ORIGINAL RESEARCH

Bioactive phytochemicals in an aqueous extract of the leaves of Talinum triangulare

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Abstract
An aqueous leaf extract of Talinum triangulare was screened for the presence of bioactive molecules, using gas chromatography coupled with pulse and flame ionization detectors. It had high carotenoids; moderate benzoic acid derivatives, hydroxycinnamates and flavonoids; and low terpenes, alkaloids, phytosterols, allicins, glycosides, saponins, and lignans contents. Ten known carotenoids (mainly 50.42% carotene and 33.30% lycopene), nine benzoic acid derivatives (mainly 84.63% ferulic acid and 11.92% vanillic acid), and six hydroxycinnamates (55.44% p-coumaric acid and 44.46% caffeic acid) were detected. Also detected were eight lignans (88.02% retusin) and thirty flavonoids (50.35% quercetin and 39.36% kaempferol). The medicinal properties of the major components of these phytochemical families that were detected in the aqueous extract of the leaves were discussed herein and proposed to be explored for their potential health benefits. The great number of potentially active biomolecules and their multifunctional properties make Talinum triangulare a ready source of health-promoting substances.

KEYWORDS
benzoic acid derivatives, carotenoids, flavonoids, hydroxycinnamates, Talinum triangulare

1 | INTRODUCTION

Talinum triangulare (Jacq.) Willd. (Family: Portulaceae), is commonly called waterleaf. It is an herbaceous, annual, coalescent, and glabrous plant widely grown in tropical regions as a leafy vegetable. In Nigeria, it is consumed as a leafy vegetable and constituent of sauces (or vegetable soups). Nutritionally, it is a good source of some minerals (e.g., calcium, magnesium, and potassium) and vitamins (e.g., ascorbic acid and pyridoxine) (Oguntona, 1998). The extract from the leaves and roots is used to cure asthma (Ogie-Odia & Oluowo, 2009). According to Ofusori et al. (2008), "waterleaf consumption has beneficial effects on the neurons of the cerebrum and may probably enhance the cognitive ability in Swiss albino mice". In Edo State, Nigeria, Talinum triangulare is used as a diuretic, and for the management of gastrointestinal disorders (Mensah, Okoli, Ohaju-Obodo, & Eifediyi, 2008). It is also used to treat Shistosomiasis, scabies, fresh cuts, high blood pressure, and anemia (Ogunlesi et al., 2010).

Preliminary phytochemical studies reported the presence of carotenoids (Ogbonnaya & Chinedum, 2013), alkaloids, flavonoids, saponins, and tannins in the leaves (Aja, Okaka, Onu, Ibiam, & Urako, 2010; Ukpabi, Akubugwo, Agbafor, Wogu, & Chukwu, 2013) and leaf extract (Swarna & Ravindhran, 2013) of Talinum triangulare. All these studies reported the total quantities of these families of compounds, without elucidating the individual compounds that constitute them. An attempt to identify these individual components by de Oliveira Amorim et al. (2014), yielded campesterol, sitosterol, stigmasterol, scotenol, 3-(N-acryloyl, and N-pentadecanoyl) propanoic acid, allantoin, 3-O-b-D-glucopyranosyl-sitosterol, 3-O-b-D-glucopyranosyl-stigmasterol, (132S,17R,18R)-phaeophytin a, 17R,18R-purpurin18 phytyl ester, fucoschlorin D acid, talichlorin A, 31,32-didehydro-151-hydroxy

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rhodochlorin-15-acetic acid d-lactone-15\textsuperscript{2}-methyl-17\textsuperscript{2}-phytol ester, and hydroperoxy-ficuschlorin D. However, de Oliveira Amorim et al. (2014) did not quantify the detected compounds. To this end, this study profiled and quantified the phytochemical composition of an aqueous extract of the leaves of *Talinum triangulare*, and in addition discussed the bioactivities of the most abundant of the detected compounds, with a view to highlighting the possibilities of the use of the leaves as a functional food, or as a source of nutraceuticals.

### 2 | MATERIALS AND METHODS

#### 2.1 | Collection of plant samples and preparation of aqueous extract

Samples of fresh waterleaf plants were collected from within the Choba and Abuja Campuses of University of Port Harcourt, Nigeria. They were identified at the Herbarium of the Department of Plant Science and Biotechnology, University of Port Harcourt, Rivers State, Nigeria. They were then rid of dirt and their leaves were removed, oven dried at 55°C, and ground into powder. The powder was soaked in boiled distilled water for 12 hrs, after which the resultant mixture was filtered and the filtrate was evaporated to dryness. The percentage recovery of the crude extract was 2.296%. The residue obtained from the crude aqueous extract was subjected to phytochemical analysis.

#### 2.2 | General procedures

Gas chromatography was carried out at Multi-environmental Management Consultants Limited, Igbe Road, Ikorodu, Lagos, with a Hewlett Packard HP 6890, gas chromatograph, fitted with HP Chemstation Rev. A09.01[1206] software, to identify and quantify the compounds. The standards were from Sigma-Aldrich Co. and Lynncem Biological Technology Co. Standard solutions were prepared in methanol for alkaloids, flavonoids, allicins and benzoic acid derivatives; acetone for carotenoids and lignans; methylene chloride for phytosterols and terpenes; and ethanol for hydroxycinnamates, glycosides and saponins. The linearity of the dependence of response on concentration was verified by regression analysis. Identification was based on comparison of retention times and spectral data with standards. Quantification was performed by establishing the calibration curves for each compound determined, using the standards.

#### 2.3 | Determination of phytochemical composition

The flavonoids’ extract was obtained in a similar way as was reported by Millogo-Kone et al. (2009), and subjected to gas chromatography, with similar conditions as earlier reported by Ikewuchi, Onyeike, Uwakwe, and Ikewuchi (2011). The hydroxycinnamates’ extraction was carried out according to the method of Ortan et al. (2009), and subjected to gas chromatographic analysis, with similar conditions as earlier reported by Ikewuchi, Onyeike, and Ijeh (2013). The allicins’ extraction was carried out in a similar way as reported by Ortan et al. (2009). The resultant extract was subjected to gas chromatography with similar conditions as was earlier reported by Ikewuchi et al. (2014). The saponins’ extraction was carried out in a similar manner as the one reported by Oluwaniyi and Ibiyemi (2007), and subjected to gas chromatography, with similar conditions as earlier reported by Ikewuchi, Ikewuchi, Ifeanacho, Igboh, and Ijeh (2013). The glycosides’ extraction was obtained in a similar manner as the one reported by Oluwaniyi and Ibiyemi (2007), and subjected to gas chromatography, with similar conditions as earlier reported by Ikewuchi et al. (2013). The saponins’ extraction was carried out in a similar manner as the one reported by Guo, Zhang, and Liu (2009). The extract obtained was subjected to gas chromatography with similar conditions as was earlier reported by Ikewuchi et al. (2013). The terpenes’ extraction was carried out in a similar way as reported by Ortan et al. (2009). The resultant extract was subjected to gas chromatography, with similar conditions as was earlier reported by Ikewuchi et al. (2013).

### 3 | RESULTS AND DISCUSSION

The detected flavonoids (Table 1) consisted mainly of quercetin (50.3%), kaempferol (39.4%), apigenin (5.4%), isorhamnetin (3.7%) and luteolin (1.0%). The benzoic acid derivatives fraction (Table 1) consists mainly of ferulic acid (84.6%), vanillic acid (11.9%), 4-hydroxybenzoic acid (1.8%), and gallic acid (1.4%). The hydroxycinnamates fraction consisted mainly of p-coumaric acid (55.4%) and caffeic acid (44.5%); the lignans fraction consisted mainly of retusin (88.0%), galgravin (5.943%), dehydroabietic acid (2.5%), and apigenin-4’7-dimethyl ether (2.2%). As shown in Table 2, the carotenoids fraction consisted mainly of carotene (50.4%), lycopene (33.3%), malvidin (11.5%), and asta-xanthin (4.2%); while the phytosterols fraction consisted mainly of sitosterol (99.0%), and glycosides fraction consisted...
mainly of arbutin (99.9%). The saponins fraction consisted mainly of avenacin-B1 (76.8%) and avenacin-A1 (23.0%); while the allicins fraction consisted of diallyl thiosulphinate (89.7%), methylallyl thiosulphinate (9.1%), and allyl methyl thiosulphinate (1.2%). The alkaloids fraction (Table 3) consisted mainly of indicine-N-oxide (52.1%), ellipcine (8.1%), criniane-3α-ol (4.5%), augustamine (4.4%), 1β,2β-epoxyambelline (3.8%), cinchonine (3.8%), 13α-hydrorhombifoline (3.5%), dihydro-oxy-demethoxyhaemanthamine (3.0%), o xoasso- mine (3.0%), caffeine (2.3%), augustifoline (2.1%), 9-octadecinamide (2.0%), theobromine (2.0%), thalicarpin (1.7%), lupanine (1.4%), and crinamidine (1.3%). The terpenoids fraction (Table 4) consisted mainly of limonene (65.1%), camphor (5.0%), 1,8-cineole (3.7%), terpinen-4-ol (2.9%), borneol acetate (2.4%), geranyl acetate (2.2%), neral (1.9%), borneol (1.6%), β-pinene (1.5%), camphene (1.5%), sabinene (1.4%), neryl acetate (1.1%), citronellol (1.1%), and β-amyrin (1.0%).

The results showed the presence of bioactive compounds in the aqueous extract of the leaves of *Talinum triangulare*. These compounds have a wide range of biological properties. For example, quercetin has analgesic, antiallergenic, antibacterial, antidiabetic, anti-inflammatory, and antiviral activities (Prabha, Dahms, & Malliga, 2014). Studies have shown that kaempferol has a wide range of biological activities, including antioxidant, anti-inflammatory, antimicrobial, anticancer, cardio-protective, neuroprotective, anti-diabetic, antosteoporotic, estrogenic/anti-estrogenic, anxiolytic, hepatoprotective, analgesic, and antiallergic activities (Calderón-Montaño, Burgos-Morón, Pérez-Guerrero, & López-Lázaro, 2011). Numerous studies

**TABLE 1** Isolated and detected flavonoids, benzoic acid derivatives, hydroxycinnamates, and lignans in an aqueous extract of the leaves of *Talinum triangulare*

| Compounds                  | Composition (mg kg⁻¹) | Compounds                  | Composition (mg kg⁻¹) |
|----------------------------|-----------------------|----------------------------|-----------------------|
| (−)-Catechin               | (+)- Catechin          | Benzoic acid derivatives   |                       |
| 0.00017 ± 0.00013          | 0.00062 ± 0.000025    | 4-Hydroxybenzaldehyde      | 0.00035 ± 0.00015     |
| Resveratrol                | Genistein             | 4-Hydroxybenzoic acid      | 0.049 ± 0.044         |
| 0.000067 ± 0.000025        |   0.000067 ± 0.000020 | 4-Hydroxybenzoic acid methyl ester | 0.0000065 ± 0.00000014 |
| Daidzein                   | Apigenin              | Vanillic acid              | 0.33 ± 0.0061         |
| 0.29 ± 0.10                | Daidzin               | Gallic acid                | 0.037 ± 0.031         |
| Butein                     | Naringenin            | Ferulic acid               | 2.3 ± 0.17            |
| 0.00013 ± 0.000043         | Biochanin             | Capsaicin                  | 0.0050 ± 0.0049       |
| Luteolin                   | Luteolin              | Rosmarinic acid            | 0.0028 ± 0.0012       |
| 0.054 ± 0.011              | Kaempferol            | Tannic acid                | 0.0000083 ± 0.0000073 |
| 2.1 ± 0.57                 | (-)-Epicatechin       | Total benzoic acid derivatives | 2.7 ± 0.17           |
| 0.00043 ± 0.000083         | (-)-Epigallocatechin  | Hydroxycinnamates          |                       |
| 0.00044 ± 0.00000032       | Quercetin             | p-Coumarin                 | 0.0013 ± 0.00047      |
| 2.7 ± 0.67                 | Galloccatechin         | p-Coumaric acid            | 1.2 ± 0.069           |
| 0.00024 ± 0.000097         | (-)-Epicatechin-3-gallate | Scopoletin              | 0.00019 ± 0.000062    |
| 0.000030 ± 0.000002        | (-)-Epigallocatechin-3-gallate | Chlorogenic acid       | 0.00028 ± 0.00014     |
| 0.000027 ± 0.0000029       | Isorhamnetin          | Chicoric acid              | 0.00029 ± 0.000013    |
| 0.20 ± 0.037               | Robinetin             | Total hydroxycinnamates    | 2.2 ± 0.12            |
| 0.000094 ± 0.0000032       | Ellagic acid          | Lignans                    |                       |
| 0.00015 ± 0.000049         | Myricetin             | 2-Alyl-5-ethoxy-4-methoxyphenol | 0.00020 ± 0.00018    |
| 0.00077 ± 0.000015         | Baicalein             | (9E, 12E, 15E)-9, 12, 15-Octadecatrien-1-ol | 0.000044 ± 0.000037  |
| 0.00011 ± 0.000023         | Nobiletin             | Apigenin-4,7-dimethyl ether | 0.00066 ± 0.00040    |
| 0.00014 ± 0.000032         | Baicalin              | Dehydroabietic acid        | 0.00073 ± 0.00047     |
| 0.00011 ± 0.000027         | Tangeretin            | Retusin                    | 0.026 ± 0.0043        |
| 0.000042 ± 0.0000011       | Artemetin             | Galgravin                  | 0.0018 ± 0.0016       |
| 0.000038 ± 0.000015        | Silymarin             | Epieudesmin                | 0.000054 ± 0.000018   |
| 0.000065 ± 0.0000017       | Naringin              | Sakuranin                  | 0.000098 ± 0.000023   |
| 0.000059 ± 0.000031        | Rutin                 | Total lignans              | 0.030 ± 0.0066        |
| 0.000011 ± 0.0000039       | Hesperidin            | Total flavonoids           | 5.4 ± 1.4             |

Values are mean ± SD (standard deviation) of duplicate determinations.
IKEWUCHI ET AL. have demonstrated the antioxidant, antihypertensive, anticancer, and antiosteoporotic properties of lycopene, as well as its ability to protect against cardiovascular diseases, and amyotrophic lateral sclerosis (Rao & Rao, 2007).

β-Carotene is an antioxidant and antiosteoporotic agent (Rao & Rao, 2007), and a major precursor of vitamin A (Agea et al., 2014). Malvidin possesses antioxidant, anti-inflammatory, cardioprotective, antihypertensive, and antitumor properties (Huang, Zhu, ...}

### Table 2: Isolated and detected carotenoids, phytosterols, glycosides, saponins and allicins in an aqueous extract of the leaves of *Talinum triangulare*

| Compounds       | Composition (mg kg⁻¹) |
|-----------------|-----------------------|
| Carotenoids     |                       |
| Malvidin        | 2.1 ± 0.16            |
| β-Cryptoxanthin | 0.0070 ± 0.00051      |
| Lycopene        | 6.12 ± 0.037          |
| Carotene        | 9.3 ± 0.062           |
| Lutein          | 0.0086 ± 0.00066      |
| Xanthophyll     | 0.00083 ± 0.00013     |
| Anthera-xanthin | 0.028 ± 0.022         |
| Asta-xanthin    | 0.78 ± 0.071          |
| Viola-xanthin   | 0.075 ± 0.0079        |
| Neo-xanthin     | 0.0013 ± 0.00013      |
| Total carotenoids | 18.0 ± 0.34          |
| Phytosterols    |                       |
| Cholesterol     | 0.0000078 ± 0.000000010 |
| Cholestanol     | 0.00050 ± 0.000089    |
| Ergosterol      | 0.00068 ± 0.00024     |
| Campesterol     | 0.00094 ± 0.000015    |
| Stigmasterol    | 0.0034 ± 0.0011       |
| 5-Avenasterol   | 0.0034 ± 0.0011       |
| Sitosterol      | 0.88 ± 0.13           |
| Total phytosterols | 0.89 ± 0.13        |
| Glycosides      |                       |
| Arbutin         | 0.093 ± 0.011         |
| Salicin         | 0.000042 ± 0.000031   |
| Amygdalin       | 0.000022 ± 0.0000032  |
| Total glycosides | 0.094 ± 0.011        |
| Saponins        |                       |
| Avenacin-A1     | 0.012 ± 0.00038       |
| Avenacin-B1     | 0.039 ± 0.011         |
| Avenacin-A2     | 0.000029 ± 0.00000096 |
| Avenacin-B2     | 0.000043 ± 0.0000026  |
| Total saponins  | 0.051 ± 0.010         |
| Allicins        |                       |
| Diallyl thiosulphinate | 0.020 ± 0.00027    |
| Methylallyl thiosulphinate | 0.0020 ± 0.00038 |
| Allyl methyl thiosulphinate | 0.00026 ± 0.0000089 |
| Total allicins  | 0.022 ± 0.00066       |

Values are mean ± SD (standard deviation) of duplicate determinations.

have demonstrated the antioxidant, antihypertensive, anticancer, and antiosteoporotic properties of lycopene, as well as its ability to protect against cardiovascular diseases, and amyotrophic lateral sclerosis (Rao & Rao, 2007). β-Carotene is an antioxidant and antiosteoporotic agent (Rao & Rao, 2007), and a major precursor of vitamin A (Agea et al., 2014). Malvidin possesses antioxidant, anti-inflammatory, cardioprotective, antihypertensive, and antitumor properties (Huang, Zhu, ...}

### Table 3: Isolated and detected alkaloid composition of an aqueous extract of the leaves of *Talinum triangulare*

| Compounds       | Composition (mg kg⁻¹) |
|-----------------|-----------------------|
| Choline         | 0.00046 ± 0.00033    |
| Trigonelline    | 0.0012 ± 0.00079     |
| Theobromine     | 0.0030 ± 0.00       |
| Theophylline    | 0.00089 ± 0.00026    |
| Caffeine        | 0.0035 ± 0.00       |
| Augustifoline   | 0.0033 ± 0.00       |
| Sparteine       | 0.0011 ± 0.00078    |
| Ellipicine      | 0.012 ± 0.00085     |
| Lupanine        | 0.0022 ± 0.00021    |
| 13-α-Hydorhombifoline | 0.0053 ± 0.00024 |
| 9-Octodecinamide | 0.0031 ± 0.00023    |
| Dihydro-oxo-demethoxyhaemanthamine | 0.0047 ± 0.00013 |
| Augustamine     | 0.0067 ± 0.00045    |
| Oxoasaoamine    | 0.0047 ± 0.00023     |
| Crinane-3α-ol   | 0.0070 ± 0.000093   |
| Cinchonine      | 0.0058 ± 0.00048    |
| Buphanidrine    | 0.0015 ± 0.000023   |
| Cinchonidine    | 0.0013 ± 0.000053   |
| Indicine-N-oxide | 0.081 ± 0.0017      |
| Powelline       | 0.00060 ± 0.000012  |
| Undulatine      | 0.00021 ± 0.0000094 |
| Ambelline       | 0.000088 ± 0.0000095 |
| 6-Hydroxybuphanidrine | 0.000088 ± 0.000044 |
| Acrony cine     | 0.000069 ± 0.000018 |
| Monocrotaline   | 0.000042 ± 0.0000    |
| 6-Hydroxypowelline | 0.000068 ± 0.000028 |
| Nitidine        | 0.00023 ± 0.000      |
| Crinamide       | 0.0020 ± 0.00019     |
| 6-Hydroxyundulatine | 0.00077 ± 0.000       |
| 1β,2β-Epoxyambelline | 0.0059 ± 0.0000    |
| Epoxy-3,7-dimethoxycrinane-11-one | 0.00068 ± 0.000053 |
| Echitamminidine | 0.00061 ± 0.000       |
| Akuummidine     | 0.0015 ± 0.000       |
| Voacangine      | 0.00026 ± 0.000       |
| Mitraphylin     | 0.00046 ± 0.000       |
| Camptothecin    | 0.00022 ± 0.000       |
| Echitamine      | 0.00027 ± 0.000       |
| Colchicine      | 0.00028 ± 0.000       |
| Tetrandrine     | 0.00021 ± 0.000       |
| Emetine         | 0.00050 ± 0.000       |
| Thalcarpin      | 0.0026 ± 0.000       |
| Paclitaxel      | 0.000093 ± 0.000       |
| Total alkaloids | 0.15 ± 0.00063       |

Values are mean ± SD (standard deviation) of duplicate determinations.
Table 4: Isolated and detected terpene composition of an aqueous extract of the leaves of *Talinum triangulare*

| Compounds                  | Composition (mg kg⁻¹)              |
|----------------------------|-----------------------------------|
| α-Pinene                   | 0.0013 ± 0.0000011                |
| β-Pinene                   | 0.0022 ± 0.000096                 |
| Limonene                   | 0.093 ± 0.0068                    |
| Cis-oicimene               | 0.00029 ± 0.00000017              |
| Myrcene                    | 0.00064 ± 0.00024                 |
| Alloocimene                | 0.0010 ± 0.00000015               |
| Camphene                   | 0.0022 ± 0.0012                   |
| Sabinene                   | 0.0020 ± 0.00059                  |
| α-Thujene                  | 0.0014 ± 0.00022                  |
| Camphor                    | 0.0072 ± 0.0037                   |
| Neral                      | 0.0027 ± 0.00026                  |
| 1,8-Cineole                | 0.0053 ± 0.0026                   |
| Borneol                    | 0.0023 ± 0.00013                  |
| Nerol (geraniol)           | 0.00083 ± 0.0000000035            |
| α-Terpineol                | 0.0011 ± 0.000000020              |
| Terpinen-4-ol              | 0.0042 ± 0.0014                   |
| Citronellol                | 0.0015 ± 0.0000000010             |
| Borneol acetate            | 0.0035 ± 0.0012                   |
| Neryl acetate              | 0.0016 ± 0.00028                  |
| Geranyl acetate            | 0.0031 ± 0.0011                   |
| Taraxeron                  | 0.0014 ± 0.00000021               |
| α-Amyrin                   | 0.0013 ± 0.00000021               |
| β-Amyrin                   | 0.0014 ± 0.000060                 |
| Lupeol                     | 0.0014 ± 0.000000013              |
| Total terpenoids           | 0.14 ± 0.016                      |

Values are mean ± SD (standard deviation) of duplicate determinations.

Li, Sui, & Min, 2016; Quintieri et al., 2013; Seo et al., 2016). Therefore, a great number of potentially active molecules present in the leaves of *Talinum triangulare*, as well as the multifunctional properties these compounds, make *Talinum triangulare* a good source of health-promoting substances.

**CONFLICT OF INTEREST**

We declare that we have no conflict of interest.

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