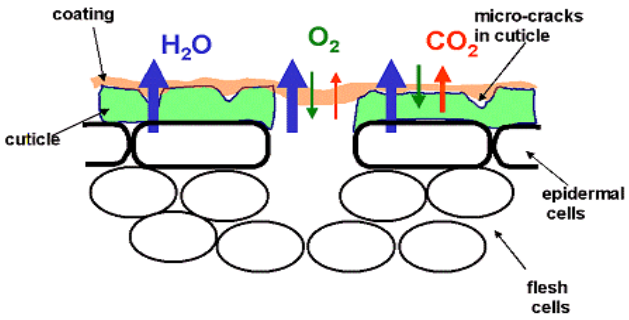
Improved Appearance
Fruits and vegetables that are waxed generally have more shine and brilliance. They also retain their color and fresh appearance for a longer period. This is desirable from a marketing standpoint, as buyers initially judge the acceptability of a product based on external appearance.

Waxing can also improve the internal color of certain commodities. Waxing of cassava can extend storage life from several days up to about 1 month by preventing discoloration in the vascular tissue.

Less Moisture Loss
All fruit and vegetables are covered naturally in a cuticle which is a barrier to moisture loss. However, some water vapor can move through the pores, cuticle and micro-cracks in the cuticle.



During the process of waxing, a tightly adhering thin film of the coating substance is applied to the surface of the fruit. The wax coating blocks the pores in the cuticle, which significantly reduces the amount of water vapor loss.



Moisture loss from fruits and vegetables results in product shriveling and/or wilting. This negatively affects the commodities appearance, causing the product to lose its desirable fresh look. Marketing of items which have suffered significant moisture loss becomes very difficult. Generally, when an item has lost 5% or more of its original weight it will be visually noticeable. This amount of moisture loss typically lowers the grade of the product or makes it completely unmarketable. The longer produce is expected to be stored, the more important waxing becomes in reducing weight loss. Application of a thin layer of wax coating can reduce product weight loss by 30 to 40%.

Moisture loss from fresh produce results in undesirable textural changes, negatively affecting the edible quality of the product. Firmness decreases and the texture becomes more flaccid. In the case of ground provisions, hollow cavities may form in the flesh tissue (pithiness) and the texture becomes dry.

Less Economic Loss

Water is the principal component of all fresh fruits and vegetables. It usually constitutes between 80 to 90% of a product's fresh weight. Once harvested, the fresh product begins to lose moisture from the processes of transpiration (evaporation of water) and respiration. This results in product weight loss, which is undesirable from an economic

standpoint. Growers often sell their fresh products based on weight, and will obtain less economic return with increasing amounts of weight loss.

Reduced Postharvest Decay
Waxing establishes a barrier against the entrance of fungal and bacterial pathogens into the product. Postharvest pathogens typically require a film of free moisture on the product's skin to grow. Waxing creates a hydrophobic (non-water compatible) surface which is not conducive to pathogen growth and development. A fungicide can also be added to the wax to provide added protection against decay.

Longer Postharvest Life
Fruits and vegetables are living organisms that continue to respire after harvest. Waxing creates a modified atmosphere inside the product in which the oxygen content is decreased and the carbon dioxide content is increased. This results in a reduction in the product's respiration rate and an increase in postharvest life. A prolonged postharvest life allows for an extension in the marketing period for the crop.

Less Susceptibility to Chilling Injury
Fruits and vegetables of tropical origin are susceptible to chilling injury (CI), which is a type of physiological injury that occurs at low temperatures. The amount of CI depends on the temperature and duration of exposure to the low temperature. It occurs between 13°C (56°F) and 0°C (32°F), depending on crop. Waxing reduces the severity of CI and allows for storage of CI-sensitive commodities at slightly lower temperatures without incurring damage. However, waxing does not eliminate CI on the susceptible commodities.

Fruits and Vegetables Benefited by Waxing

The following fruits and vegetables produced in Guyana may benefit from a postharvest wax application.

Fruits: avocado (pear), breadfruit, carambola, coconut, guava, grapefruit, lemons, lime, mango, orange, papaya, passion fruit, pineapple, tangerine

Vegetables: bitter melon, cassava, cucumber, eggplant, peppers, pumpkins, sweetpotato, tomato, yam

Disadvantages of Waxing

Artificial Appearance
In some cases, consumers prefer the natural color and appearance of the commodity rather than a shinny, waxed product. Waxing may be construed by these consumers as a type of alteration in the product, changing the real external appearance into something more artificial.

Added Cost
Waxing adds cost to the commodity and slightly extends the time required to prepare the product for market. The added costs are due to the extra labor and/or equipment needed to apply the wax, along with the cost of the wax material.

Surface Burn
Waxes which are improperly applied can result in surface burn to the commodity. In the case of ground provisions, an excessively long period of submergence in hot melted paraffin wax can burn the skin and inner flesh tissue. Ideally, the length of submergence should be no more than one second. Tissue damage can also occur if the wax temperature is too high.

Wax Whiting (Chalking)
Wax may whiten on the surface of fruits or vegetables if they have been subjected to excessive heat or moisture. This problem results when pure shellac is the waxing ingredient. This often occurs after removal of the waxed product from cold storage to higher temperatures. When the temperature gradient between the commodity and ambient air is large, sweating is induced on the product surface. The condensation of the moisture causes the shellac to become partly solubilized and subsequently results in white deposits that are translucent in appearance. Heavy shellac coatings tend to aggravate the problem. Whitening may also occur when too much residual moisture is present during waxing.

Off-flavor development
All fruits and vegetables are living organisms and require an intake of O2 and release of CO2 for normal metabolism. Waxing restricts gas exchange through the peel and thus reduces internal O_2 levels and increases internal CO_2 levels. Low O_2 levels not only may stimulate anaerobic respiration and the production of compounds that impart off-flavors, but may also cause a peel disorder that severely reduces marketability. The wax coating should not be applied too thick to the surface of the commodity.

Wax Application Methods

Waxes may be applied in several different ways, ranging from manual rubbing of the product surface to automated roller brush application.

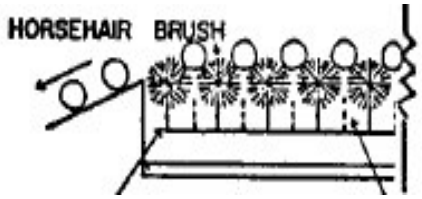
Manual Rubbing
Liquid waxes can be applied by manually rubbing the commodity and smearing the wax evenly over the surface. A soft absorbent cloth or fine bristled brush can be used to speed up the process. After application, the products should be left to air dry for about 15 minutes before packing.

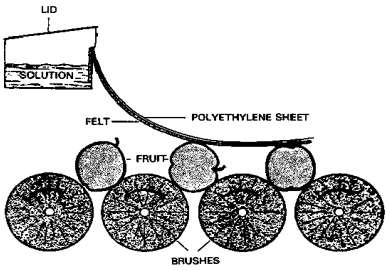
Dipping/Submergence
Paraffin wax is typically applied as a brief dip or submergence of the product in a bath of melted paraffin. Submergence time is usually one second or less. Upon removal from the melted solution, the paraffin solidifies almost instantaneously. The products are ready for packing within a minute after submergence.

It is very important the product surface be completely dry before dipping. If not dry, the high temperature of the melted wax converts the surface moisture on the product into steam and forms pockets or blisters under the wax coating. The wax will then loosen and drop off.

Roller Brushing
Liquid waxes can be applied automatically to the surface of the commodity by using a series of roller brushes. The wax is dispensed from above and saturates the brushes, which rotate and spin the product, smearing the wax evenly over the product surface. The

brushes on the wax applicator should be completely saturated with the wax solution before any product passes over them.





Fruit should be damp dry prior to wax application to prevent wax dilution. The wax is typically sprayed or dripped on to the fruit over a bed of brushes. The wax can be sprayed manually or by pump through low pressure nozzles. Irrigation drippers spaced across and over a bed of soft brushes can also be used to apply the wax. An electronic timer may be needed to interrupt the wax flow to avoid excessive use of wax. Industrial wool felt can also be used to distribute the liquid wax to the fruits or vegetables from a trough made the same width as the roller brushes. Evaporation of wax from the felt is reduced by covering the felt with a layer of heavy polyethylene sheeting.

The roller brushes should have at least 50% horsehair to help spread the wax over the fruit. Brush speed should not exceed 100rpm. The brushes should be kept soft by regular washing with hot water.

Types of Food-Grade Waxes

Several different raw materials are used as a base for formulating food-grade waxes. The most commonly used materials are paraffin, carnauba, shellac, and polyethylene. Less frequently used wax bases include beeswax and candelila wax. Each of these raw materials has unique and different properties which determine its shine, firmness, gas exchange, and other physical characteristics. The raw materials are mixed with water and wetting agents to provide a thin continuous coating. The waxes available commercially are already pre-mixed and ready for immediate application. The amount of wax applied to each individual fruit or vegetable is very small. For example, one gallon of liquid carnauba, shellac, or polyethylene based wax applied with a roller brush will cover up to 75,000 tomatoes, and up to 95,000 peppers or cucumbers. The amount of individual ground provisions covered by paraffin wax will be significantly less due to the thicker wax coating and the larger surface area of the products.

Paraffin (Candle Wax)
Paraffin is a petroleum-based wax obtained from the distillation of crude oil. It is commonly used in making candles. Paraffin wax is a solid at room temperature and must be heated to about 52°F (125°F) to melt. Temperature of the liquid wax influences the translucence upon solidification. Paraffin wax can be re-solidified and melted again for

later use. Paraffin wax is commonly used on cassava for export marketing. It can also be used on sweetpotatoes, yams, coconut, and thick-skinned fruits like breadfruit.

Carnauba

Carnauba wax is obtained from the leaves of carnauba palm, which is native to Brazil. The leaves produce wax in such abundance that heating in a little water can yield 5-10 grams of wax from each leaf. Carnauba is a moderate gloss wax. It imparts a much better shine to the product than paraffin, but less than shellac. A carnauba wax finish is more permeable than shellac and does not whiten.

Shellac

Shellac is produced from the resinous secretions of the tiny lac insect (*Laccifer lacca*). The lac insect secretes the resin form its glands onto a host tree in the form of tiny platelets, which are gathered, crushed, washed, and purified into food-grade shellac. Shellac is hard at normal temperatures but softens under pressure when heated. Shellac is a hard, tough resin that has good water resistance and produces high lustrous finishes. However, the waxed products are more likely to whiten or chalk upon removal from cold storage. Shellac is less permeable to gas exchange than carnauba and care must be taken to avoid over-application and possible product fermentation. It is the most popular wax currently used on citrus.

Polyethylene
Polyethylene-based waxes are obtained from the polymerization of ethylene under heat and pressure. They are generally the least expensive waxes and provide a reasonable shine to the product. They are used on a wide diversity of fruits and vegetables.

Sources of Fruit and Vegetable Waxes

A number of commercially available food-grade waxes for fresh produce are on the market. They are mostly proprietary formulations designed to optimize the appearance of the specific commodity. In North America, there are four principal producers of waxes for the fresh fruit and vegetable industry. Each of these companies manufactures different types of waxes for different products. These waxes are all approved by the Food and Drug Administration (FDA) for use on products sold in the U.S. Canadian regulations closely resemble U.S. guidelines. However, European countries (particularly Germany) may have different regulations on permissibility of postharvest waxes for fresh produce. The principal wax producers in the U.S. are:

Brogdex Co.
1441 W. Second Ave.
Pomona, California 91766
Tel: 909-622-1021; Fax: 909-629-4564

FMC Corporation
P.O. Box 1708 Fairway Avenue
Lakeland, FL 33802
Tel: 941-683-5411; Fax: 941-680-3620

Cerexagri Inc.
630 Freedom Business Center, Suite 402
King of Prussia, Pennsylvania 19406
Tel: 610-491-2800; Fax: 610-491-2801

Moore & Munger, Inc.
Two Corporate Drive, Suite 434
Shelton, Connecticut 06484
Tel: 203-925-4300; Fax: 203-926-9844

ANNEX I

PUBLICATIONS IN THE POSTHARVEST HANDLING TECHNICAL BULLETIN SERIES

PH Bulletin No. 1	Pineapple: Postharvest Care and Market Preparation, November 2002.
PH Bulletin No. 2	Plantain: Postharvest Care and Market Preparation, June 2003.
PH Bulletin No. 3	Mango: Postharvest Care and Market Preparation, June 2003.
PH Bulletin No. 4	Bunch Covers for Improving Plantain and Banana Peel Quality, June 2003.
PH Bulletin No. 5	Papaya: Postharvest Care and Market Preparation, June 2003.
PH Bulletin No. 6	Watermelon: Postharvest Care and Market Preparation, October 2003.
PH Bulletin No. 7	Peppers: Postharvest Care and Market Preparation, October 2003.
PH Bulletin No. 8	Oranges: Postharvest Care and Market Preparation, October 2003.
PH Bulletin No. 9	Tomato: Postharvest Care and Market Preparation, October 2003.
PH Bulletin No. 10	Okra: Postharvest Care and Market Preparation, October 2003.
PH Bulletin No. 11	Pumpkin: Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 12	Lime: Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 13	Grapefruit: Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 14	Passion Fruit: Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 15	Green Onions: Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 16	Sweet Potato: Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 17	Eggplant (Boulanger): Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 18	Avocado (Pear): Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 19	Bitter Melon: Postharvest Care and Market Preparation, January 2004.
PH Bulletin No. 20	Bora: Postharvest Care and Market Preparation, April 2004.
PH Bulletin No. 21	Cassava: Postharvest Care and Market Preparation, April 2004.

PH Bulletin No. 22	Eddoes: Postharvest Care and Market Preparation, April 2004.
PH Bulletin No. 23	Ginger: Postharvest Care and Market Preparation, May 2004.
PH Bulletin No. 24	Breadfruit: Postharvest Care and Market Preparation, May 2004.
PH Bulletin No. 25	Cabbage: Postharvest Care and Market Preparation, May 2004.
PH Bulletin No. 26	Calaloo: Postharvest Care and Market Preparation, May 2004.
PH Bulletin No. 27	Coconut: Postharvest Care and Market Preparation, May 2004.
PH Bulletin No. 28	Cucumber: Postharvest Care and Market Preparation, May 2004.
PH Bulletin No. 29	Lemon: Postharvest Care and Market Preparation, May 2004.
PH Bulletin No. 30	Starfruit: Postharvest Care and Market Preparation, May 2004.
PH Bulletin No. 31	Tangerine: Postharvest Care and Market Preparation, May 2004.
PH Bulletin No. 32	Yam: Postharvest Care and Market Preparation, May 2004.
PH Bulletin No. 33	Waxing Fruits and Vegetables: Postharvest Care and Market Preparation, June 2004.