to pick them until fairly late in the day when their turgor pressure is lower. Post-harvest decay in mangos is reduced by a hot water bath.

The problem of quality in avocados and limes has been helped by maturity and grade regulations administered under federal marketing orders. These orders specify a minimum juice content for limes, while for avocados there is a rather complex schedule of minimum weights and dates for most of the cultivars grown in commercial quantities. The problem of too many different avocado cultivars, and of some which have poor eating or shipping quality remains with us. Mangos, like avocados, come in too many shapes, sizes and colors, as well as wide variation in their eating quality. These problems usually occur as an industry develops; we can look forward to improvement in the future.

Today, after eighty years of trial and error, the southern half of Dade County produces over a million bushels of avocados, close to two million bushels of limes and 300,000 bushels of mangos yearly, with promise of other exotic fruits to come. Cultivars and cultural practices developed here have been carried to many other parts of the world, repaying them for the gifts of fruit we have received from them. I believe Dr. Fairchild and my father would be pleased, and I suspect William Jackson would be astonished.

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POSTHARVEST RESPONSE OF CARAMBOLAS TO STORAGE AT LOW TEMPERATURES

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Abstact. **Carambola (*Averrhoa carambola* L.) is a tropical fruit crop relatively new to Florida, but despite its increasing popularity, little is known about optimum procedures for harvesting, handling, or storage. The fruit are yellow when ripe and have a distinct star-shape in cross section. The present study was undertaken to determine the optimum storage conditions for Florida carambolas and to assess changes in quality of fruit exposed to these treatments. 'Arkin' and 'Golden Star' carambolas stored at 10°C were of better quality than those held at 15°C or 20°C. Despite concern about chilling injury in carambolas stored below 10°C, fruit kept at 5°C had a better appearance, less weight loss, and less reduction in levels of soluble sugars (glucose, fructose, and sucrose), and organic acids (oxalic and malic) than did fruit stored at higher temperatures. Storage at 5°C followed by 6 days at room temperature (23°C) showed that fruit developed no symptoms of chilling injury, and retained the capacity to ripen normally. Results demonstrate that Florida carambolas therefore can be stored most effectively at 5°C.**

Averrhoa carambola L. Oxalidaceae is a small tree (common name "carambola" or "starfruit") grown commercially in South Florida for its attractive star-shaped fruit. Carambola was introduced into Florida more than a century ago but did not gain commercial status until recently (2, 8). There are 75 hectares of carambola orchards planted in Florida, with more planned (4). Because the carambola industry is new, optimum cultural practices are unknown and there is inadequate information on postharvest handling practices for the tender fruit. Most orchards are young; therefore, many potential problems associated with monoculture of a species may await carambola growers, packers, and researchers.

A strong national interest and demand for tropical fruits has fostered a young, but expanding, fresh-fruit industry in South Florida. Carambola is one of several tropical fruits that have recently become popular commercial crops in Dade County, Florida (3). These fruit are grown in southern Florida and marketed in many states throughout the nation. Postharvest losses are a significant problem in these new crops, and in carambola as well. The scarcity of information on postharvest handling of many tropical fruits has forced producers to rely on a trial-and-error approach to harvest and storage practices. The resulting losses may occur at harvest, in the packinghouse, and during transit and retail sale.

If carambola fruit could be stored successfully for four weeks before sale, then the irregularity in supply of carambolas could be minimized. Retailers are reluctant to purchase new commodities when consistent and high quality supplies cannot be guaranteed. Carambola brokers at present cannot provide adequate amounts of fruit continuously throughout the season. Rather, abundant supplies of fruit are available only about every two weeks during the two bearing seasons for carambola. One of the primary difficulties is a need for information on precisely what constitutes optimum, or even acceptable, postharvest handling procedures for carambolas. Research on the development and postharvest biology of this fruit will hopefully lead to improved handling procedures which will in turn reduce losses and strengthen the industry.

The objectives of this study were to determine the optimum postharvest storage temperature for Florida carambolas, and to document changes which occur in fruit exposed to these conditions. Fruit color, appearance, water content, and levels of soluble sugars (glucose, fructose, sucrose) and acids (malic and oxalic) were measured during and after storage. The overall goal of this research was to examine potential methods of extending the effective storage life of this unique Florida crop.

Materials and Methods

Current practices in wholesale handling operations provided the basis for the first set of experiments. Carambolas generally arrive at the packinghouse in fiberboard boxes of about 125 fruit each. They are then sorted into three size categories and unmarketable fruit are discarded. Other than the removal of surface debris, no other postharvest treatment is employed. Each fruit is wrapped in tissue and packed 15 to 25 per box. Cartons are stored in large refrigerated rooms at 15°C until shipping.

The first experiments in the present study were conducted using 'Arkin' and 'Golden Star' carambolas obtained in late October, 1986 from a commercial handler in Homestead, Fla. Five boxes of each cultivar, packed as described above, were transferred to each of three storage chambers (2 m X 2 m X 2 m) and maintained at 10, 15, or 20°C. Relative humidity was maintained at 85 to 95% and cartons were arranged to allow maximum air circulation. Fruit were visually examined and photographed after 15, 30, and 45 days.

Commercially-obtained fruit were not used for subsequent research due to extensive variability in fruit condition. In addition, sweet and tart carambolas are typically boxed separately, but cultivar identity is not always certain within these categories. Also, data on actual harvest date is often unavailable and stage of maturation for individual fruit may vary considerably.

To circumvent these problems, 'Arkin' carambolas were harvested directly from a productive, six-year-old grove in Homestead, Fla. They were picked at a consistent stage of maturation (color-break) in February, 1987, from all locations within canopies of 20 randomly selected trees. Fruit were packed in commercial containers (as described above), transported to the University of Florida Gainesville, and arranged in storage chambers at 5°C and 10°C.

All fruit were weighed prior to storage. Twenty random samples were also taken for determinations of color, and 10 for compositional analysis of sugars and organic acids. All measurements were repeated after 44 days of cold storage, and again after 6 days at room temperature (23°C).

High performance liquid chromatography (HPLC) was used to identify and quantify soluble sugars (glucose, fructose, and sucrose) and organic acids (oxalic and malic) in carambolas. Ten fruit were pooled for each sample, except after rewarming, when 6 fruit were used. Extraction and identification of soluble constituents were conducted as described previously (1), using refractometric detection for sugars and UV for organic acids. Wilson *et al.* (11) reported that only slight amounts of the oxalic acid in carambola are present as insoluble Ca-oxalate, so the methanol:chloroform:water extraction used here was considered effective.

Carambola color was determined visually and also quantified using a Hunter ColorQuest Color Difference Meter (Hunter Assoc. Lab Inc, Reston, VA). Results were also compared to Munsell Color Plates (Munsell Color Co., Baltimore, MD).

Results and Discussion

'Arkin' and 'Golden Star' carambolas obtained from a commercial packinghouse were seriously decayed after 30 days of storage at 20°C. At 15°C, acute fungal growth was evident on 'Arkin' fruit, but some of the 'Golden Star' carambolas remained marginally acceptable. Desiccation was apparent in all fruit maintained at this temperature. In contrast, carambolas stored at 10°C were considerably more turgid and less deteriorated than those exposed to higher temperatures.

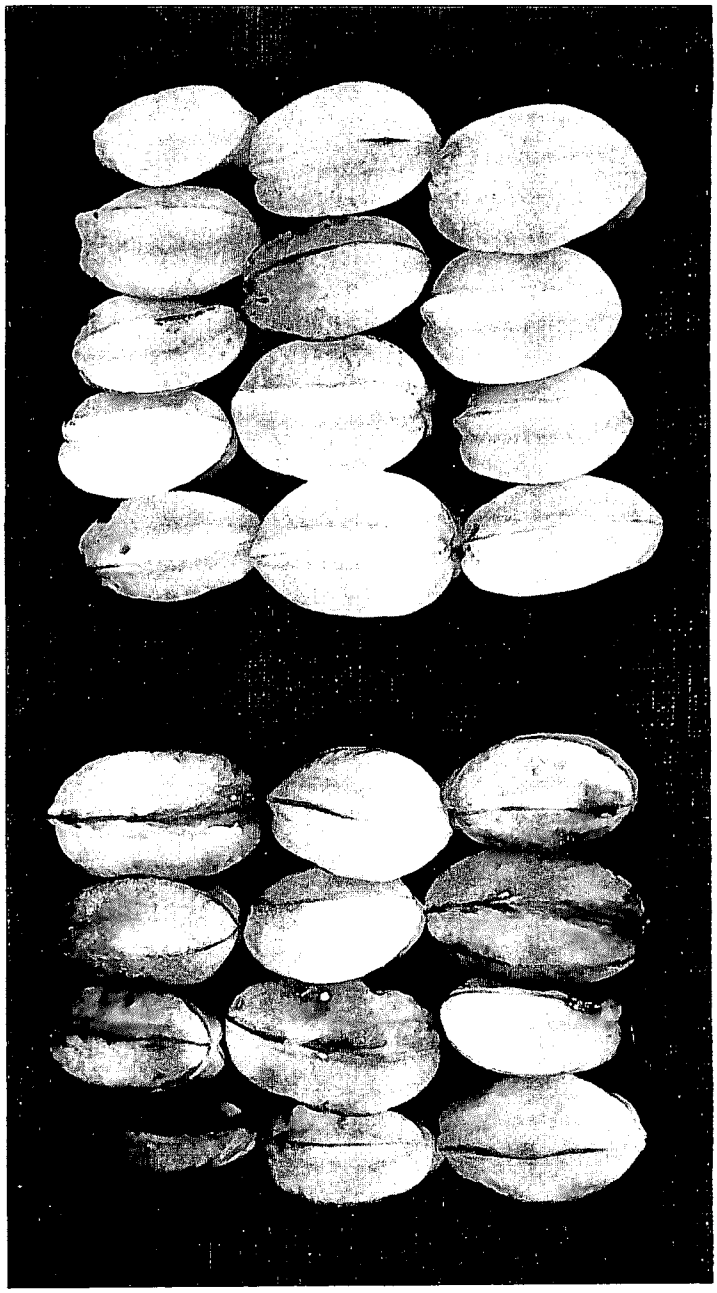

Fig. 1. 'Arkin' carambolas stored 44 days at either 5°C (top of figure) or 10°C (bottom of figure).

Chilling injury is often evident in tropical commodities at low, but non-freezing, temperatures (5, 10). For this reason, storage under such conditions is not common (6). The lack of chilling injury symptoms in carambolas stored at 10°C in the present study, and other instances (1, and unpublished data of R. McDonald, USDA, Orlando, Fla.), prompted investigation of responses to lower temperatures.

In an effort to avoid the variable and unknown maturity of commercially-available fruit, further studies were performed using carambolas harvested at color break.

A comparison of 'Arkin' carambolas stored 44 days at 10°C *vs* 5°C showed considerably less necrosis, desiccation, and greater firmness in fruit maintained at the lower temperature (Fig. 1). Fruit at both temperatures were less green than when harvested, but carambolas kept at 5°C had not become as yellow as those stored at 10°C (data not shown).

No apparent chilling injury was evident in fruit maintained at either temperature. An earlier report to the contrary appears to have been due to fruit desiccation (7). Numerous subsequent investigations have verified information on chilling tolerance presented here. Levels of metabolites indicative of chilling injury were monitored in carambolas exposed to 5°C for extended periods and showed that no chilling injury had occurred (unpublished data, R. McDonald, USDA, Orlando, FL). Packinghouse trials in response to the present study have produced consistantly favorable results at 5°C (unpublished data, J. R. Brooks and Sons, Inc.).

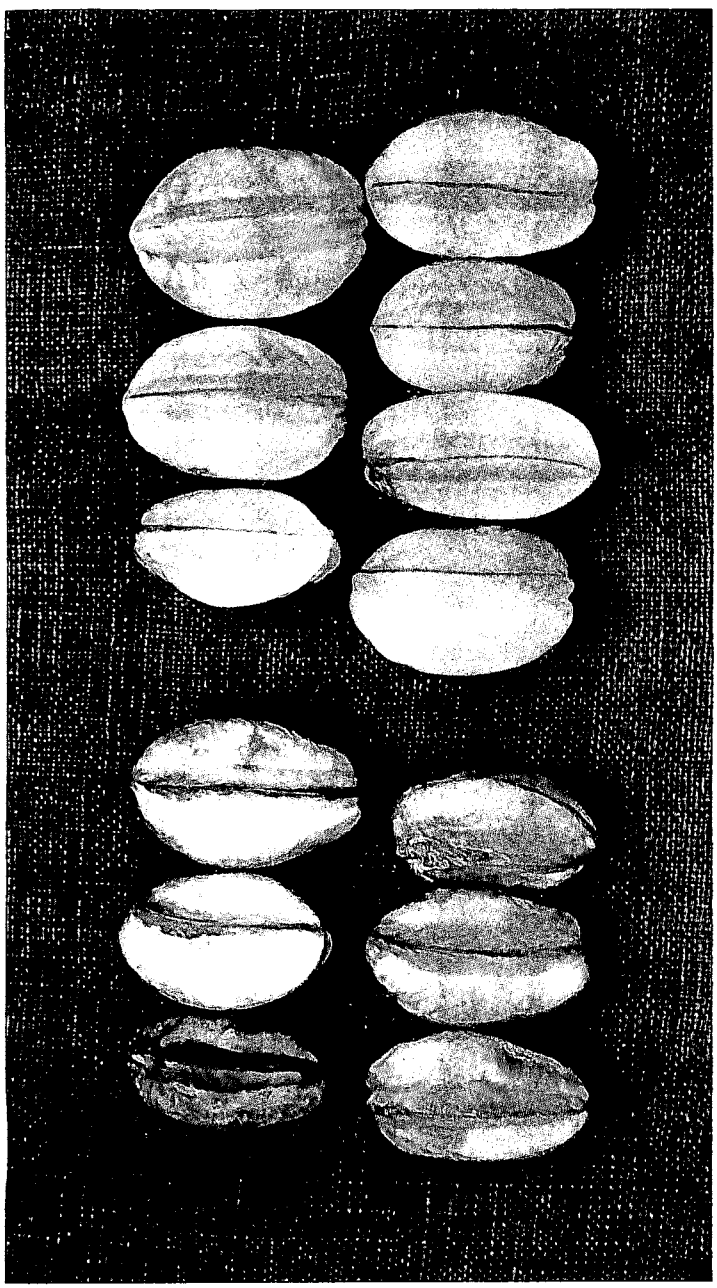

Fig. 2. 'Arkin' carambolas after 6 days at room temperature (23°) preceeded by either 44 days at 5°C (top of figure), or 10°C (bottom of figure).

Visual differences in quality of carambola fruit were also apparent when they were transferred to room temperature (23°C) and held for 6 days after cold storage (Fig. 2). Fruit previously exposed to 5°C continued to show no evidence of chilling damage, and proceeded to develop a normal yellow color.

Table 1 summarizes the data on changes in quality parameters of carambola fruit stored at 5°C or 10°C. Approximately 90% of the carambolas from the 5°C treatment were commercially acceptable after 44 days, whereas only 50% remained so at 10°C. Fruit did not show symptoms of chilling injury at either temperature. Loss of fresh weight during storage was greater at 10°C than at 5°C, but the difference between treatments was even more pronounced after an additional 6 days at room temperature.

Analysis of sugars and organic acids (Table 1) showed that fruit composition at harvest was typical of carambolas at colorbreak (1), and was comparable to values obtained by others (9). Fruit sugar levels remained relatively unchanged during 44 days at either 5°C or 10°C. After transfer to 23°C for 6 days, however, both glucose and fructose dropped sharply in fruit previously stored at 10°C. The same trend did not occur in carambolas maintained at 5°C. In addition, decreases in sucrose levels were more pronounced after warming (23°C) of fruit which had been stored at 10°C as opposed to 5°C.

Organic acids of carambolas at harvest are primarily malic and soluble oxalic acid (1, 11). Levelst of oxalic acid in the sweet 'Arkin' fruit are only about 20% as great as those in the tart 'Golden Star' fruit, and levels in both carambolas are less than half of those commonly reported for spinach (11). During cold storage of 'Arkin' fruit, acid levels decreased in those exposed to 10°C, but not 5°C. Both oxalic and malic acids dropped to approximately half their prestorage levels when fruit remained 44 days at 10°C. Unlike sugars, organic acids appeared to change little during the 6-day, poststorage period at 23°C.

Table 1. Quality of 'Arkin' carambola fruit at harvest, after storage 44 days at 5°C and 10°C, and after an additional 6 days at 23°C.[z]

Fruit quality parameters	At harvest (color break)	After storage for 44 days of		6 days at 23°C after 44 days of	
		5°C	10°C	5°C	10°C
		Percent			
% marketable[y]	100	90	50	00	00
Visible chilling	—	—	—	—	—
% weight loss	—	4.4	6.7	>10	>20
Composition:					
sugars:		(mg/g)[x]			
fructose	15	13	13	13	10
glucose	13	12	12	12	6.0
sucrose	4.0	3.0	3.0	2.0	<1.0
organic acids:					
oxalic	1.5	1.5	0.8	1.5	0.8
malic	1.0	1.0	0.5	1.0	0.5

[z]Samples consisted of ten or more fruit.
[y]Marketability based on firmness and extent of browning/necrosis.
[x]Sugar composition determined by HPLC and expressed as milligrams per gram fresh weight. Each sample was pooled from five randomly selected fruit.

Data reported here demonstrate that carambola fruit can be effectively stored for extended periods at 5°C. Furthermore, this temperature maintains fruit quality to a greater extent than previously recommended conditions (6). No chilling injury occurred at 5°C, and normal color development and ripening resumed in fruit transferred to 23°C. Composition of soluble sugars and organic acids, important components of taste, also remained at levels similar to those of freshly-harvested fruit.

Literature Cited

1. Campbell, C. A. 1987. Carambola fruit developement and storage in Florida. M.S. Thesis. University of Florida.
2. Campbell, C. W. 1971. Commercial production of minor tropical fruit crops in Florida. Proc. Fla. St. Hort. Soc. 84:320-323.
3. Campbell, C. W. 1986. Tropical fruit crops in Florida: A rapidly changing situation. Proc. Fla. St. Hort. Soc. 99:217-219.
4. Campbell, C. W., R. J. Knight, Jr., and R. Olzack. 1985. Carambola production in Florida. Proc. Fla. St. Hort. 98:145-149.
5. Graham, D. and B. D. Patterson. 1982. Responses of plants to low, nonfreezing temperatures: Proteins, metabolism, and acclimation. Ann. Rev. Plant Physiol. 33:347-372.
6. Hardenburg, R. E., A. E. Watada, and C. Y. Wang. 1986. The commercial storage of fruits, vegetables, and florist and nursery stocks. USDA, Agr. Hdbk. No. 66.
7. Kenny, P. and L. Hull. 1986. Effects of storage condition on carambola quality. Proc. Fla. St. Hort. Soc. 99:222-224.
8. Reasoner Brothers. 1887. Annual catalogue and price list of the Royal Palm Nurseries. Manatee, Florida. 10.
9. Shaw, P. E. and C. W. Wilson, III. 1983. Separation of fructose, glucose, and sucrose in fruit by high performance liquid chromatography using UV detection at 190 nm. J. Sci. Food Agr. 34(1):109-112.
10. Wills, R. B. H., T. H. Lee, D. Graham, W. B. McGlason, and E. G. Hall. 1981. Postharvest: an introduction to the physiology and handling of fruit and vegetables. AVI Publishing Inc., Westport, Conn.
11. Wilson, C. W., III, P. E. Shaw, and R. J. Knight, Jr. 1982. Analysis of oxalic acid in carambola (*Averrhoa carambola* L.) and spinach by high-performance liquid chromatography. J. Agr. Food Chem. 30(6):1106-1108.

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CARAMBOLA PRODUCTION IN MALAYSIA AND TAIWAN

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Abstract. **The carambola, *Averrhoa carambola* L. was first introduced to Florida in the 1880's. It was not considered to be a commercially viable crop until the early 1980's. Since that time, carambola acreage in south Florida has shown a dramatic increase, to the current estimate of 300 acres. The carambola is indigenous to Southeast Asia. Concurrently, in Malaysia and Taiwan, acreage is also increasing. Malaysia has 200-300 acres in cultivation. Taiwan has 6900 acres of carambolas. In these countries the average size farm is less than five acres. Little farm machinery is utilized. Much of the labor is supplied by the family. Because of insect problems, fruits are bagged on the trees. Fruits are selectively thinned to produce large size. Sweet fruits are preferred.**

The carambola, *Averrhoa carambola* is thought to be indigenous to Southeast Asia (8). Small sized, tart carambolas were first introduced to Florida in the late 1880s. Later, Dr. H. S. Wolfe sent seeds from Hawaii which resulted in the 'Golden Star' and 'Newcomb' cultivars (2). Some commercial production of carambola, 10 acres or less, was in existance in the 1960's. In 1973, Dr. R. Knight on a Rare Fruit Council sponsored collecting trip, sent back seeds from Malaysia that resulted in the 'Arkin' cultivar, and also grafted 'Fwang Tung' plants. These are sweet, low acid cultivars. The 'Arkin' is the major carambola cultivar being planted in south Florida groves. Acreage is currently expanding (3) to approach 300 acres. The 'Arkin' is a medium size orange-yellow fruit, with high sugar and low acid, having thick fleshy ribs (1).

The introduction and development of superior carambola cultivars was one factor which led to the recent surge in planted carambola acreage. Another factor of equal importance is the immigration of people from tropical countries into the United States who brought their cultural heritage with them (5). Five million oriental people now live in the United States. Since the carambola is thought to be indigenous to Southeast Asia, a significant number of these Asian American people are familiar with this fruit, and provide a ready market. This paper was the result of a fact finding trip to Malaysia and Taiwan in June of 1987. The object was to learn about the carambola industry in a part of the world that has historically appreciated and grown them.

Malaysia and Its Cultivars

In Southeast Asia, carambolas have grown for hundreds of years. These fruit trees were found in the wild, are popular as dooryard trees, or for local consumption (4). In the acid soils and tropical climatic conditions, carambolas grow vigorously. Their leaves are large and deep green, showing little of the micronutrient deficiency so prevalent in south Dade's calcareous soils. Since carambolas grow readily from seed, little cultivar selection was made in Malaysia until the late 1960's or early 1970's, when superior cultivars were identified and numbered.

Malaysia, originally Malaya, is home to 15 million people. This multi-ethnic nation is comprised of peninsular Malaysia (West Malaysia), bordered on the north by Thailand, and to the south by the island nation of Singapore; and across the China Sea, East Malaysia, on the island of Borneo. Malaysia has an equatorial climate influenced by monsoons. Temperatures from 72°-92°F. Mean rainfall amounts are approximately 100 inches a year.

The area considered to have the best quality carambolas is in the state of Selangor in West Malaysia approximately 15 miles south of Kuala Lumpur at 3° N latitude (4). The 4.5 pH of the sandy soils in this area is in the extremely acid range. In Selangor, 200-300 acres of caram-