A Comparative Study of Fatty Acid Profiles of *Passiflora* Seed Oils from Uganda

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ABSTRACT: A comparative study is presented of the FA composition (FAC) of the seed oils from the yellow passion fruit *Passiflora edulis* Sims var. *flavicarpa* (**I**), the purple fruit *Passiflora edulis* Sims var. *edulis* (**II**), the purple *Kawanda* hybrid, which is a cross between **I** and **II** (**III**), and the light-yellow apple passion fruit *Passiflora maliformis* L. (**IV**) grown in Uganda. Oil yields from the four varieties were between 18.5 and 28.3%. A GC analysis of the oils showed the most dominant FA to be linoleic (67.8–74.3%), oleic (13.6–16.9%), palmitic (8.8–11.0%), stearic (2.2–3.1%), and α-linolenic (0.3–0.4%) acids. The unsaturated FA content in the oils was high (85.4–88.6%). Iodine values of the seed oils of **I**, **II**, **III**, and **IV** calculated from the FAC were 133, 141, 133, and 138, respectively. The FAC and the iodine value of the seed oil in **III** are distinctly closer to the rootstock (**I**) than the scion (**II**). This indicates that the rootstock influence on the FAC of passion fruit seeds is graft-transmissible. The study further confirms that passion fruit seed oils represent a good source of essential unsaturated FA.

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KEY WORDS: Fatty acid composition, grafting, iodine value, Ugandan passion fruit seed oils.

There are over 500 species worldwide of *Passiflora* in the family Passifloraceae. Of these, the fruits of only about 20 varieties are edible, and only about four varieties are cultivated on a large scale, namely, *Passiflora edulis* Sims, P. *ligularis* Juss., *P. molissima* Bailey, and *P. quadrangularis* L. Of these four varieties, only *P. edulis* is of significant commercial value (1). Two subvarieties of *P. edulis* Sims, namely, the purple passion fruit (*P. edulis* Sims var. *edulis*) and the yellow passion fruit (*P. edulis* Sims var *flavicarpa*), grow prolifically in many parts of Uganda. The yellow form has a more vigorous vine, a generally larger fruit, and a higher proportion of juice than the purple, but the pulp of the purple is richer in aroma and flavor (2). However, unlike the yellow variety, the purple passion fruit is particularly vulnerable to various *Fusarium* wilts caused by forms of *Fusarium oxysporium* and root and collar rot by *Fusarium solani* (3,4).

To increase resistance to soil-borne fungal diseases in the purple passion fruits, a scion of the purple variety is grafted onto the rootstock of the yellow passion fruit to produce the high-yielding *Kawanda* hybrid (5). This hybrid has been added to the passion fruit varieties available on the local fresh fruit market. Of less commercial significance on the local market but of growing importance for breeding purposes is the light-yellow, hard-shelled sweet calabash passion fruit, *P. maliformis*. This variety, also referred to as the sweet calabash, conch apple, or apple-fruited granadilla, grows wild and is common in many parts of Uganda. It has a pleasingly aromatic flavor and is very resistant to pests and diseases that affect its relatives (6). The growing demand for fresh passion fruits on the local market and for export offers revenue-earning opportunities for Ugandan farmers.

Locally, the potential of passion fruits as a source of essential PUFA in the human diet has received no attention because passion fruit seeds, which contain most of the PUFA in the fruit, are usually discarded after extraction of the juice from the fruit. But studies conducted elsewhere suggest that seeds of *P. edulis* Sims var. *edulis* and *P. edulis* Sims var. *flavicarpa* might represent novel sources of premium-grade edible oils with varying contents of unsaturated FA (6–8). Oil content and FA composition (FAC), e.g., iodine value and the ratio of oleic (C18:1) to linoleic (C18:2) acids, are widely used as reliable criteria for the stability of oils to oxidation and oil flavors (9). In addition, the FAC, in part, determines the value and suitability of any seed oil for nutritional or industrial purposes (9).

To date, no research has been reported on the FAC of the seed oils from passion fruit varieties commonly produced in Uganda. Knowledge of the FAC of the passion fruit seed oils could open new avenues for exploiting these oils for edible and/or technical purposes. Furthermore, the effect of grafting *P. edulis* Sims var. *edulis* onto the rootstock of *P. edulis* Sims var. *flavicarpa* on the FAC of the seed oil of the Kawanda hybrid has not been investigated. Yet this relatively easy and cheap biotechnological process might provide alternative ways of incorporating desirable attributes, such as altering the FAC in a new crossbreed. The purpose of this study was therefore to determine and compare the FAC of seed oils from passion fruit varieties commonly grown in Uganda. Knowledge of the FA profiles of these seeds could lead to the exploitation of these seeds as an additional dietary source of essential PUFA.

EXPERIMENTAL PROCEDURES

Reagents and standards. All reagents were of analytical reagent grade. FA standards were purchased from Sigma-Aldrich (Diesenhoven, Germany), and solvents (heptane,

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methanol) were purchased from Fluka (Neu-Ulm, Germany). Heptane was UV grade, and other solvents were distilled in glass-quality apparatus. Distilled water was used for the analyses.

Fruit collection. Seedlings of the yellow (*P. edulis* Sims var. *flavicarpa*), purple (*P. edulis* Sims var. *edulis*), and grafted (Kawanda hybrid) passion fruits were obtained from Mityana District Farm Institute in Mubende district, Uganda. Kawanda hybrid was obtained by grafting the purple passion fruit scion onto the yellow variety rootstock. These vines were planted at a private farm in Mubende in March 2001. Ripe yellow, purple, and Kawanda hybrid passion fruits were collected from the ground after they had fallen off their respective vines between March and September 2002. The sweet calabash passion fruits (*P. maliformis* L.) were obtained from a private farmer in Mubende district between June and September 2002.

Separation and drying of seeds. The yellow, purple, or Kawanda hybrid passion fruits were cut with a knife into two parts. The sweet calabash passion fruit was split into two using a nutcracker. The fruit pulp was transferred and blended with a Moulinex Turbo Blender (Model D70; Cologne, Germany). The juice was strained, and the seeds were collected separately, washed several times with water, cleaned to remove foreign materials such as fibers, and dried to a constant weight in a solar dryer.

Extraction of passion fruit seed oils. Sun-dried passion fruit seeds from the four *passiflora* varieties were separately ground using a mortar and pestle. About 20 g of the finely ground seed material was weighed into six separate reservoirs. Petroleum ether (150 mL; b.p. 40–60°C) was introduced into each reservoir. Oil was extracted from the seed material by using an automatic Soxhlet apparatus (Soxtherm 2000 automatic; Gerhardt, Germany). The operating conditions of the Soxhlet apparatus were as follows: initial mass, 20 g; disintegration time, 120 min; solvent reduction time A, 6×15 min, extraction time 90 min; solvent reduction time B (period in which solvent is reduced to dryness), 15 min; solvent reduction time C (period in which glass reservoir is lifted from the heating plate and allowed to cool with slight solvent reduction), 10 min. To complete the oil extraction stages, the oil-containing reservoirs were dried first on a laboratory sand bath (110°C, 30 min) followed by a cabinet drier (80°C, 120 min). The extraction of the seed oil was done in triplicate.

GC determination of the FAC. The FAC of the four seed oils were determined as their FAME using GC. FAME were prepared as follows: 1 mL of methanolic potassium hydroxide (0.5 mol) was added to 20 mg of the seed oil in a boiling tube. The mixture was boiled for 5 min at 90°C. One milliliter of a boron trifluoride/methanol solution (14–16%) was added and boiling was continued for another 5 min. The boiling tube contents were allowed to cool. Two milliliters of saturated sodium chloride and 2 mL of heptane were then added; the mixture shaken well and allowed to separate. A 1-µL aliquot of the organic layer was injected directly into a PerkinElmer Autosystem XL gas chromatograph.

The gas chromatograph was equipped with a DB 23-Megabore column (50% cyanopropyl, 50% methyl silicone; i.d., 0.53 mm, film thickness 0.5 µm, length 30 m; J&W Scientific Products, Cologne, Germany) and an FID. The injector temperature was set at 200°C, detector at 230°C, and oven at 50°C initially. The oven temperature program was as follows: 50°C (hold 2 min), 8°C/min, 220°C (hold 8 min). The carrier gas was helium with a flow rate of approximately 50 mL/s. A mixture of FAME standards was used to identify and quantify the FAME in the various lipid extracts. FAME are reported as averages of three determinations conducted on three independent assays.

The FAME compositions of these seed oils were calculated using Equation 1:

$$FA_i[\%] = \frac{P_i}{\Sigma P_i} \times 100 \qquad [1]$$

where FA_i = ratio of component i corresponding to the FA mixture and P_i = peak area(s).

To determine the retention times of FAME, it was necessary to inject a standard mixture into the gas chromatograph. This mixture included, in ascending order of retention times, the following FAME: C4:0, C5:0, C6:0, C8:0, C10:0, C12:0, C14:0, C16:0, C16:1, C18:0, C18:1, C18:2, C18:3-γ, C18:3-α, C20:0, C20:1, C22:0, C22:1, C24:0, and C24:1.

RESULTS AND DISCUSSION

Oil content in Passiflora *seeds.* The highest oil yield was found in the *P. maliformis* L. seeds (28.3%), and the least was obtained from the seeds of *P. edulis* Sims var. *edulis* (18.5%) (Table 1). The oil contents of the *P. edulis* Sims var. *flavicarpa* and the Kawanda hybrid seeds were 20.6 and 21.4%, respectively. Studies conducted in other countries have shown that seeds from *P. edulis Sims* var. *edulis* and *P. edulis* Sims var. *flavicarpa* yield oil in the range of 21–29% (8,10). But differences in the seed oil content may exist even within the same fruit variety. For example, Debideen and Sammy (11) reported a seed oil yield of 24.8% from *P. edulis* Sims var. *edulis*, whereas Lopez (7) obtained a seed oil content of 29.4% in the same variety. Differences in oil yields, even within the same variety or subvariety, have been attributed mainly to climatic and geographical differences in the oil crop growing areas (12).

FAC of the passion fruit seed oils. The GC analysis of the FA in the four species of passion fruit seed oils established the presence of six saturated and six unsaturated FA. Linoleic acid (C18:2), oleic acid (C18:1), palmitic acid (C16:0), and stearic acid (C18:0) were the major FA. In all four passion fruit seed oils, C18:2 was the most dominant FA, ranging between 67.8 and 74.8% (Table 1). Oleic acid (C18:1) was the second most dominant FA in the seed oils and ranged between 13.6 and 16.9%. Palmitic (C16:0) and stearic (C18:0) acids exhibited the third- and fourth-highest FA contents and ranged between 8.8 and 11.0 and 2.2 and 3.0%, respectively. The rest of the FA, i.e., myristic (C14:0), palmitic (C16:0),

TABLE 1
Quality Characteristics of Passion Fruit (*Passiflora*) Seed Oils[a]

Oil characteristics	*P. edulis* Sims var. *flavicarpa*	*P. edulis* Sims var. *edulis*	Kawanda hybrid	*P. maliformis* L.
Oil yield (%)	20.6 ± 0.1	18.5 ± 0.2	21.4 ± 0.3	28.3 ± 0.2
C16:0 Palmitic	11.0 ± 0.0	8.8 ± 0.0	10.7 ± 0.1	9.2 ± 0.1
C18:0 Stearic	3.1 ± 0.0	2.2 ± 0.0	2.6 ± 0.0	2.3 ± 0.0
C18:1 Oleic	16.9 ± 0.0	13.6 ± 0.1	16.8 ± 0.0	15.3 ± 0.2
C18:2 Linoleic	67.8 ± 0.2	74.3 ± 0.3	67.9 ± 0.2	71.9 ± 0.3
C18:3 α-Linolenic	0.4 ± 0.0	0.4 ± 0.0	0.3 ± 0.0	0.3 ± 0.0
Unsaturated FA (%)	85.4 ± 0.2	88.6 ± 0.3	85.8 ± 0.3	87.9 ± 0.2
Iodine value	133.0 ± 0.3	141.1 ± 0.3	133.0 ± 0.3	138.2 ± 0.2
Oleic/linoleic ratio	0.3 ± 0.0	0.2 ± 0.0	0.3 ± 0.0	0.2 ± 0.0

[a]Each value is the mean ± SD of triplicate extractions and determinations.

margaric (C17:0), α-linolenic (C18:3), arachidic (C20:0), gadoleic (C20:1), behenic (C22:0), and erucic (C22:1), were present in trace amounts (<1%).

Differences in the FAC of the seed oil may exist even within the same passion fruit variety. For example, Debideen and Sammy (11) reported that the dominant FA in the seed oils of *P. edulis* Sims var. *flavicarpa* in Trinidad and Tobago was oleic acid with a composition of 69%. They further observed that a comparison with the Hawaiian *P. edulis* Sims var. *flavicarpa* fruit seed oil showed some differences in the contents of both the unsaturated and saturated FA. But Gaydou and Ramanoelina (13) identified the dominant FA in the seed oil of *P. edulis* Sims var. *flavicarpa* as linoleic acid, in the 57.2–64.4% range (13). The results of the two research groups differ significantly with respect to the major FA in the seed oil of the yellow passion fruit variety.

In our study, the seed oils from *P. edulis* Sims var. *edulis* and *P. edulis* Sims var. *flavicarpa* showed the highest (74.3%) and lowest (67.8%) contents of linoleic acid, respectively. The FAC of *P. maliformis* L., hitherto unknown in the literature, also revealed a high level (71.9%) of linoleic acid.

In addition, the total unsaturated FA content of the four seed oils was between 85.4 and 88.6%. These data compare very well with the unsaturated FA range of 84–87% in passion fruit seed oils reported by other workers (8,11). The degree of unsaturation of an oil, expressed as its iodine value, serves as an indicator of the uses to which an oil can be put, i.e., salad oil, cooking grease, soap, or candle stock. The iodine values were directly calculated from the FAC of the seed oils using a procedure reported by Ham *et al.* (14). Seed oils from *P. edulis* Sims var. *flavicarpa*, *P. edulis* Sims var. *edulis*, Kawanda hybrid, and *P. maliformis* L. gave iodine values of 133, 141, 133, and 138, respectively (Table 2). A comparison of the iodine values of passion fruit seed oils with those of other vegetable oils, such as palm oil and cottonseed oil, that are commonly imported and consumed in Uganda strongly suggests that passion fruit seed oils have a higher content of PUFA. In using iodine values as an indicator, passion fruit seed oils are comparable to sunflower oil, which is generally considered a premium edible oil (Table 2).

Although temperature has been identified as the most important factor influencing the biogenesis (biosynthesis) and subsequently the content of unsaturated FA (12,15,16), this factor could be regarded as constant because the four *Passiflora* species were grown within the same geographical locality in Uganda. It is therefore reasonable to attribute the differences in iodine values to the genetic differences between the four *Passiflora* species.

Effect of grafting on the FAC of the hybrid seed oil. Grafting of passion fruits has been used largely to develop hybrids that are resistant to *Fusarium* wilt diseases, which cause collar and root rot. In particular, the Kawanda hybrid is a result of crossing a *P. edulis* Sims var. *edulis* scion onto the *P. edulis* Sims var. *flavicarpa* rootstock. In Table 1 one can see that the FAC of the Kawanda hybrid seed oil is much closer to that of *P. edulis* Sims var. *flavicarpa* oil than that of *P. edulis* Sims var. *edulis* oil. A comparative study of the FAC of the three passion fruit seed oils strongly suggests that the lipid properties

TABLE 2
Oil Contents, Major Fatty Acids, and Iodine Values of Passion Fruit Seed Oils in Comparison with Some of the Common Edible Oils in Uganda

Oil characteristics	Passion fruit seed oils from present study	Cottonseed oil[a]	Palm kernel oil[a]	Sunflower seed oil[a]
Oil yield (%)	19–28	15–22	4–53	57–67
C16:0 Palmitic	9–11	22–26	—	—
C18:1 Oleic	14–17	15–20	55–70	15–45
C18:2 Linoleic	68–74	49–58	10–25	50–70
Iodine value	133–141	105–114	50–55	110–143

[a]From Reference 9.

of the rootstock are transmitted to the hybrid seed oil during the grafting process.

Potential uses of passion fruit seed oils. A comparative study of the FAC of the four passion fruit seed oils demonstrates the presence of a high content of linoleic acid, between 67.8 and 74.3%, followed by oleic acid in the range 13.6–16.9%. The high content of these PUFA in passion fruit seed oils compares very well with sunflower oil, which is generally considered a premium edible oil because it is rich in linoleic (50–70%) and oleic (15–45%) acids (Table 2). Since the linoleic acid content in all four passion fruit seed oils exceeds 62%, the oils may be used for the manufacture of polyunsaturated products such as margarines (17). But as edible oils, passion fruit seed oils contain a higher content of the PUFA that are essential in a human diet. In contrast, the most commonly used vegetable oils in Uganda, namely, cottonseed oil and palm kernel oil, are imported and contain high levels of saturated FA, the consumption of which may increase total blood cholesterol and subsequently increase the risk of cardiovascular disease (18).

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