

MORPHOLOGICAL AND BIOCHEMICAL CHARACTERISTICS OF *AVERRHOA* FRUITS

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ABSTRACT

Averrhoa bilimbi, L. (bimbuli) and *Averrhoa carambola* (star fruit) [Oxalidaceae] are widely cultivated throughout tropical countries for their fruits. This study provides morphological and biochemical characteristics of mature *Averrhoa* fruits. Physical features such as color, texture, length, width, volume, weight, moisture and number of seeds and ridges of mature fruits were noted. The fruits are acidic and pH was low in *bilimbi* compared to star fruit. Oxalic acid is the main acid in *Averrhoa* spp. Greenish yellow mature fruits were dried and studied for proximate composition and minerals. Except for protein content all other biochemical nutrients studied were higher in *carambola*. Mature *Averrhoa* fruits are good source of minerals such as potassium, calcium, phosphorous and iron. *Averrhoa* fruits are low in calorie, sodium and lipids which qualifies it as an excellent source of natural antioxidants and minerals.

Keywords: *Averrhoa bilimbi*, *A. carambola*, proximate composition, minerals.

INTRODUCTION

Averrhoa bilimbi, L. (bimbuli) and *Averrhoa carambola* (star fruit) are the only two species belonging to the genus *Averrhoa*, family oxalidaceae. They are widely cultivated throughout tropical countries for their fruits¹. These unconventional fruits are easily available as backyard plants and are nutritionally rich. Young fruits are green in color which turns yellowish as they ripe. They can be eaten raw or are commonly used in the preparation of pickles and also as a substitute for tamarind in dishes. Mature fruits are commonly preserved in sugar or are cut, sun dried and preserved for future use. The fruit juice is sour and is used to prepare a beverage. *Bilimbi* fruits are used for cleaning utensils, and are very effective to remove iron rust from metals. *Carambola* can also be eaten raw, pickled or used in dishes similar to *bilimbi*. Ripened *carambola* are "sweet and sour" and used in preparation of juices unlike *bilimbi*. Star fruits are commercially utilized in the preparation of concentrated juices and soft drinks², fruit jams³. Both fruits are rich in vitamin

C, low in calorie and high in antioxidants which are very beneficial to human health. Now a days, research is oriented towards foods which are a good source of natural antioxidants. There is a lot of demand on natural sources of antioxidants and their potential for nutraceuticals and functional food^{2,4-6} and information about the nutrient composition of *A. carambola* and *A. bilimbi* is scarce. Hence, the present study is aimed at determining the physical features, proximate nutrients and mineral composition of mature green fruits of *Averrhoa* species.

MATERIALS AND METHODS

Fruits

Mature fruits of *Averrhoa bilimbi* and *A. carambola* were collected during January 2012. Mature green fruits were hand washed in distilled water and twenty healthy ones were selected for the study. Physical features, dimensions, volume, fresh and dry weight, number of seeds and ridges per fruit and thickness of ridge were recorded. Measurements were made using a vernier

calipers. Each fruit was cut into four pieces and dried at 60°C to a constant weight. Dried fruit pieces were ground (Wiley Mill, 30 mesh), sieved and stored in airtight containers in desiccators for biochemical analysis.

Proximate analysis

The moisture of the fruit powders were gravimetrically assessed on drying at 100°C until reaching constant weight. Total nitrogen and crude protein ($N \times 6.25$) were determined by micro-Kjeldhal method⁷. Crude lipid on Soxhlet extraction, crude fiber and ash were estimated based on the procedures outlined in AOAC⁸. Total carbohydrates and gross energy were calculated by the procedures outlined by Müller and Tobin⁹ and Ekanayake *et al.*¹⁰ methods respectively. Fresh fruits were crushed, juice collected for determining pH at 25 °C.

Mineral composition

For extraction of minerals, the fruit powder was ashed, digested with HCl (1:4 v/v) and filtered. Sodium, Potassium, Calcium, Magnesium, Iron, Copper, Zinc, Manganese and Selenium were estimated by Atomic Absorption Spectrophotometer⁸ (GBC 932 plus, Australia). Total phosphorus was determined by ascorbic acid method¹¹. The absorbance was read at 690nm (Spectrophotometer, Hitachi Japan).

Statistical analysis

Differences in physical features, proximate composition and minerals of *A. bilimbi* vs *A. carambola* were assessed by paired t-test using the statistical software GraphPad Prism for Windows version 2.01 (GraphPad Software Inc, San Diego, California).

RESULTS AND DISCUSSIONS

Fruit features

Morphological features of the mature *Averrhoa* fruits are presented in Table 1. Physical parameters of fruits are important indicators of their maturation. *Bilimbi* fruits are crisp and firm when raw and soften as they ripe. The mature fruits are greenish yellow in color with firm texture. *Bilimbi* fruits weigh 10.41g with 94.81% moisture, 4.95, 1.94 and 2.04 cm length, width and

thickness respectively. The process of ripening in star fruits is studied and reported that color determines the stage of fruit ripeness and they are classified based on color as green-mature, half-ripe and ripe^{12, 13}. Physical features, physico-chemical and chemical characteristics of star fruits at different stages of maturity have been reported¹³. Characteristic features of mature *carambola* fruits were comparable with available literature¹³ 47.07 vs 59.23g fresh weight, 94.22 vs 90.32% moisture, 6.89 vs 7.65 cm length of fruit. Physical features of *Averrhoa* fruits qualify its suitability as a vegetable for human consumption.

Proximate composition

The biochemical composition of *Averrhoa* fruits are presented in Table 2. Except for protein content (0.9 vs 0.53%) all other parameters were higher in *carambola* compared to *bilimbi*. Crude protein content of star fruits (0.53%) was within the published range (0.34 – 0.73%)¹⁴, but more than data provided by Narain *et al.*¹³ (0.39 – 0.45%). Crude lipid fraction (0.32%) was parallel to values of Narain *et al.*, 2001¹³ (0.29 – 0.32%) but very low (0.023 – 0.027%) when compared to the range given by Moreschi *et al.*¹⁴. Crude fiber composition is within the reported values (1.01 vs 1.08%)¹³. The fruits are acidic which is confirmed by low pH values. The pH was less (2.76) in *carambola* compared to reported literature (3.4 – 3.6¹⁵; 3.3 – 3.5¹⁶, and 2.4 – 3.44¹³), and very low in *bilimbi* (0.9 – 1.5)¹⁷.

Mineral composition

Table 3 shows the mineral constituents of mature *Averrhoa* fruits. All minerals except iron and copper were higher in *carambola*. Sodium, potassium, calcium, phosphorous and magnesium were major minerals. Iron, zinc and manganese are considered antioxidants¹⁸, which strengthens the immune system. Low sodium content of the fruits is favorable for consumption by hypertensive patients. Overall mineral composition is on par with the published data^{13, 14}. The variations in proximate and mineral compositions observed may be due to environmental conditions, soil fertility, ripening stage, climate and harvesting season.

Table 1: Physical features of mature fruits of *Averrhoa* species (n=20) (mean \pm SD)

Physical features	<i>Averrhoa bilimbi</i>	<i>Averrhoa carambola</i>	<i>Averrhoa carambola</i> *
Color	Greenish yellow	Greenish yellow	Yellowish green
Texture	Firm	Firm	Firm
Fresh weight (g/fruit)	10.41 \pm 0.87 ^a	47.07 \pm 0.38 ^{bc}	59.23 \pm 16.36 ^{bd}
Dry weight (g/fruit)	0.55 \pm 0.17 ^a	4.59 \pm 0.81 ^{bc}	-
Moisture (%)	94.81 \pm 0.43 ^a	94.22 \pm 1.75 ^{ac}	90.32 \pm 0.98 ^{bd}
Length (cm)	4.95 \pm 0.54 ^a	6.89 \pm 0.83 ^{bc}	7.65 \pm 0.58 ^{bd}
Width (cm)	1.94 \pm 0.18 ^a	3.93 \pm 0.43 ^{bc}	-
Thickness (cm)	2.04 \pm 0.17 ^a	2.7 \pm 0.52 ^{bc}	-
Volume (ml)	9.54 \pm 0.48 ^a	31.67 \pm 0.7 ^{bc}	-
No. of seeds per fruit	6.7 \pm 0.88 ^a	5.35 \pm 0.87 ^{bc}	4.89 \pm 1.81 ^{bc}
No. of ridges per fruit	5.45 \pm 0.76 ^a	4.85 \pm 0.37 ^{bc}	4.9 \pm 0.31 ^{bc}
Mean thickness of ridge per fruit	1.03 \pm 0.12 ^a	1.57 \pm 0.37 ^{bc}	-

* Narain et al., 2001²

Figures across the column with different letters are significant (p<0.03, paired t-test)

Table 2: Proximate composition of mature fruits of *Averrhoa* species on dry weight basis (g 100 g⁻¹ except where stated; n=5; mean \pm SD)

Component	<i>Averrhoa bilimbi</i>	<i>Averrhoa carambola</i>	<i>Averrhoa carambola</i> *
Crude Protein	0.9 \pm 0.14 ^a	0.53 \pm 0.04 ^{bc}	0.40 \pm 0.02 ^{bd}
Crude lipid	0.27 \pm 0.06 ^a	0.32 \pm 0.02 ^{bc}	0.29 \pm 0.02 ^{ad}
Crude fiber	0.96 \pm 0.02 ^a	1.01 \pm 0.09 ^{bc}	1.08 \pm 0.34 ^{ac}
Ash	0.33 \pm 0.02 ^a	0.34 \pm 0.02 ^{ac}	0.33 \pm 0.25 ^{ac}
Total carbohydrates	9.75 \pm 0.12 ^a	9.78 \pm 0.1 ^{ac}	-
Energy value (kJ 100 g ⁻¹)	135.02 \pm 0.56 ^a	154.18 \pm 0.51 ^{bc}	-
pH	2.16 \pm 0.11 ^a	2.76 \pm 0.18 ^{bc}	2.71 \pm 0.33 ^{bc}

* Narain et al., 2001²

Figures across the column with different letters are significant (p<0.03, paired t-test)

Table 3: Mineral composition of mature fruits of *Averrhoa* species on dry weight basis (mg 100 g⁻¹) (n=5; mean \pm SD)

Mineral	<i>Averrhoa bilimbi</i>	<i>Averrhoa carambola</i>	<i>Averrhoa carambola</i> *
Na	2.1 \pm 0.02 ^a	3.8 \pm 0.05 ^{bc}	-
K	103.03 \pm 0.04 ^a	167.13 \pm 0.16 ^{bc}	-
Ca	2.03 \pm 0.09 ^a	6.37 \pm 0.06 ^{bc}	3.55 \pm 0.85 ^{bd}
P	15.4 \pm 0.04 ^a	17.87 \pm 0.11 ^{bc}	21.62 \pm 3.43 ^{bd}
Mg	3.45 \pm 0.12 ^a	11.85 \pm 0.48 ^{bc}	-
Fe	0.74 \pm 0.23 ^a	0.34 \pm 0.27 ^{bc}	0.52 \pm 0.24 ^{bd}
Cu	0.79 \pm 0.16 ^a	0.19 \pm 0.35 ^{bc}	-
Zn	0.22 \pm 0.08 ^a	0.29 \pm 0.22 ^{ac}	-
Mn	0.02 \pm 0.11 ^a	0.04 \pm 0.47 ^{ac}	-
Se	ND	ND	-

ND – Not detectable

* Narain et al., 2001²

Figures across the column with different letters are significant (p<0.03, paired t-test)

*Averrhoa bilimbi**Averrhoa carambola***Fig. 1: Mature fruits of *Averrhoa* species****CONCLUSION**

Physical properties and dimensions of mature *Averrhoa* fruits are ideal as green vegetable for human consumption. This study reveals that mature *Averrhoa* fruits are acidic, with high fiber content. They are high in minerals such as calcium, phosphorous, iron and potassium. Published data show that *Averrhoa* fruits are rich source of vitamin C, antioxidants and are low in fat. The available information on the toxic effects of star fruits in uremic patients may be attributed to its oxalic acid content. Studies on different methods of processing to reduce the acidic content of these fruits may be helpful in wide acceptance of these fruits as a source of natural antioxidants and mineral supplements.

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