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Agency for International Development
Washington, D.C. 20523

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MEMORANDUM

TO: AFR/TR, Richard A. Cobb

FROM: S&T/RUR, Curtis R. Jackson

SUBJECT: Research Results from Tuskegee University HBCU Reserch Project

The attached journal article resulted from research done by Dr. Jenice Rankins of Tuskegee University. AFR/TR reviewed the proposal for us prior to its funding. The results appear to be useful.

Attachment a/s

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PALATABILITY AND NUTRITIONAL SIGNIFICANCE OF SOLAR DRIED MANGOES FOR SENEGAL

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Three varieties of grafted mangoes were dried to a moisture content of 9-11 percent utilizing a greenhouse model solar dryer which measured about 4.5 sq m and had a drying capacity of 20 kg of tray-ready mangoes. The results showed that after six months of storage, 1) retinol equivalents of beta carotene and vitamin C contents of 100 gms of dried mangoes averaged recommended dietary allowances respectively for children; 2) the Kent variety contained relatively substantial amounts of iron; and 3) acceptability ratings for dried slices and desserts were generally ok to excellent and were not influenced by the brightness and sweetness additives tested. these results have significant relevance to nutritionally at-risk populations in Tropical Africa where mangoes are seasonally plentiful and popular but go to waste in large amounts because of the lack of appropriate preservation technologies.

KEY WORDS: Mango, B-carotene, carotenoids, vitamin C, solar dryers, dried fruits, Senegal, iron, mango snacks, mango desserts

INTRODUCTION

Senegal is located at the western tip of Africa and is bordered on the north by Mauritania, the east by Mali, and the south by Guinea-Bissau (Fig. 1). The country is about the size of South Dakota.

Food availability, dietary habits and food consumption studies (Berggren, 1981; Thomas, 1982; Vincent, 1981) have shown that diets of weaning age children in Senegal are often low in certain micronutrient elements, especially iron, calcium, vitamins A and C, folic acid, and riboflavin. Anemia incidences (hb < 10.8g percent) approaching 50 percent have been reported for some segments of the population. Clinical signs of riboflavin deficiency are common. Of children 0-3 years of age 10% show severe and 35% moderate signs of protein-energy malnutrition in certain regions (Conseil National des Femmes Noires Americaines, 1983; DANAS, 1985).

Meats and animal products (eggs, milks, cheese) are too expensive for most families to consume enough regularly to substantially increase intakes of limited nutrients. Vegetables and fruits are cheap and good sources of many vitamins and minerals. However, because they are perishable and seasonal, appropriate preservation technologies are essential to ensure year-round availability at affordable cost.

By the end of the normal dry season, certain fruits and vegetables have become extremely scarce. Drought conditions, such as those chronically facing much of sub-Saharan Africa (including Senegal), extends the dry season and increases the severity of shortages. In contrast, when fresh fruits and vegetables are in season, they are in abundant supply. Some of the most perishable and plentiful fruits, such as mangoes, for

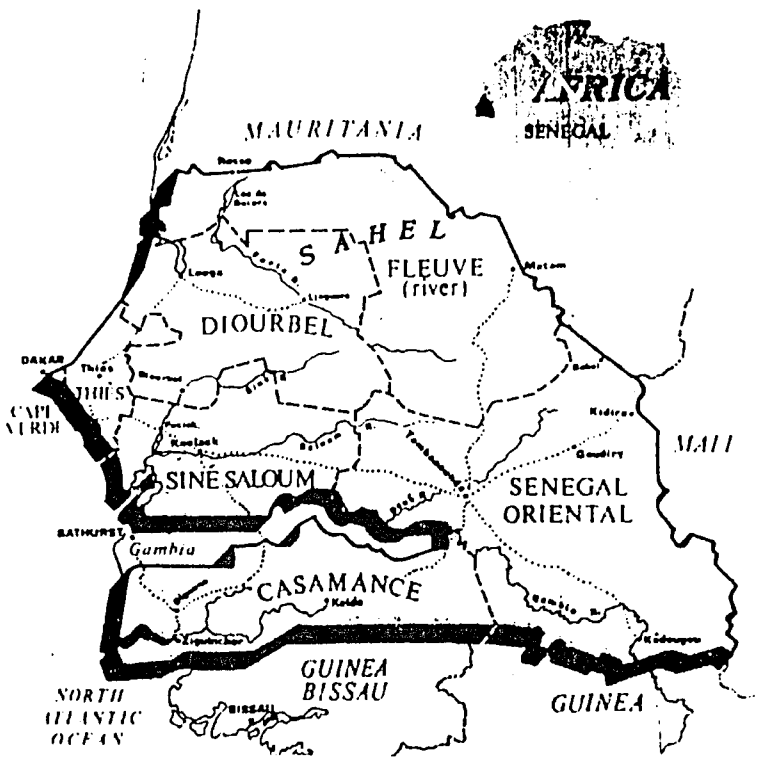

FIGURE 1 Map of Senegal

which there is no sufficient export market, either rot or must be sold at prices substantially below their market value. Market garden women in the Casamance region of Senegal estimate mango waste at about half while others claim that the amount that rots exceeds the amount eaten (Rankins, 1986).

Literature on the palatability and nutritional value of dried mango is scanty. Values reported for nutrients, especially B-carotene show a wide range of variability. Mango variety, stage of maturation, and processing methods have all been shown to influence acceptability and nutritional value (Amin and Bhatia, 1982; Gomez, 1980; Dabhade and Khedkar, 1980; Swanson, 1987; Rao and Susanta, 1980). The purpose of this study was to demonstrate to both policy makers and health/nutrition professionals, the potential nutritional value of solar dried mangoes for Senegal.

METHODS AND PROCEDURES

Mangoes

Three grafted varieties of mangoes (Divine, Sensation and Kent) were selected for study. The three varieties became available at different stages of the growing season. (Divine is an early variety and was available between May and June to mid-July; Sensation, semi-late, from the end of June to the end of July; and Kent, a late

variety, from the beginning of August to the beginning of September.) Mangoes were obtained from an orchard about 100-110km from Dakar. Nine trees (three for each of the varieties) were rented for the sole use of the project. The mangoes were harvested at a stage of physiological maturity, crated and transported immediately to the Food Technology Institute (ITA) in Dakar, where they were thoroughly washed. To achieve the desired stage of uniform ripeness and firmness, mangoes were placed in chambers and subjected to indirect complimentary maturation for 24 hours with 2,000 ppm ethylene, generated from burning charcoal. After the mangoes were removed from the maturation chambers they were held at room temperature or placed in a refrigerator at 12°C depending upon the degree of ripeness achieved.

Treatments

Matured mangoes were washed thoroughly several times in clean water and sorted to remove fruit which was bruised, over ripened, or torn. Fruits selected for study were weighed, manually peeled, sectioned away from the seed and thinly sliced (4-6mm thick): peel and seed weights were also determined to measure waste.

Mango slices from each of the three varieties were immersed for five minutes in one of seven solutions (or, in the case of the control Group IV, no treatment) which are listed below:

	A Without sulfite solution	B With sulfite solution (1%)
1% Citric Acid	Group I	Group V
20% Sucrose	Group II	Group VI
1% Citric Acid + 20% Sucrose	Group III	Group VII
Control	Group IV	Group VIII

Solar Drying

After treatment, mangoes were arranged on perforated trays in single layers without overlapping. Trays were placed on shelves in a greenhouse model walk-in solar dryer between 9 and 11 am and removed after 48 hours. The dryer was covered with a transparent polyethylene exterior, supported by wooden framing with cemented floor. It measured 4.5sqm and had a drying capacity of approximately 20kg of tray-ready fruit.

Dryer temperature generally ranged from 34 to 48°C over the 48 hour drying period. During the night the dryer ventilation outlet was left open. Dried mangoes (moisture content 9-11%) were immediately packaged in sanitary, plastic, prelabeled sacks, and heat sealed. Samples to be analyzed for nutrients (carotenoids, vitamin C and iron) were transported by airline with a courier to Tuskegee University.

Palatability

Indices of acceptability of dried mango slices subjected to the eight different study treatments were measured at the ITA sensory laboratory. A cadre of eight

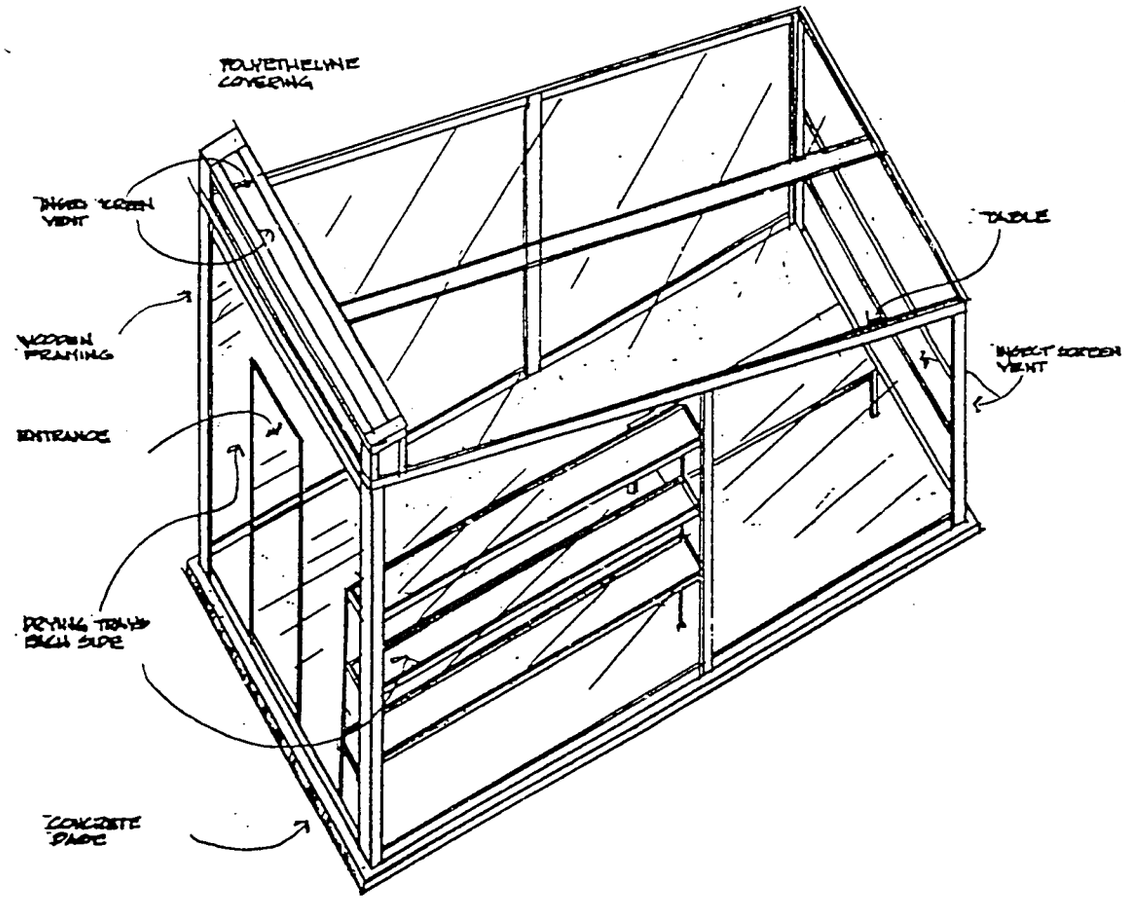

FIGURE 2 Mango solar dryer 4.5 sq.meters

experienced panelists evaluated samples dried on three different days. Evaluations were conducted on dried mango slices of the Divine variety (before and after six months storage), and after six months storage with Kent mangoes. Panelists were asked to score the dried mango slices on a scale of 1-5 for three sensory values: brightness, sweetness and overall acceptability.

Dried mango slices, as ingredients in several desserts (ice cream, sherbet, yogurt, pastry, cake) were also evaluated with both an American (n = 22) and Senegalese (n = 39) audience. Mangoes used in desserts for both of these audiences were untreated (control group IV). The Americans were US embassy staff and affiliates; Senegalese were government employees, chefs and food vendors. Desserts were prepared with dried or fresh mango of the Divine variety with the American audience who ranked them on a scale from 1-10. Only dried mangoes (Kent) were used in desserts with the Senegalese audience because fresh mangoes were out of season and not accessible; tasters evaluated the desserts as bad, good, very good or excellent. These tests were conducted within one month of storage. Where tasters (Senegalese audience) rated mango desserts as bad, good, very good or excellent, values recorded were tallied by respective categorical rating.

Nutrient Analysis

Mango samples were stored at ambient temperature in cardboard boxes and analyzed after four and six months. After storage, samples were placed in a drying oven at 72°C for 48 hours to complete dehydration. To assure uniform sampling, dried slices were then pulverized into a powder. Vitamin C was determined by titration (AOAC, 1980) and total carotenoids by the method of Reddy and Sistrunk (1980). Total carotenoids in mango samples were subsequently reduced by 50% to estimate B-carotene content of samples (John, *et al.*, 1970). Iron was determined by atomic absorption spectrophotometry after wet digestion of the samples with concentrated HNO_3 followed by the appropriate dilutions with demineralized water (Anonymous, 1971).

Statistical Analysis

Means were determined for each mango variety, storage period (four or six months), and each of the eight treatments. Between groups, comparisons were made using the Duncan's multiple range test (SAS Institute, 1985).

RESULTS AND DISCUSSION

Weight of mangoes ranged from 340-450gms and edible portions represented approximately 65 percent. Panelists showed no taste preference for mangoes pre-treated with 20% sugar solution over the controls (Table 1). Also, samples that had been dipped in sulfite (1%) and/or citric acid (1%) received brightness ratings similar to those which had not. Within treatments, neither variety nor storage influenced significantly any of the three variables. Overall, scores fell more in the upper half of the 1-5 point evaluation scale than the lower portion suggesting that the samples were "OK" or acceptable.

Based on western experience, higher taste scores were expected for mangoes pre-treated with the sugar solution. However, sugar is not extensively added to food in Senegal, especially fruits. The sweetness affinity cultivated in Western societies via advertising and food processing has so far occurred only marginally. Likewise,

TABLE I
Comparison of variety and storage means[a] within treatments and between treatment-control .

Samples[b]	Variables (on a scale of 1-4) Brightness	Sweetness	Overall acceptability
		1% Citric Acid	
A	3.20 ± 0.42	3.60 ± 0.42	3.56 ± 0.46
B	2.87 ± 0.37	2.65 ± 0.49	3.25 ± 0.35
C	2.00 ± 0.00	3.20 ± 0.28	3.45 ± 0.07
		20% Sucrose	
A	2.70 ± 1.13	3.00 ± 0.42	3.40 ± 0.00
B	2.67 ± 0.47	2.43 ± 1.65	2.60 ± 0.42
C	2.55 ± 0.35	2.65 ± 0.49	2.70 ± 0.42
		1% Sulfite	
A	3.30 ± 0.28	3.35 ± 0.63	3.75 ± 0.21
B	2.40 ± 0.57	3.10 ± 0.14	3.29 ± 0.07
C	2.40 ± 0.57	3.30 ± 0.14	3.30 ± 0.00
		Control	
A	2.85 ± 0.92	3.70 ± 0.14	3.25 ± 0.21
B	2.69 ± 1.00	2.65 ± 0.50	2.95 ± 0.78
C	2.60 ± 0.84	2.90 ± 0.14	3.20 ± 0.42

[a]Means within each treatment based on two observations. Comparison means were not significantly different at $p < .05$ probability using Duncan's multiple range test.
[b]A = Kent variety, dried and evaluated after six months storage.
B = Divine variety, dried and evaluated prior to storage.
C = Divine variety, dried and evaluated after six months storage.

preservatives are generally not used in local foods in Senegal to achieve and/or maintain color "perfection." This population, therefore, is likely to be less sensitive to the kind of browning that occurs with a highly pigmented fruit such as mango.

Dried slices (no additives) incorporated into tortes, cakes, ice cream, frozen yogurt, and flan, whether made with fresh or dried mangoes were ranked equally by a panel of Americans (Table II). The audience of primarily Senegalese food vendors and chefs also ranked dried mango desserts favorably. Six desserts tasted received 66 ratings of excellent, 50 of very good and 76 good. Thirty-nine persons scored items and only 1-5 rated any of the items tasted as bad (Table III).

In Table IV are shown the overall levels of study nutrients for the three varieties of mangoes after storage (four-six months). One hundred grams of dried mangoes contained 4410-5261 ug carotene, about 50% (2205-2630) is reportedly B-carotene (John, *et al.*, 1970). On this basis, B-carotene concentration is equivalent to 367-438 retinol equivalents (1 retinol equivalent = 6 ug B-carotene; Olson, 1986). Four hundred retinol equivalents/day are required for children (FAO/WHO, 1967). Vitamin C values per 100 gms meet requirements for children (20 mg/day) both before and subsequent to six months storage (FAO/WHO, 1970). Iron content ranged from 1.50 mg/100 g for Sensation and Divine to 2.39 for Kent. Carotenoid, ascorbic acid, and iron contents were significantly ($P < .01$) influenced by mango variety.

Only vitamin C was significantly ($P < .01$) influenced by storage time (four or six months). Predrying treatment caused no consistently significant influence on levels of any of the three nutrients measured (Table V).

TABLE II
Mean palatability scores for desserts made from fresh and dried mango slices of the Divine variety

Desserts[b]	Palatability score[a] (scale = 1-10; N = 22) Fresh mango	Dried mango
Ice cream	7.3 ± 1.0	7.3 ± 0.9
Sherbet	7.3 ± 0.9	8.3 ± 1.3
Cake	—	8.4 ± 1.1
Cocktail torte	—	8.0 ± 0.9
Open torte	7.9 ± 1.5	—
Frozen yogurt	—	7.5 ± 0.8

[a]Mean ± SD
[b]Demonstration: a few of the possibilities with dried mangoes, American Cultural Center, Dakar, Senegal, July 1987.

TABLE III
Palatability rating distribution for desserts made from dried mangoes of the Kent variety[a]

Desserts	Palatability rating (n = 31-39) Bad	Good	Very good	Excellent
Le Gâteau de Mangue (mango cake)	2	12	19	2
Le St. Romain (pastry)	3	10	6	3
Le Bisque Glacé (glazed biscuit)	3	12	8	3
Le Petite Tarte (tiny torte)	1	8	15	1
Le Tarte Tatine (torte)	5	7	18	5
Le Glace (ice cream)	2	9	10	2

[a]Seminar 'Potentials for solar dried mangoes,' Savana Hotel, Dakar, Senegal, October 1987

SUMMARY AND CONCLUSIONS

Results of this study show that solar dried mangoes are excellent sources of both B-carotene and vitamin C as well as a relatively good source of iron. There are more mango trees in the Casamance Region of Senegal than any other type of fruit tree and mango, by and large, is the most popular fruit among many Senegalese. Generally, the fruit is sold, eaten by the cultivator's family, or given away. Little is preserved and much of the harvest perish by rotting; all of the marketed preserved fruit are imported.

The sun is the only adequate source of affordable energy for most developing countries in the tropics, especially in remote rural food producing areas. Efficient and durable solar dryers for village level use are commonly constructed with local materials at a cost of $300 or less. There is improved probability of adoption of solar drying among villagers because: (1) food preservation by sun drying is widely practiced; and (2) the sun is available year round in the tropics at no cost. Sensory results suggest that pre-treatment dips are not necessary for local acceptance of dried mangoes. Actually certain food establishments expressed a preference and others insisted that mangoes be dried without additives.

In Tropical Africa, food shortages and dietary deficiences still present major problems for large population segments, especially children. Nevertheless, much

TABLE IV
Averaged mean nutrient values for three study mango varieties after four and six months of storage (A) and by treatment (B)

Mango varieties (Divine, Sensation, Kent)	Nutrient values[1] per 100gm dry weight: Total carotenoids (ug)	Ascorbic acid (mg)	Iron (mg)
	(A. Storage comparisons)[2]		
Storage period			
4 months	5124 ± 315[a]	35.5 ± 3.3[a]	1.7 ± 0.27[a]
6 months	5068 ± 197[a]	26.8 ± 2.5[b]	1.7 ± 0.22[a]
	(B. Treatment comparisons)[3]		
Treatment Solutions (w/o sulfite solution)			
1. 1% citric acid	5122 ± 317[a]	31.8 ± 4.5[a]	1.8 ± 0.14[a]
2. 20% sucrose	4916 ± 258[a]	29.2 ± 4.1[ab]	1.8 ± 0.20[a]
3. 1% citric acid + 20% sucrose	5030 ± 403[a]	31.3 ± 3.1[a]	1.7 ± 0.23[a]
4. Control	5058 ± 319[a]	29.6 ± 3.7[ab]	1.7 ± 0.08[a]
(w/1% sulfite solution)			
5. 1% citric acid	5075 ± 222[a]	32.5 ± 4.9[a]	1.7 ± 0.20[a]
6. 20% sucrose	5164 ± 249[a]	31.0 ± 3.8[ab]	1.6 ± 0.21[a]
7. 1% citric acid + 20% sucrose	5281 ± 271[a]	27.6 ± 4.1[b]	1.7 ± 0.15[a]
8. Control (1% sulfite only)	5133 ± 299[a]	28.3 ± 3.9[ab]	1.6 ± 0.17[a]

[1]Mean ± SD
[2]Values represent all treatments for the three varieties
[3]Values represent four and six months storage periods for the three varieties
[a,b]Any two means within columns with the same superscript are not significantly different at $p < .01$ probability using Duncan's multiple range test.

TABLE V
Mean nutrient values for the three varieties of mangoes

Mango varieties	N	Nutrient values[1] per 100gm dry weight: B-carotene (ug)	Ascorbic acid (mg)	Iron (mg)
Divine	48	5261 (±437)[a]	34.4 (±4.1)[a]	1.55 (±0.34)[b]
Sensation	14	4410 (±159)[b]	23.1 (±3.7)[b]	1.45 (±0.10)[b]
Kent	16	5200 (±173)[a]	23.5 (±2.0)[b]	2.39 (±0.25)[a]

[1]Mean ± SD
[a,b]Any two means within columns with the same superscript are not significantly different at $p < .01$ probability using Duncan's multiple range test.

food is wasted because of the lack of appropriate village level food preservation technologies. Solar drying can be readily adapted to developing environments. It, therefore, offers good potential for increasing food availability.

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