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PRODUCTION AND CHARACTERIZATION OF CARAMBOLA ESSENCE

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Abstract. **The carambola (*Averrhoa carambola* L. cv. Arkin), also known as star fruit, was obtained from a South Florida packinghouse, and the juice extracted with an FMC citric juice finisher. The juice was then concentrated to 62° Brix using a 3-effect, 4-stage pilot-plant TASTE citrus evaporator equipped with an essence recovery unit. The recovered essence possessed an unripe apple-like or apricot-like aroma note. Carambola essense was examined by gas chromatography-mass spectrometry and revealed ethyl acetate, *trans*-2-hexenal, *cis*-3-hexenol, *trans*-2-hexenol, n-hexanol and several minor alchols, esters and terpenes. The pleasant aromatic property of carambola essense suggests potential commercial utilization in fruit juices and drinks.**

The carambola (*Averrhoa carambola* L.), also known as star fruit and other names specific to different geographic locations, is thought to have originated in Sri Lanka and the Moluccas (7). The fruit is ovoid to ellipsoid, 6-15 cm in length, with 5 (rarely 4 or 6) prominent longitudinal ribs, and star-shaped in cross section. The flesh is light yellow to yellow, translucent and very juicy. Wagner et al. (11) reported ascorbic and oxalic acid contents, acidity, Brix, and taste panel evaluation for carambolas that were mostly of the yellow varieties. Campbell et al. (3) reported postharvest changes in color and compositional characteristics (soluble sugars, organic acids) in 'Arkin' and 'Golden Star' carambolas.

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The flavor of carambola is variable, and ranges from sour with little sugar to sweet with little acid (4, 11). Few studies on the identity and quantitative approximation of volatile flavor components of carambolas have been reported (12). Siota (10) and Wilson et al. (13) reported GLC area percentages for volatile components from solvent extracts of carambola purees. In the study by Wilson et al. (13), 43 volatiles were enumerated, namely, 13 alcohols, 4 aldehydes, 6 ketones, 13 esters, 3 hydrocarbons and 4 compounds classified as miscellaneous.

In this study, an attempt was made to evaluate the adaptation of commercial citrus processing equipment for potential application in tropical fruit processing. We report for the first time, the volatile composition and aroma quality of carambola essence prepared by a 3-effect, 4-stage TASTE citrus evaporator. This study should enhance our knowledge for potential commercialization of carambola products, especially carambola essense and juice.

Materials and Methods

Samples. Ripe carambolas (cv. 'Arkin') were obtained from a major South Florida packinghouse (J. R. Brooks and Sons, Homestead) and transported to the Citrus Research and Education Center, Lake Alfred, FL. The fruit were stored at 40°F until processing.

Processing. The juice was extracted from the fruit at about 40°F using a screw-type finisher (FMC Model 35 finisher with reinforced .027 finisher screen openings). The juice was then concentrated to 62°Brix. The carambola concentrate was produced using a 3-effect, 4-stage TASTE citrus evaporator capable of evaporating 500 lbs of water per hour (5, 8). The TASTE citrus evaporator was equipped with an essence recovery system that recovered the carambola essence (2). The TASTE citrus evaporator was designed to pasteurize juice at about 212°F for 10 sec, which is sufficient for most fruit juice processing.

Essence Analyses. Samples were chromatographed on a Hewlett-Packard Model 5890 gas chromatograph fitted with a 0.32 mm i.d. x 30 m bonded-phase, nonpolar RTX-5 fused silica capillary column (film thickness 1 micron) (Restek Corp., Bellefonte, PA). Operational parameters included: injection port and flame ionization detector set at 240°C and 250°C, respectively. The carrier gas (hydrogen) flow rate was 41 cm/sec, and the injection split ratio was 50:1. Sample components were resolved by temperature programming the column, namely: samples injected at a temp. of 32°C and held 3 min; then temp. programmed from 32°C to 230°C at 7.5°C/min; and, finally, held at 230°C for 1 min. Essence components were identified by comparison to retention times of authentic compounds and/or by mass spectral identifications.

Mass spectral work was conducted on a gas chromatograph-mass spectrometer system consisting of: (a) Carlo Erba Fractovap 4200 gas chromatograph retrofitted with a J & W on-column injector (J & W Scientific, Folsom, CA) and a Hewlett-Packard split-splitless injector operating at a 10:1 split ratio, (b) a Kratos MS 25 magnetic sector, double focusing, mass spectrometer, and (c) a Teknivent Vector 1 data acquisition system (Teknivent, St. Louis, MO). Mass spectral searches were performed with both the Wiley/NBS and National Institutes of Science and Technology (NIST) mass spectral data bases. The capillary column was a Restec RTX-5 capillary column (.25 mm i.d. x 30 m long). Gas chromatograph programming: initial temp. at 25°C for 3 min, temp program from 25°C to 220°C at 6°C/min, and hold at 220°C for 5 min. Carrier gas (hydrogen) flow was 24 cm/sec. Mass spectral scanning was conducted at 0.7 sec/dec under the following parameters: 2 KV accelerating voltage, 70 eV ionization voltage, 200°C source temp. and GC-MS transfer line was at 210°C.

Results and Discussion

In Florida, the main crop of carambolas usually matures from late summer to early winter (7). Although trees fruit heavily in November and December, they also fruit again in March and April. In our study, carambola fruit from a March harvest was processed on March 12, 1990 and a second crop harvested in October was processed on October 30, 1990. The alcohol content of the aqueous essence prepared from fruit of the March harvest was 2.4%, whereas the alcohol content of the October harvest was only 0.1%.

The volatile constituents determined in the carambola aqueous essences of the two harvests (A and B) are enumerated in Table 1. Also listed are peak numbers, GC retention times and relative area percentages. Twenty-three compounds were identified by GC/MS and/or by comparison to GC retention of authentic compounds. Figure 1 is a representative GC profile of aqueous carambola essence, whereas Figure 2 is a profile of natural orange aroma recovered from a commercial TASTE evaporator. Both profiles are presented to illustrate the similarities and differences of both types of fruit aromas, namely, carambola and orange.

The aroma of carambola aqueous essence recovered from the TASTE essence recovery unit possessed a sweet, fruity apricot-like or unripe apple-like note. Wilson et al. (13) noted that the aroma of the essence extracted from carambola puree by methylene chloride extraction possessed a strong floral fruit aroma (grape-like, fruity and aromatic). Many compounds identified by Wilson et al. (13) from carambola puree extract were the same as recovered by our essence recovery unit, but many others were not detected. The solvent, methylene chloride, extracts slightly polar and nonpolar organics. It is not an effective extractant for highly polar compounds, e.g., water, ethanol and methanol. In contrast, the essence recovery unit of a TASTE separates essence into two phases: an oil phase (essence oil) and an aqueous essence phase (aroma). However, essentially no carambola oil phase was obtained with the essence recovery unit, but we did obtain an aqueous essence phase (carambola aroma).

As noted in Table 1 for total organic constituents, methanol plus ethanol comprised about 90% (sample A) and 56% (sample B) of the carambola aromas recovered by the TASTE essence recovery unit. In contrast, Wilson et al. (13) did not report the presence of methanol and ethanol by methylene chloride extraction of carambola puree.

Table 1. Carambola Essence Constituents recovered by the Essence Unit of the TASTE Citrus Evaporator.

GC No.	Component	RT, min	Rel. area% A[x]	Rel. area% B[y]
1	acetaldehyde[z]	1.38	0.60	15.66
2	methanol[z]	1.38	3.64	2.14
3	ethanol	1.70	86.28	54.61
4	acetone	1.97	0.26	0.06
5	2-propanol	2.00	1.23	0.40
6	methyl acetate	2.37	0.02	0.37
7	1-propanol	2.78	0.06	0.10
8	ethyl acetate	3.87	0.70	2.51
9	2-methyl-1-propanol	4.20	0.06	0.23
10	1-butanol	5.16	0.02	tr
11	1-penten-3-ol	5.62	0.05	0.35
12	3-methyl-1-butanol	7.15	0.01	0.11
13	1-pentanol	8.21	0.02	tr
14	hexanal	8.95	0.02	0.37
15	ethyl butyrate	9.00	0.01	0.08
16	*trans*-2-hexenal	10.52	4.79	13.80
17	*cis*-3-hexen-1-ol	10.61	0.39	0.58
18	*trans*-2-hexen-1-ol	10.89	1.09	1.74
19	1-hexanol	10.94	0.30	1.06
20	1-octanol	16.11	0.03	0.18
21	linalool	16.88	0.03	0.18
22	α-terpineol	19.12	0.02	0.14
23	carvone	20.30	0.02	0.08

[x]A - sample processed March 12, 1990.
[y]B - sample processed October 30, 1990.
[z]Acetaldehyde and methanol were resolved on 6' x 1/4" glass column packed with 5% Carbowax 20M on 80/120 mesh Carbopack BAW by Florida Distillers, Lake Alfred.

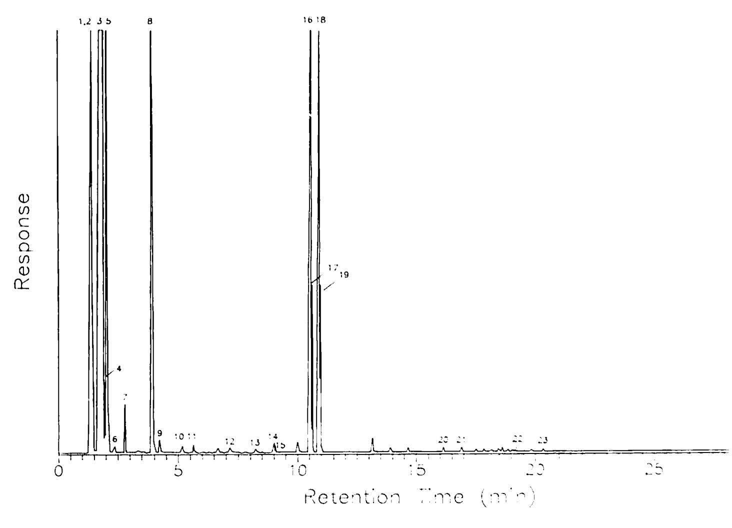

Fig. 1. Gas Chromatographic Profile of Carambola Essence

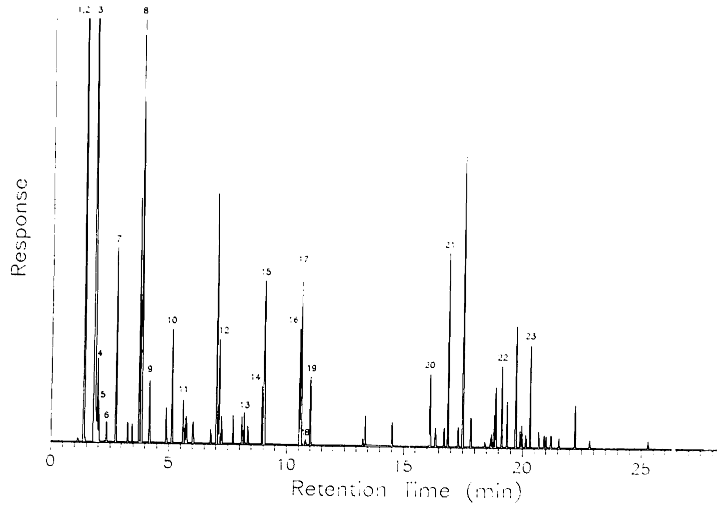

Fig. 2. Gas Chromatographic Profile of Natural Orange Aroma

The pleasant fruity, green, unripe apple-like note of carambola essence is apparently the result of a combination of acetates (methyl acetate and ethyl acetate) which impart a pleasant, fruity-sweet odor and compounds (hexanal, *trans*-2-hexenal, *cis*-3-hexen-1-ol, *trans*-2-hexen-1-ol and 1-hexanol) which impart fresh green, grassy, unripe notes (Table 2). The odor description of acetaldehyde is that of a pungent, penetrating ethereal note. Its aroma role in carambola essence is not defined; however, its aroma impact role in natural orange aroma and orange juice flavor is quite important and has been well documented (9). The dominant alcohols, methanol and ethanol, impart a slight, sweet-ethereal note. Since the odor of ethanol is perceptible in aqueous solutions down to about 12% (1), it may not be important at the low concentration levels (2.4% and 0.1%) found in the two carambola essences. Although methanol and ethanol do not impact directly on the aroma note of carambola essence, they may increase overall aroma perception by enhancing (lifting) other aroma components (1) as occurs in perfume formulations.

Carambola aroma (Figure 1) differs from orange aroma (Figure 2) by the noticeably low levels of oxygenated terpenes (retention times between 14 and 26 minutes). Wilson (12) in his comprehensive treatise of carambola and bilimbi also noted surprisingly low concentrations for the oxygenated terpenes. Although terpenes (oxygenated and nonoxygenated) are present in carambola fruit, their impact on overall flavor appears minimal because of their very low concentrations (10).

The major volatile flavor constituent extracted from carambola puree by Wilson et al. (13) was methyl anthranilate (21.2%), whereas Siota (10) reported ethyl anthanilate (11.1%) as the major volatile. Anthranilate esters impart a grape-like note. In our work, we could not detect anthanilate esters in our aroma fractions by either GC or GC/MS.

Table 2. Odor Descriptions for Selected Constituents in Carambola Essence.

Constituent	Odor Description (6)
acetaldehyde	pungent, penetrating ethereal-nauseating odor
methanol	mild sweet etheral-like
ethanol	alcoholic, sweet ethereal
2-propanol	alcoholic, somewhat unpleasant odor
methyl acetate	pleasant, fruity odor
ethyl acetate	fruit-sweet, pleasant, ether-like reminiscent of pineapple
hexanal	fatty green grassy, unripe fruit
trans-2-hexenal	pleasant fruity, fresh green, leafy odor
cis-3-hexen-1-ol	intense green, grassy odor
trans-2-hexen-1-ol	powerful, fruity, green, leafy odor
1-hexanol	mild, sweet, green

The carambola essence obtained by our TASTE essence recovery unit has a very pleasant fruity, green apple-like note. The potential use of this flavor fraction in beverage formulations appears promising. Exploitation of the use of commercial citrus processing equipment and facilities in processing carambola, as well as other nontraditional tropical fruits, awaits future developments and entrepreneurial interests.

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