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Nutritional quality and essential oil compositions of *Thaumatococcus danielli* (Benn.) tissue and seed

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ABSTRACT

Nutritional quality and essential oil compositions of *Thaumatococcus danielli* (Benn.) tissue and seed were determined. Oil was extracted from the seed using standard methods while the fatty acids of the oil, chemical and anti-nutritional properties of defatted seed flour were determined. Total fat yield of the seed flour was 12.20%. Defatted seed flour had higher crude fibre (36.92%), carbohydrate (40.07%) and ash (8.17%) contents. Major mineral contents were potassium, calcium, sodium and magnesium. The tissue contain appreciable amount of vitamin C (8.10 mg/100 g). Oleic acid (42.59%) was the major fatty acid in the seed oil and the total unsaturated fatty acid was 62.38%. The seed oil had higher acid and saponification values and low iodine value. Oxalate (11.09 mg/100 g) content was the major anti-nutrient in the defatted seed flour. Defatted *T. danielli* seed flour serves as good source of dietary fibre and energy.

1. Introduction

The sweetener plant *Thaumatococcus danielli* Benn. (Benth.) is a member of the Maranthaceae family. It has long slender stalks, reaching heights of about 2–3 m (Ojekale, Makinde, & Osileye, 2007). The thaumatins are a class of intensely sweet proteins isolated from the fruit of the tropical plant *T. danielli* Benn. (Kant, 2005). It is a rhizomatous, perennial and monocotyledonous herb, propagating itself by rhizomes. About 2 or 2.5 m long petioles arise from the rhizomes depending on the age and the environment of the plant (Yeboah, Hilger, & Kroschel, 2003). A single fruit, weighing about 16 g, consists of two or three triangular, fleshy pericarps, each of which contains a large black seed surrounded by thick, transparent, viscous mucilage with a soft, jelly-like aril at the base (van der Wel & Loeve, 1972). In addition to its sweet taste, this protein enhances certain flavours while masking others, binding specifically with taste receptors (Bartoszewski, Niedziela, Szwacka, & Niemirowicz-Szczytt, 2003).

Thaumatin is a low-calorie intensely sweet-tasting protein (Raimi et al., 2011) and flavour modifier (Green, 1999). It consists of 207 amino acid residues with eight intramolecular disulfide bonds and contains no free cysteine residues (Kant, 2005). From the aril of , an intensely sweet, non-toxic and heat stable protein – thaumatin – is extracted, used as sweetener or taste modifier in beverages, desserts, chewing gums and pet foods. The seeds of *T. daniellii* also produce a jelly that swells (entrap water) to 10 times its own weight and hence provide a substitute for agar (Yeboah et al., 2003). The thaumatins are the first sweet-tasting proteins that have been found in nature and the crystals are about 2000–3000 times sweeter than sucrose and neither allergic nor mutagenic or teratogenic (Yeboah et al., 2003). Thaumatin has been approved for use in many countries as both a flavour enhancer and a high-intensity sweetener (Zemanek & Wasserman, 1995). *T. daniellii* fruit is unpopular and lesser known crop with high potentials for use in food industry. The properties of the crop had not been widely studied leading to dearth of information on the usefulness and the properties of the crop. Apart from the sweetening properties studied, other properties such as proximate, mineral, anti-nutritional and physico-chemical characteristics of the tissue and seed flour had not been extensively researched. Therefore, the purpose of this work was to determine the nutritional and essential oil compositions of *T. danielli* tissue and seed.

2. Materials and methods

2.1. Materials

T. danielli fruits were obtained in Oke-Oro farm at Esa-Odo, Osun State, Nigeria. The pods were opened and the tissues around the seeds were carefully scraped while the seeds were dried, milled, defatted using hexane and used for the analysis.

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2.2. Methods

2.2.1. Chemical analyses of defatted seed flour

Crude protein, fat, ash and crude fibre contents of the flours were determined using the Association of Official Analytical Chemists' Approved methods 920.87, 920.39, 923.03 and 962.09E, respectively (AOAC, 1990). Carbohydrate content was determined by difference and metabolisable energy was calculated. Mineral was determined using the method of AOAC (1990). Method of Awolu, Obafaye, & Ayodele (2013) was used for fatty acid determination.

2.2.2. Ascorbic acid and physico-chemical analyses of T. danielli tissue

Ascorbic acid content was obtained by using the titration method involving 2, 6-dichlophenol-Indophenol (method 967.21 AOAC, 1990). The pH of the samples was determined using a pH metre (Jenway Model 3510, England) standardised with buffer solution of pH 7.0 and 4.0, respectively according to AOAC (1990). The tissue of *T. danielli* (10 g) were mixed with 200 cm^3 distilled water, boiled for 1 h, cooled and the mixture was then filtered. The filtrate (10 cm^3) was titrated with 0.1 M NaOH. The results were expressed as % citric acid (g-citric acid/100 g-FW (gram-fresh weight)) (AOAC, 1990).

2.2.3. Essential oil isolation

The tissue and the seeds (100 g each) were placed in 200 ml distilled water and submitted to hydro-distillation for 3 h using a Clevenger-type 5 apparatus. The condensation of each essential oil gives 2 phases: an organic phase was formed practically by essential oils to which anhydrous sodium sulphate were added to eliminate water traces and an aqueous phase that contains a negligible quantity of essential oil. Essential oils were analysed using GC–MS (Mkaddem et al., 2009).

2.2.4. GC–MS analysis

An Agilent model 6890 gas chromatograph (GC) coupled to an Agilent model 5975 Mass Spectrometry (Agilent Technologies Inc., USA) was used for the analysis of the extract at the Department of Chemistry, University of Lagos, Nigeria, comprising a AOC-20i auto sampler instrument employing the following conditions: column Elite-5MS fused silica capillary column (30 mm × 0.25 mm × 0.25 µm df composed of 5% Diphenyl/95% Dimethyl poly siloxane), operating in electron impact mode at 70 eV. Helium (99.999%) was used as carrier gas at a constant flow rate of 1 ml per minute and an injection volume of 2 µl (split ratio 10:1). An injector temperature of 250 °C and an ion-source temperature of 280 °C were employed. The oven temperature was programmed from 110 °C for 2 min with an increase of 10 °C/min to 200 °C, then 5 °C/min, ending with a 9 min isothermal at 280 °C. The percentage of each chemical constituent was calculated by comparing the average peak area to the total areas (Meenakshi, Gomathy, & Chamundeswari, 2012).

2.2.5. Physico-chemical properties of the seed oil

The oil was extracted from the seed using Soxhlet extractor and the physico-chemical properties (refractive index, specific gravity, acid value, saponification value, free fatty acid, iodine value and peroxide value) was determined using the methods described by AOAC (1990).

2.2.6. Anti-nutritional analyses

Method of Dairo (2008) was used for phytate determination while oxalate, tannin and alkaloid determination were done using the methods of Alexis and George (2012), respectively.

2.3. Statistical analysis

Chemical, physico-chemical and anti-nutritional analyses were carried out in triplicate. The mean and standard deviation of the data obtained were calculated using SPSS (17.0).

3. Results and discussion

3.1. Chemical and physico-chemical properties of fruit tissue and defatted seed flour

The chemical and physico-chemical properties of *T. danielli* fruit are shown in (Table 1). The fat yield of the seed was 12.20%. This value was lower than the values reported for oily seeds such as soybean (35%) and Indian almond oil (52.11%) (Barku, Nyarko, & Dordunu, 2012; Osho, 1991). Therefore, the seed could not be classified as oily seed due to the low oil content.

Ash and moisture contents of defatted seed flour were 8.17% and 10.39%, respectively. The moisture contents observed was within the acceptable limit (13%) for flours (Codex Alimentarius Commission, 1995). There would be increase in shelf life of the flour due to the low moisture content. Low fat content in the flour may be due to the removal of the oil content of the flour. This improves the keeping quality of the flour as a result of lower susceptibility of the flour to oxidative rancidity. *T. danielli* seed flour could not be regarded as protein source due to low protein (2.14%) content of the defatted seed flour.

The defatted seed flour contained high crude fibre content (36.92%) according to classification of IFST (2007). Food grouped as high fibre food must contain at least 6 g DF per 100 g or per 100 ml (IFST, 2007). High fibre foods was reported to encourage mastication, stimulate the secretion of digestive juices and the soluble components cause an increase in the viscosity of the stomach contents thus retarding gastric emptying (IFST, 2007). This affects the rate of digestion and the uptake of nutrients thereby creates a feeling of satiety. Soluble fibre has also been shown to lower selectively serum cholesterol and to improve glucose metabolism and insulin response (IFST, 2007). Dietary fibre may be beneficial

Table 1
Chemical properties of *Thaumatococcus danielli* seed.

Parameter	Value
Total fat yield in the seed	12.20 ± 0.12
Proximate composition and energy value of defatted Thaumatococcus danielli seed flour	
Ash (%)	8.17 ± 0.11
Moisture content (%)	10.39 ± 0.13
Fat (%)	2.32 ± 0.09
Crude fibre (%)	36.92 ± 0.10
Crude protein (%)	2.14 ± 0.04
Carbohydrate (%)	40.07 ± 0.07
Energy value (kJ/g)	830.41 ± 0.10
Mineral contents of defatted seed flour	
Calcium (ppm)	116.12 ± 0.11
Magnesium (ppm)	79.20 ± 0.13
Sodium (ppm)	113.26 ± 0.21
Potassium (ppm)	150.90 ± 0.10
Iron (ppm)	0.91 ± 0.14
Manganese (ppm)	0.11 ± 0.07
Zinc (ppm)	1.24 ± 0.10
Copper (ppm)	0.12 ± 0.19
Nickel (ppm)	0.11 ± 0.22
Cadmium (ppm)	ND
Lead (ppm)	ND
Vitamin and physicochemical compositions of Thaumatococcus danielli fruit tissue	
Vitamin C (mg/100 g)	8.10 ± 0.09
pH	7.30 ± 0.00
Titratable acidity (% of citric acid)	0.19 ± 0.10

Mean ± standard deviation, ND-not detected.

in weight reduction and has laxative effects which cause relief of constipation in the elderly, the pregnant and the young people (IFST, 2007).

T. danielli seed flour contained appreciable amount of carbohydrate (40.07%) content which could serve as source of metabolisable energy. Energy value of the seed flour was 830.41 kJ/g. The vitamin C content of the fruit tissue was 8.10 mg/100 g. The value was higher when compared *Opuntia ficus-indica* but lower than pineapple as reported by Chiteva and Wairagu (2013) and Nitu et al. (2010). pH value was 7.30 signifying low acidity in the fruit. The titratable acidity (0.19%) was also lower than other fruits such as peach cultivars reported by Hajilou and Fakhimrezaei (2011) and citrus fruits (Nitu et al., 2010). Processing of this fruit is required to prevent deterioration and wastage of the fruit during its season thus improving the utilisation and keeping quality of

Table 2
Fatty acid composition of *Thaumatococcus danielli* seed oil.

Name	Formula	Amount (%)
Palmitic acid	C16:0	24.27
Palmitoleic acid	C16:1	0.93
Stearic acid	C18:0	12.15
Oleic acid	C18:1	42.59
Linoleic acid	C18:2	18.05
Linolenic acid	C18:3	0.81
Arachidic acid	C20:0	0.69
Behenic acid	C22:0	0.51
Total saturated fatty acid	37.62%	
Total unsaturated fatty acid	62.38%	
Total monounsaturated fatty acid	43.52%	
Total polyunsaturated fat acid	18.86%	

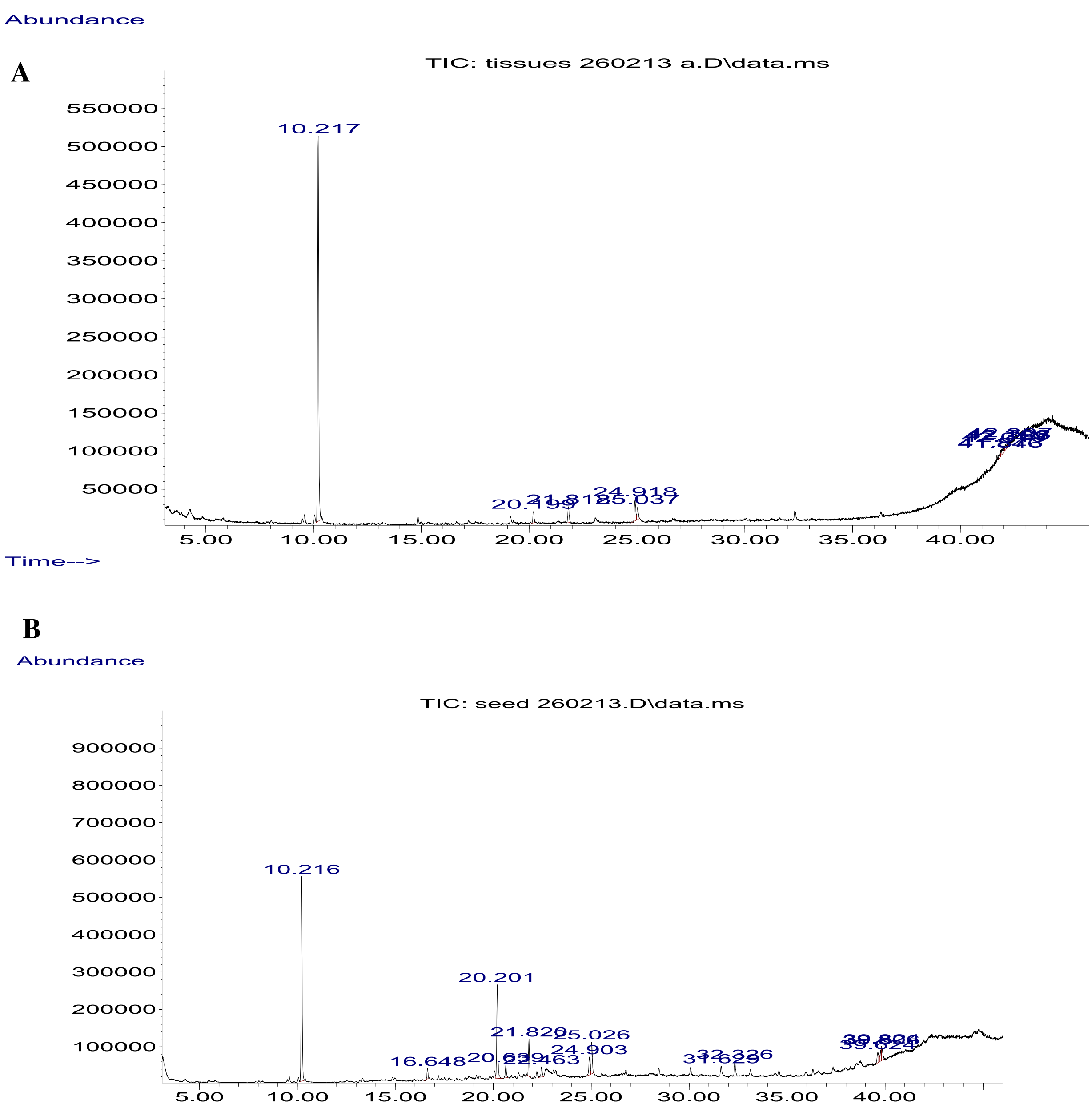

Fig. 1. Compositions of essential oil in *Thaumatococcus danielli* fruit A – tissue, B – seeds using GC–MS chromatography.

the product. The major mineral content in the defatted seed flour was potassium (150.90 ppm). Calcium, sodium and magnesium were also present in decreasing order. Cadmium and lead were not detected in the defatted seed flour. Mineral content depends on the soil type, location, species and cultural practices adopted during planting.

3.2. Fatty acid composition of T. danielli defatted seed flour

The fatty acid compositions of *T. danielli* seed flour are presented in Table 2. The unsaturated fatty acids content was 62.38% and comprises of oleic acid (42.59%), linoleic acid (18.05%), Palmitoleic (0.93%) and linolenic acid (0.81%). Saturated fatty acids concentration was 37.62% consisting of palmitic (24.27%), stearic (12.15%), arachidic (0.69%) and behenic (0.51%) acid. Oleic acid was the principal fatty acid followed by palmitic, linoleic and stearic acids in decreasing order. Oleic acid observed in this work was slightly lower than the value (44.7%) reported for *Jatropha curcas* Oil seed (Akbar, Yaakob, & Kamarudin, 2009). Oleic acid, stearic acid, linoleic acid and palmitic acid of *T. danielli* seed oil were higher than carrot seed oil (Ozcan & Chalchat, 2007). The presence of high oleic and linoleic acid suggest that the oil is nutritious and may be used as edible cooking oils. It could also be used in food industry for margarine and salad oil production (Alfawaz, 2004).

3.3. Essential oils of tissue and seed

GC – MS chromatogram of the extract of miracle fruit tissue and seed showed 11 and 13 peaks indicating the presence of chemical constituents in the tissue and seed, respectively (Fig. 1). The active principles with their retention time (RT) are presented in (Tables 3a and 3b). On comparison to the library the constituents present in the two components were identified. The GC–MS analysis yielded mainly unsaturated hydrocarbons, aldehydes, ketones and fatty acid methyl esters. The most abundant constituents in the tissue (79.60%) and seed (40.43%) were cyclopropane, 5-Tetradecene, (E)-, 7-Tetradecene, (Z)-. Other constituents in the tissue include 1, E-11, Z-13-Octadecatriene, 9, 12-Octadecadienoic acid methyl ester, Bicyclo [2.2.2] octane and Hexadecanoic acid methyl ester. In the seed, 6, 10, 14-trimethyl-2-Pentadecanone, 2-Tetradecanone, 2-Isopropyl-5-oxohexanal, Pentadecanoic acid, Hexadecanoic acid, 7, 10, 13-Hexadecatrienoic acid methyl ester, Cyclooctene, (1S,15S) Bicyclo [13.1.0] hexadecane-2-one were present. The abundant compounds in the tissue and the seed were the alkene and cycloalkane nitrile group which had been reported to have no activity it played in the food (Meenakshi et al., 2012). Other compounds present were 1, E-11, Z-13-Octadecatriene, 9, 12-Octadecadienoic acid methyl ester which were linolenic acid ester compound with cancer preventive, anti-inflammatory, hypocholesterolemic, hepatoprotective nematicide, antihistaminic, anti-eczemic antiacne, alpha reductase inhibitor, anti-androgenic, anti-arthritic, anti-coronary and insectifuge activities (Meenakshi et al., 2012).

3.4. Physico-chemical properties of the seed oil

Table 4 showed the physico-chemical properties of the extracted seed oil. Refractive index and specific gravity of the oil were 1.429 and 0.764, respectively. The values observed in the oil were lower than that of natural fats and oils and are related to their average degree of unsaturation (Barku et al., 2012). The refractive index of 1.47 and the specific gravity between 1.02 and 1.04 were reported for edible refined oil (EL-Kheir, Alamin, Sulafa, & Ali, 2012). Barku et al. (2012) also observed higher specific gravity (0.923) and refractive index (1.465) for Indian almond nut. The specific gravity of an oil according to Rudan-Tasic and Klofutar (1999) at any given temperature compared to water at a specified

Table 3a
Compositions of essential oil in *Thaumatococcus danielli* fruit tissue.

SN	Retention time (min)	Area (%)	Peak height	Library/ID	CAS no
1	10.216	79.602	505,659	Cyclopropane, nonyl-	074663-85-7
				5-Tetradecene, (E)-	041446-66-6
				7-Tetradecene, (Z)-	041446-60-0
2	20.199	2.488	14,749	7-Octen-2-one	003664-60-6
				2-Pentadecanone	002345-28-0
				2-Undecanone, 6,10-Dimethyl-	001604-34-8
3	21.818	3.616	20,826	Hexadecanoic acid, methyl ester	000112-39-0
4	24.918	5.172	28,200	1,E-11,Z-13-Octadecatriene	080625-36-1
				9,12-Octadecadienoic acid, methyl ester, (E,E)-	002566-97-4
				Bicyclo[2.2.2]Octane, 2-Methyl-	000766-53-0
5	25.037	2.927	16,856	1,15-Pentadecanediol	014722-40-8
				cis-Vaccenic acid	000506-17-2
				6-Octadecenoic acid, Methyl ester, (Z)-	002777-58-4
6	41.846	1.162	8285	Octadec-9-Enoic acid	1000190-13-7
				6-Octadecenoic acid, (Z)-	000593-39-5
				Oleic acid	000112-80-1
7	41.873	0.258	7305	9-Oxabicyclo[6.1.0]Nonane	000286-62-4
				9-Octadecenal	005090-41-5
				9-Octadecenoic acid (Z)-, 2-Hydroxy ethyl ester	004500-01-0
8	42.019	2.003	8476	Oleyl Alcohol	000143-28-2
				Carbonic acid, isobutyl undec-10-	1000314-60-8
				Enyl ester, 1,19-Eicosadiene	014811-95-1
9	42.169	1.442	5718	cis-Vaccenic acid	000506-17-2
				Oleic acid	000112-80-1
				Oleic acid	000112-80-1
10	42.228	0.636	5142	cis-13-Octadecenoic acid	013126-39-1
				Oleic acid	000112-80-1
				trans-13-Octadecenoic acid	000693-71-0
11	42.307	0.695	4444	Oleic acid	000112-80-1
				Butyl 9-Tetradecenoate	1000336-51-4
				9-Hexadecenoic acid	002091-29-4

Table 3b
Compositions of essential oil in *Thaumatococcus danielli* fruit seeds.

SN	Retention time (min)	Area (%)	Peak height	Library/ID	CAS no
1	10.216	40.434	548,268	Cyclopropane, nonyl-	074663-85-7
				5-Tetradecene, (E)-	041446-66-6
				7-Tetradecene, (Z)-	041446-60-0
2	16.648	1.915	27,079	3,9-Dodecadiyne	061827-89-2
				Cyclohexane, 1,2,4 Tris(methylene)	014296-81-2
				2,8-Decadiyne	004116-93-2
3	20.201	20.057	25,2234	6,10,14-trimethyl-2-Pentadecanone	000502-69-2
				2-Tetradecanone	002345-27-9
				2-Isopropyl-5-Oxohexanal	015303-46-5
4	20.639	2.684	34,441	1,2-Benzenedicarboxylic acid, butyl octyl ester	000084-78-6
				1,2-Benzenedicarboxylic acid, butyl cyclohexyl ester	000084-64-0
				Phthalic acid, isobutyl octyl ester	1000309-04-5
5	21.820	7.233	99,080	Pentadecanoic acid, 14-Methyl-, Methyl ester	005129-60-2
				Hexadecanoic acid, methyl ester	000112-39-0
				Hexadecanoic acid, methyl ester	000112-39-0
6	22.463	2.520	27,331	1,2-Benzenedicarboxylic acid, butyl 2-Ethylhexyl ester	000085-69-8
				Phthalic acid, hexadecyl propyl ester	1000309-06-5
				Phthalic acid, propyl octadecyl ester	1000308-96-7
7	24.903	3.842	47,374	2-Chloroethyl linoleate 9,12-Octadecadienoic acid, methyl	025525-76-2
				ester, (E,E)-	002566-97-4
				1-Methyl-2-Methylenecyclohexane	002808-75-5
8	25.026	7.049	84,911	7,10,13-Hexadecatrienoic acid, methyl ester	056554-30-4
				Cyclooctene, 3-Ethenyl-	002213-60-7
				(1S,15S)-Bicyclo[13.1.0]hexadecan- 2-One	102572-89-4
9	31.629	2.350	26,259	1-Octadecanesulphonyl chloride	1000342-70-4
				Hexatriacontane	000630-06-8
				Tetradecane	000629-59-4
10	32.326	3.716	39,628	1,2-Benzenedicarboxylic acid, diisooctyl ester	027554-26-3
				Phthalic acid, cyclohexyl neopentyl ester	1000315-54-2
				1,2-Benzenedicarboxylic acid, dicyclohexyl ester	000084-61-7
11	39.624	2.676	29,347	1,6-Dimethyl-9-(1-Methylethylidene) -5,12-Dioxatricyclo[9.1.0.0(4,6)] dodecan-8-one	1000072-83-2
				5(1H)-Azulenone, 2,4,6,7,8,8a-Hexa hydro-3,8-dimethyl-4-(1-Methylethy lidene)-, (8S-Cis)-	006754-66-1
				11,13-Dimethyl-12-tetradecen-1-ol	1000130-81-0
				Acetate	
12	39.806	2.561	35,950	2-Methyl-Z,Z-3,13-Octadecadienol	1000130-90-5
				Bicyclo[3.1.1]Heptane, 2,6,6-Trimethyl, (1.alpha.,2.beta.,5.alpha.)	006876-13-7
				11,13-Dimethyl-12-tetradecen-1-Ol acetate	1000130-81-0
13	39.824	2.963	37,805	2-Methyl-Z,Z-3,13-Octadecadienol	1000130-90-5
				3-Eicosene, (E)-	074685-33-9
				1,12-Bis(2-Nitrophenoxy)Dodecane	155056-69-2

Table 4
Physicochemical properties of *Thaumatococcus danielli* seed oil.

Parameter	Values
Refractive index 30 °C	1.429 ± 0.00
Specific gravity	0.764 ± 0.00
Acid value (mg/g)	44.93 ± 0.01
Saponification value (mg/g)	190.08 ± 0.06
Peroxide value (mg/g)	11.00 ± 0.02
Iodine value (mg/g)	60.34 ± 0.10
Free fatty acid (mg/g)	22.58 ± 0.13

Mean ± standard deviation.

temperature and increase as the mean molecular weight diminished and as the degree of unsaturation increased.

Acid value observed (44.93 mg/g) was higher than the Codex standard value for virgin oil therefore the oil is not suitable for direct consumption. The oil requires refining process to improve the quality. Acid value represents free fatty acid content due to enzymatic activity and indicating the level of oil spoilage. Acid value showed the degree of edibility of the oil and suitability in cosmetics industry. The saponification value (190.08 mg/g) compared well with moringa oil (190.40 mg/g) reported by Ogunsina et al. (2011). Saponification value of *T. danielli* seed oil was higher than almond nut (168.27 mgKOH/kg) reported by Barku et al. (2012). High saponification value required more alkali to neutralise the available free fatty acid liberated by the oil. The peroxide value was 11.00 mg/g. Codex standard value for refined vegetable oil was 10 Meq/kg (Codex, 1993) while FAO/WHO (1993) allows maximum value of 20 Meq/kg for unrefined olive oil. The low peroxide value in the unrefined seed oil indicates lower oxidation state in the oil and suggests strong presence or high levels of antioxidant (Barku et al., 2012). Lower iodine value (60.34 mg/g) was observed in the oil due to high levels of palmitic and stearic acids in the oil (Table 2). Iodine value signifies degree of unsaturation and the extent of the oil becoming rancid due to oxidation. Free fatty acid of the oil was 22.58 mg/g. This value was high when compared to the Codex standard value for edible oil (Codex, 1993).

3.5. Anti-nutritional composition of defatted T. danielli seed flour

Table 5 showed the anti-nutritional composition of defatted *T. danielli* seed flour. Oxalate (11.09 mg/100 g) was the major anti-nutrient in the seed flour. Oxalic acid and its salts have

Table 5
Anti-nutrient composition of defatted *Thaumatococcus danielli* seed flour.

Parameter	Value
Phytate (mg/100 g)	2.16 ± 0.09
Oxalate (mg/100 g)	11.09 ± 0.10
Tannin (mg/100 g)	0.39 ± 0.12
Alkaloid (mg/100 g)	1.67 ± 0.34

Mean ± standard deviation.

deleterious effects on human nutrition and health, mainly by decreasing calcium absorption and aiding the formation of kidney stones (Nooman & Savage, 1999). Processes such as boiling, blanching, roasting and other processing methods before consumption had been reported to reduce the level of the oxalate drastically and considerably in food (Eka, 1998). Phytate, tannin and alkaloid contents were 2.16 mg/100 g, 0.39 mg/100 g and 1.67 mg/100 g, respectively. Low levels of phytate, tannin and alkaloid contents in the seed flour signified their inability to cause health hazard in human nutrition since these anti-nutrients could further be reduced or eliminated during processing.

4. Conclusions

T. danielli fruit is one of the underutilised fruit with high potentials for industrial use. Although, the fruit deteriorates within a short period of time due to low acidity but the potentials could be employed in the food industry for jam and pectin production. The fatty acids composition and physico-chemical properties of the seed oil showed that the oil could be used in cosmetics industry and also suitable for cooking after refining. The seed flour could be used in diet requiring high fibre content. *T. danielli* seed flour may not cause health problem to the consumer due to low anti-nutritional composition.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foodchem.2014.03.114.

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