Research Journal of Medicinal Plant

ISSN 1819-3455

Academic Journals Inc.

www.academicjournals.com

OPEN ACCESS Research Journal of Medicinal Plants

ISSN 1819-3455
DOI: 10.3923/rjmp.2017.115.123

Review Article
Azanza garckeana Fruit Tree: Phytochemistry, Pharmacology, Nutritional and Primary Healthcare Applications as Herbal Medicine: A Review

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Abstract
Azanza garckeana is an important food plant and herbal medicine in tropical Africa. This study was aimed at reviewing the nutritional value, the phytochemical compounds, ethnomedicinal uses and validated pharmacological properties of *A. garckeana*. The extensive literature survey revealed that ripe fruit carpels of *A. garckeana* are edible and widely used as food additives throughout the distributional range of the species. *Azanza garckeana* is also traditionally used to treat or manage at least 22 human diseases and ailments. The species is used as herbal medicine for diseases and ailments such as chest pains, cough, infertility, liver problems, menstruation problems and sexually transmitted infections. Multiple classes of compounds including alkaloids, amino acids, ascorbic acid, carotenoids, cyanogenic glucosides, flavonoids, lipids, phenols, saponins and tannins have been isolated from *A. garckeana*. Pharmacological studies on *A. garckeana* indicate that the species has a wide range of pharmacological activities such as antibacterial, antifungal, antihyperglycemic, antimalarial, antioxidant and iron absorption. *Azanza garckeana* is worth to be subjected to detailed scientific investigations for elucidating its chemical, nutritional and toxicological properties. Such detailed research should also include experimental animal studies, randomized clinical trials and target-organ toxicity studies involving *A. garckeana* and its derivatives.

Key words: *Azanza garckeana*, ethnomedicinal uses, food additive, *Malvaceae*, nutraceutical

Citation: Alfred Maroyi, 2017. *Azanza garckeana* fruit tree: phytochemistry, pharmacology, nutritional and primary healthcare applications as herbal medicine: A Review. Res. J. Med. Plants, 11: 115-123.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In tropical Africa, *Azanza garckeana* (F. Hoffm.) Exell and Hillc. is among the popular multipurpose fruit trees, characterized by edible fruits with different plant parts used as herbal medicines and plant products sold to local markets generating substantial incomes for the household[1]. The World Agroforestry Centre identified *A. garckeana* as one of the fruit trees that should be integrated in the domestication process in farming systems to support nutritional, health and income security of local communities in tropical Africa[2]. For centuries, local communities in developing countries and marginalized areas have relied on wild edible fruits as food, medicines and nutritional supplements. In recent decades, there has been a resurgence of interest in wild edible fruits as they are known to broaden the food, nutritional security and livelihood needs of the poor and those people living in marginalized areas[3,4]. Accumulated evidence generated over the years categorize large proportion of wild edible fruits as both food and medicines as the plants are characterized by several micronutrients and allelochemicals that are important for human nutrition and health[5,6]. These nutritional and medicinal properties of wild edible fruits enable some people to use wild edible fruits as medicines and also broaden the diversity of the human diet, nutritional options, vitamins and minerals. Medicinal properties of wild edible fruits include their antioxidant effects which play a crucial role in the prevention of chronic ailments such as heart disease, cancer, diabetes, hypertension, stroke and alzheimer's disease by combating oxidative stress[5]. Research by Glew *et al.*[1] and Lamien-Meda *et al.*[6] revealed that wild edible fruits are characterized by remarkable nutrient values as well as being an excellent source of minerals, fibre, vitamins C, A and E, polyphenols, ascorbic acid and fatty acids that add flavour and colour to the diet. Some researchers like Leonti[7] argued that the consumption of fruits, spices and vegetables are perceived as healthy and endowed with prophylactic effects against modern lifestyle diseases.

This study reviewes on *A. garckeana* throughout its distributional range in tropical Africa. Therefore, this study was aimed at reviewing the nutritional value, the phytochemical compounds, ethnomedicinal uses and validated pharmacological properties of *A. garckeana*. This review focusing on *A. garckeana* is important as the species is deemed essential and opens the possibility for utilizing both its nutritional and nutraceutical properties. *Azanza garckeana* has great potential as high-value nutraceutical and an important source of several bioactive compounds which can be used as dietary supplements of functional foods.

Plant profile: *Azanza garckeana* is a member of the *Malvaceae* family. The generic name "Azanza" is derived from the word "Azania", a word meaning black and surviving in Zanzibar[8]. The specific name "garckeana" is in honour of Professor August Garcke (1819-1904), a German botanist and plant collector who specialized in pharmacognosy[8,9]. Synonyms of *A. garckeana* include *Bupariti garckeana* (*F. Hoffm.*) *Rothm., Shantzia garckeana* (*F.Hoffm.*) *Lewton* and *Thespesia garckeana F. Hoffm.*[8] *Azanza garckeana* has been recorded in Botswana, Burundi, Democratic Republic of Congo (DRC), Kenya, Malawi, Mozambique, Namibia, Nigeria, South Africa, South Sudan, Sudan, Tanzania, Zambia and Zimbabwe. The species occurs in a wide range of warmer parts of Southern, Eastern and Western Africa in open woodlands, wooded grasslands, thickets, riverine vegetation and rocky places. It grows naturally over a range of altitudes from 0-2000 m above sea level, from semi-arid areas receiving lowest annual rainfall of 250 mm and highest rainfall of 1270 mm[10].

Azanza garckeana is a shrub or small tree, growing up to 10 m tall, with stem diameter at breast height of upto 25 cm[9,10]. The leaves are alternate, simple, round, 3-5 lobe upto 20×20 cm in size, subcircular in outline and palmately with 3-5 lobes[9]. The leaf lobes are rounded to broadly tapering at the apex, the base is cordate, margins are entire, 5-7 veined from the base, sparsely hairy above, woolly and leathery below with a petiole upto 13 cm long[9]. The flowers are 6 cm in diameter, yellow or purplish in colour with dark purple or dark red centre[9]. The peduncle is 2-7 cm long, the calyx is fused, with 9-10 teeth, each tooth up to 12 mm long and petals are 6×4 cm in size[9]. The staminal tube is 10-12 mm long with 2-5 cm long filaments[9]. The fruit is a round woody capsule about 35 mm in diameter, red when mature, covered with short dense hairs, clearly divided into 4 or 5 segments[9]. The seeds are 10×7 mm in size, hemispheric, with a brownish woolly floss[9].

Dietary and medicinal uses of *Azanza garckeana*: The ripe fruit carpels of *A. garckeana* are edible and widely consumed throughout the distributional range of the species (Table 1). *Azanza garckeana* is also used a food additive (Table 1) with the jelly or syrup from the species added into soups or made into porridge and occasionally dried to be reconstituted later[11]. Considerable quantities of *A. garckeana* fruits are sold in local markets in Botswana, Kenya, Zambia and Zimbabwe[2,12,13]. The species is semi domesticated in Botswana, Nigeria, Zambia and Zimbabwe where local people grow the species in home gardens and crop fields[2,13-16]. *Azanza garckeana* has been identified as one of the few

Table 1: Food value and ethnomedicinal uses of *Azanza garckeana* in tropical Africa

Medicinal use	Plant part(s) used	Country practised	References
Dietary uses			
Edible fruits	Fruits	Botswana, Kenya, Malawi, Nigeria, Sudan, Tanzania, Zambia, Zimbabwe	Mojeremane and Tshwenyane[13], Maroyi[15], Maundu *et al.*[20], Chensembu[34], Hines and Eckman[35],
Food additive	Fruits	Sudan, Tanzania	Bunderson *et al.*[36] and Suliman *et al.*[37]
Medicinal uses			
Abscesses	Fruit poultice applied	Nigeria	Ochokwu *et al.*[16] and Msheila *et al.*[21]
Anemia	Ripe fruits	Sudan	Ahmed *et al.*[28]
Antiemetic	Root infusion taken orally	Zimbabwe	Gelfand *et al.*[19]
Aphrodisiac	Ripe fruits taken orally	Nigeria	Dikko *et al.*[27]
Asthma	Root decoction mixed with *Sterospermum kunthianum* Cham.	Malawi	Morris[22]
Chest pains	Root infusion taken orally	Nigeria, Zimbabwe	Gelfand *et al.*[19] and Mshelia *et al.*[21]
Cough	Root infusion taken orally	Kenya, Nigeria, Zimbabwe	Gelfand *et al.*[19], Maundu *et al.*[20] and Mshelia *et al.*[21]
Diabetes	Leaf decoction taken orally	DRC	Maroyi[31]
Earache	Root infusion dropped into ear	Zimbabwe	Gelfand *et al.*[19], Maroyi[30] and Maroyi[31]
Edema	Leaf decoction taken orally	DRC	Amuri *et al.*[32]
Epilepsy	Leaf decoction taken orally	DRC	Amuri *et al.*[32]
Fever	Root decoction taken orally	Malawi	Morris[22]
Gonorrhoea	Roots and stem bark taken orally	Malawi, Nigeria	Morris[22] and Nkafamiya *et al.*[25]
Induce labour	Root decoction taken orally	Tanzania	Augustino *et al.*[29]
Infertility	Ripe fruits or root decoction taken orally	Botswana, Malawi, Nigeria	Morris[22], Soladoye and Oyesiku[24], Hedberg and Staugard[26] and Dikko *et al.*[27]
Liver problems	Stem and leaf decoction taken orally	Kenya, Nigeria	Ochokwu *et al.*[16] and Maundu *et al.*[20]
Madness (mental illness)	Root decoction taken orally	Zimbabwe	Gelfand *et al.*[19]
Malaria	Eat raw fruit or cook and eat as relish	Zambia	Chinsembu[34]
Membrane rupture	Root decoction taken orally	DRC	Esther *et al.*[33]
Menstruation	Root infusion taken orally	Nigeria, Zimbabwe	Gelfand *et al.*[19] and Msheila *et al.*[21]
Retained placenta	Root infusion taken orally	Zimbabwe	Gelfand *et al.*[19]
Sexually transmitted diseases	Root and bark infusion taken orally	Zambia	Ndubani and Höjer[23]
Syphilis	Root decoction taken orally	Nigeria	Soladoye and Oyesiku[24]

plant species that should be integrated in the domestication process in farming systems in sub-Saharan Africa to support nutritional, medicinal and income security of local communities[2,17,18]. According to Van Wyk[18], the fruits of *A. garckeana* have potential in the development of new food and beverage products.

The bark, fruits, leaves, roots and stems of *A. garckeana* are reported to possess diverse medicinal properties and used to treat or manage various diseases and ailments throughout its distributional range (Table 1). Total of 22 traditional medicinal uses of *A. garckeana* are documented in literature (Table 1) from 9 countries in tropical Africa, representing 64.3% of the countries where the species is indigenous. The country with the highest ethnomedicinal uses is Nigeria (nine) based on 4 literature records, followed by Zimbabwe with 7 uses and 2 literature records, Democratic Republic of Congo (DRC) with 4 uses based on 2 literature records and Malawi with three uses based on a single literature record (Table 1). Root infusion of *A. garckeana* is taken orally as remedy for chest pains, cough and menstruation in Nigeria, Zimbabwe and Kenya[19-21]. The root and stem bark decoction of *A. garckeana* is taken orally as remedy for gonorrhoea, sexually transmitted diseases and syphilis in Malawi, Nigeria and Zambia[22-25]. The leaf, stem, root decoction or ripe fruits of *A. garckeana* are taken orally as remedy for infertility and liver problems in Botswana, Kenya, Malawi, Nigeria[16,20,22,24,26,27]. In Nigeria, fruit poultices are applied on abscesses[16,21] and ripe fruits are taken orally as aphrodisiac[27]. In Sudan, ripe fruits are taken orally for anemia[28], while in Tanzania, the root decoction is taken by pregnant women to induce labour[29]. In Zimbabwe, the root decoction of *A. garckeana* is taken orally as antiemetic, as remedy for madness or mental illness, retained placenta and root infusion is dropped into ear as remedy for earache[19,30,31]. In the DRC, the leaf or root decoction of *A. garckeana* is taken orally as remedy for diabetes, edema, epilepsy and membrane rupture[32,33]. In Malawi, the root decoction of *A. garckeana* is taken orally for fever while in Zambia, people suffering from malaria are advised to eat raw fruit of the species or cook the fruit and eat it as relish[23,34]. The root decoction of *A. garckeana* is mixed with roots of *Sterospermum kunthianum* Cham. and taken orally as remedy for asthma in Malawi[22].

Phytochemical composition of *Azanza garckeana*: Multiple classes of compounds including alkaloids, amino acids, ascorbic acid, carotenoids, cyanogenic glucosides, flavonoids,

Table 2: Chemical composition of fruits, leaves, roots, seeds and stem bark of *Azanza garckeana*

	Amount in different plant parts					
Chemical composition	Fruits	Leaves	Roots	Seeds	Stem bark	References
Dry matter	52.8 %					Saka and Msousthi[40]
pH	5.96					Saka and Msousthi[40]
Ascorbic acid (mg/100 g)	20.5					Saka and Msousthi[40]
Alkaloids (w/w) (%)	18.40	13.60	6.80	3.70	12.80	Nkafamiya *et al.*[25] and Michael *et al.*[38]
Calcium (mg/100 g)	*127±0.04	129±0.45	100±0.04		28.02±0.89	Nkafamiya *et al.*[25]
Carotenoids (%)				3.40		Michael *et al.*[38]
Cobalt (mg/100 g)	0.02±0.01	0.04±0.02	0.02±0.01		0.91±0.01	Nkafamiya *et al.*[25]
Copper (mg/100 g)	0.45±0.33	2.01±0.25	0.35±0.01		0.97±0.12	Nkafamiya *et al.*[25]
Crude fibre (w/w) (%)	45.30	25.00	11.89		13.75	Nkafamiya *et al.*[25]
Crude protein (w/w) (%)	12.0	5.60	7.42		4.91	Nkafamiya *et al.*[25]
Crude protein (%)	12.0					Saka and Msousthi[40]
Cyanogenic glucosides				0.33 μg g^{-1}		Michael *et al.*[38]
Energy value (kcal/100 g)	2313.08±0.0					Suliman *et al.*[37]
Fat	1.04±0.01					Suliman *et al.*[37]
Flavonoids (w/w) (%)	24.40	26.50		1.00		Nkafamiya *et al.*[25] and Michael *et al.*[38]
Iron (mg/100 g)	12.00±0.43	15.00±0.73	5.05±0.23		6.00±0.36	Nkafamiya *et al.*[25]
Lipid content (w/w) (%)	1.10	0.96	0.68		1.12	Nkafamiya *et al.*[25]
Magnesium (mg/100 g)	96.25±0.67	100.00±0.12	45.05±0.24		40.09±0.45	Nkafamiya *et al.*[25]
Manganese (mg/100 g)	0.23±0.02	0.24±0.01	0.98±0.01		0.24±0.01	Nkafamiya *et al.*[25]
Moisture (w/w) (%)	6.50	5.50	2.70		0.50	Nkafamiya *et al.*[25]
Phenols (w/w) (%)			29.00	2.60		Nkafamiya *et al.*[25] and Michael *et al.*[38]
Phosporous (mg/100 g)	30±0.87	29.07±0.07	10.09±0.90		9.09±0.67	Nkafamiya *et al.*[25]
Potassium (mg/100 g)	1360.00±1.3					Suliman *et al.*[37]
Protein	10.05±1.8					Suliman *et al.*[37]
Saponin (%)		30.00	24.50	1.72	34.50	Nkafamiya *et al.*[25] and Michael *et al.*[38]
Sodium (mg/100 g)	60.00±0.5					Suliman *et al.*[37]
Tannin (w/w) (%)	15.05				0.22	Nkafamiya *et al.*[25] and Suliman *et al.*[37]
Total ash (w/w) (%)	6.70	11.00	8.70		7.56	Nkafamiya *et al.*[25]
Total carbohydrate (w/w) (%)	28.40	49.94	70.81		72.16	Nkafamiya *et al.*[25]
Vitamin A (mg/100 g)	75.00±0.23	28.75±0.66				Nkafamiya *et al.*[25]
Vitamin B1 (mg/100 g)	1.28±0.97	1.00±0.67				Nkafamiya *et al.*[25]
Vitamin B2 (mg/100 g)	1.18±0.45	0.95±0.78				Nkafamiya *et al.*[25]
Vitamin C (mg/100 g)	319.09±0.45	98.02±0.65				Nkafamiya *et al.*[25]
Vitamin E (mg/100 g)	3.08±0.55	2.09±0.77				Nkafamiya *et al.*[25]
Zinc (mg/100 g)	12.02±0.9	11.06±0.21	6.09±0.9		5.06±0.23	Nkafamiya *et al.*[25]
Zinc (mg/100 g)						Nkafamiya *et al.*[25]
Zinc (mg/100 g)						Nkafamiya *et al.*[25]
Zinc (mg/100 g)						Nkafamiya *et al.*[25]

*Range represents standard deviation

lipids, phenols, saponins and tannins (Table 2, 3) have been isolated from *A. garckeana* fruits, leaves, roots, seeds and stem bark[25,39,40]. Some of the documented phytochemicals are recommended by nutritionists because of their health benefits as they are considered to be responsible for positive health outcomes. Zhang *et al.*[41] argued that phytochemicals such as alkaloids, flavones, saponins, steroids, tannins and triterpenoids isolated from fruits, vegetables and grains exert a protective effect against the development chronic diseases such as cardiovascular diseases (CVD), diabetes and cancers. According to Zhang *et al.*[41] the protective role of phytochemicals may be associated with their antioxidant activity, since over production of oxidants (reactive oxygen species and reactive nitrogen species) in the human body is involved in the pathogenesis of many chronic diseases. Nkafamiya *et al.*[25] isolated amino acids from fruits and leaves of *A. garckeana* with aspartic acid, glutamic acid, leucine and lysine being the most abundant amino acids constituting 9.67-12.97 g/100 g (Table 3).

Detection, isolation and purification of chemical compounds from fruit pulp, heartwood, roots and stem bark of *A. garckeana* has been done through mass

spectrometry (MS) and nuclear magnetic resonance (NMR) for structural elucidation of the compounds (Table 4). Letcher and Shirley[42] isolated the following compounds from heartwood of *A. garckeana*, O-naphthoquinones 6, mansonones E 7, mansonones F 8, mansonones G 9, mansonones H 10, azanzone A 11 and azanzone B 12 (Table 4). Mutindi[43] isolated the following phenolic compound disesquiterpene aldehydes from the crude root extract of A. *garckeana*, gossypol 1, 6, 6-Dimethoxygossypol 2, 6-Methoxygossypol 3, stigmasterol 4, *E*-docosyl 3-(3,4-dihydroxyphenyl) acrylate 5 and betulinic acid 13. Masila *et al.*[44] isolated gossypol 1, 6, 6-Dimethoxygossypol 2, 6-Methoxygossypol 3 from the root extract of A. *garckeana* and the stem bark yielded stigmasterol 4, E-Docosyl-3-(3,4-dihydroxyphenyl) acrylate 5 and betulinic acid 13.

Pharmacological activities: A number of pharmacological activities of *A. garckeana* have been reported in literature justifying some of its ethnomedicinal uses. These include antibacterial[27,43,44], antifungal[27,43,44], antihyperglycemic[32], antimalarial[45], antioxidant[21] and iron absorption[28] activities.

Antibacterial: Mutindi[43] evaluated antibacterial activities of crude root extract of *A. garckeana* and pure compounds isolated from the roots of the species which included gossypol 1, 6, 6-Dimethoxygossypol 2, 6-Methoxygossypol 3, stigmasterol4, *E*-docosyl 3-(3,4-Dihydroxyphenyl) acrylate 5 and betulinic acid 13 against *Eschericia coli*, *Enterococcus faecalis, Enterococcus faecium* and *Staphylococcus aureus* using ciprofloxacin as control. Compounds gossypol 1, 6, 6-Dimethoxygossypol 2 and 6-Methoxygossypol 3 exhibited antibacterial activities against *Enterococcus faecalis* and *Enterococcus faecium* with half maximal inhibitory concentration (IC_{50}), minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) values ranging from 0.89-20 μg mL^{-1} [43]. Gossypol 1 exhibited antibacterial activity against *Staphylococcus aureus* with IC_{50} value of 6.98 μg mL^{-1} [43]. Similarly, Masila *et al.*[44] evaluated antibacterial activities of compounds gossypol 1, 6, 6-Dimethoxygossypol 2 and 6-Methoxygossypol 3 isolated from *A. garckeana* against *Enterococcus faecium* and *Staphylococcus aureus* using ciprofloxin, methicillin and vancomycin as controls. Compound gossypol 1 showed strong activity against

Table 3: Amino acids isolated from fruits and leaves of *Azanza garckeana*

	Amounts (g/100 g) from fruits and leaves	
Amino acids	Fruits	Leaves
Alanine	3.30	4.00
Arginine	7.01	7.69
Aspartic acid	9.67	10.97
Cysteine	3.00	3.66
Glycine	1.00	1.23
Glutamic acid	10.79	11.09
Histidine	3.67	4.00
Isoleucine	4.98	5.00
Leucine	12.01	12.97
Lysine	11.78	12.85
Methionine	2.00	2.78
Phenylalanine	8.00	9.00
Proline	4.00	4.78
Serine	3.97	4.00
Threonine	4.78	4.97
Tyrosine	4.89	4.99
Valine	6.00	6.76

Nkafamiya *et al.*[25]

Table 4: Chemical compounds isolated and characterized from *Azanza garckeana*

Compounds	Extract	Plant parts	Method of compound characterization	References
Sesquiterpenoids				
Gossypol	Ethyl acetate in n-hexane; methanol in dichloromethane	Root	*MS; NMR	Mutindi[43], Masila *et al.*[44]
6, 6-Dimethoxygossypol	Ethyl acetate in n-hexane; methanol in dichloromethane	Root	MS; NMR	Mutindi[43], Masila *et al.*[44]
6-Methoxygossypol	Ethyl acetate in n-hexane; methanol in dichloromethane	Root	MS; NMR	Mutindi[43], Masila *et al.*[44]
Phytosterol				
Stigmasterol	Ethyl acetate in n-hexane; methanol in dichloromethane	Root and stem bark	MS; NMR	Mutindi[43], Masila *et al.*[44]
E-docosyl 3-(3, 4-Dihydroxyphenyl) Acrylate	Ethyl acetate in n-hexane; methanol in dichloromethane	Root and stem bark	MS; NMR	Mutindi[43], Masila *et al.*[44]
O-naphthoquinones	Mansonones E	n-hexane	Heart wood	NMR Letcher and Shirley[42]
Mansonones F	n-hexane	heartwood	NMR	Letcher and Shirley[42]
Mansonones G	n-hexane	heartwood	NMR	Letcher and Shirley[42]
Mansonones H	n-hexane	heartwood	NMR	Letcher and Shirley[42]
Azanzone A	n-hexane	heartwood	NMR	Letcher and Shirley[42]
Azanzone B	n-hexane	heartwood	NMR	Letcher and Shirley[42]
Triterpene				
Betulinic acid	Ethyl acetate in n-hexane; n-hexane; methanol in dichloromethane	Fruit pulp, root, stem bark	MS; NMR	Dikko *et al.*[27], Mutindi[43] and Masila *et al.*[44]

*MS: Mass spectrometry, NMR: Nuclear magnetic resonance spectroscopy

Enterococcus faecium with IC_{50}/MIC/MBC values of 1.71/4.82/19.31 µM[44]. Compounds 6, 6-Ttramethoxygossy pol 2 and 6-Methoxygossypol 3 were less active with IC_{50}/MIC/MBC values of 2.73/4.70/9.40 µM and 6.14/18.32/18.32 µM against *Enterococcus faecium*. Compound gossypol 1 demonstrated modest activities against *Staphylococcus aureus* with IC_{50} value of 9.15 µM[44]. In another study, Dikko *et al.*[27] evaluated antibacterial activities of fruit pulp ethyl acetate, n-hexane and methanol extracts of *A. garckeana* against *Enterococci*, *Escherichia coli, Helicobacter pylori, Proteus mirabilis, Pseudomonas aeruginosa* and *Staphylococcus aureus* using agar diffusion method. Ethyl acetate fraction of *A. garckeana* was the most active with MIC value of 0.625 mg mL^{-1} against *Escherichia coli*, while MIC and MBC values of fractions against the rest of bacteria species ranged between 1.25-2.5 mg mL^{-1} [27]. These findings somehow confirm the species' antibacterial potential and its usefulness in the treatment and management of abscesses[16,21] and syphilis[24] in Nigeria, gonorrhoea in Malawi[22] and Nigeria[25] and sexually transmitted diseases in Zambia[23].

Antifungal: Mutindi[43] evaluated antifungal activities of crude root extract of *A. garckeana* and pure compounds isolated from the roots of the species which included gossypol 1, 6, 6-Dimethoxygossypol 2, 6-Methoxygossypol 3, stigmasterol 4, *E*-docosyl 3-(3,4-Dihydroxyphenyl) acrylate 5 and betulinic acid 13 against *Candida albicans*, *Candida glabrata, Candida krusei* and *Aspergillus fumigatus* using ampotericin B as control. *Azanza garckeana* crude root extract showed strong antifungal activity of 100 % inhibition against *Candida glabrata* at a concentration of 50 µg mL^{-1}. Compound 6-Methoxygossypol 3 exhibited strong antifungal activity against *Candida glabrata* with IC_{50} value of <0.8 µg mL^{-1} while gossypol 1 exhibited activity against *Candida glabrata* with IC_{50} value of 3.2 µg mL^{-1} [43]. Similarly, Masila *et al.*[44] evaluated antifungal activities of compounds gossypol 1, 6, 6-Dimethoxygossypol 2 and 6-Methoxygossypol 3 isolated from *A. garckeana* against *Candida glabrata* using amphotericin B as control. Compound gossypol 1 demonstrated modest activities against *Candida glabrata* with IC_{50} values of 0.73 µM[44]. In another study, Dikko *et al.*[27] evaluated antifungal activities of fruit pulp ethyl acetate, n-hexane and methanol extracts of *A. garckeana* against *Candida albicans, Candida krusei* and *Candida tropicalis* using agar diffusion method. Best antifungal activities were demonstrated by ethyl acetate, n-hexane and methanol fractions of *A. garckeana* with MIC value of 1.25 mg mL^{-1} against *Candida krusei*[27]. Ethyl acetate extract demonstrated the best minimum fungicidal concentration (MFC) of 2.5 mg mL^{-1} against *Candida albicans* and *Candida tropicalis*[27].

Antihyperglycemic: Amuri *et al.*[32] evaluated the hypoglycemic and antihyperglycemic activities of aqueous leaf extracts of *A. garckeana* by administering 500 mg kg^{-1} to guinea pigs (*Cavia porcellus*), both in glucose baseline conditions and in oral glucose tolerance test with follow-up over 210 min. In oral glucose tolerance test, *A. garckeana* was active with inhibition of glycemia increase of 36.9% compared with the hyperglycemic inhibition rate of glibenclamide (50%)[32]. This data support the traditional use of *A. garckeana* leaf decoction as herbal medicine for diabetes in DRC[32].

Antimalarial: Connelly *et al.*[45] evaluated antimalarial activities of aqueous and organic fractions of *A. garckeana* against *Plasmodium falciparum. Azanza garckeana* showed weak antimalarial activity with median inhibitory concentration which was >3 µg mL^{-1} [43]. Antimalarial evaluations carried out by Connelly *et al.*[45] demonstrated weak activities but such findings may imply that *A. garckeana* has bioactive constituents with potential in controlling mosquito vectors.

Antioxidant: Mshelia *et al.*[21] evaluated antioxidant potential of petroleum ether, ethyl acetate, acetone, methanol and water stem bark extracts of *A. garckeana* using the DPPH (2,2-Diphenyl-1-picrylhydrazyl) radical scavenging activity. The methanol stem bark extracts exhibited antioxidant activity with IC_{50} value of less than 100 µg mL^{-1} while acetone extracts exhibited activity with IC_{50} value of 160 µg mL^{-1} against the standard ascorbic acid activity with IC_{50} value of 220 µg mL^{-1} [21]. These antioxidants activities of stem bark are probably due to the presence of flavonoids and phenolics[46]. There is now a global trend towards the use of natural phenolics as antioxidants and functional ingredients due to their perceived safety and prevalence in wild edible fruits[47].

Iron absorption: Ahmed *et al.*[28] evaluated iron absorption capability of aqueous extract of *A. garckeana* fruits *in vivo* by using everted gut sacs of wistar albino rats. Ahmed *et al.*[28] administered 2 g kg^{-1} b.wt. of *A. garckeana* aqueous extract to iron deficient rats for 3 weeks in a nutritional anemia experimental model. Administration of *A. garckeana* extracts caused slight alterations on hematological parameters of the nutritionally iron deficient rats except on red blood cells counts of these animals[28]. Thus, *A. garckeana* extract was found to have stimulating iron absorption properties when

used on *in vitro* iron absorption model. This effect may justify its use for treatment of iron deficiency anemia in Sudan[28] as this plant contributes to enhancement of iron deficiency rather than providing the body with rich iron source. Thus this effect of *A. garckeana* extract may be attributed to its saponins contents causing an increase in production of red blood cells and hence increasing their numbers[28].

Cytotoxicity: Mshelia *et al.*[21] evaluated cytotoxicity activities of petroleum ether, ethyl acetate, acetone, methanol and water stem bark extracts of *A. garckeana* using the brine shrimp lethality test. The concentration killing 50% (LC_{50}) of the shrimps was 3.98 μg mL^{-1} for acetone extract, methanol extract exhibited LC_{50} of 47.66 μg mL^{-1}, ethyl acetate extracts (LC_{50} of 100 μg mL^{-1}), water extracts (LC_{50} of 138.04 μg mL^{-1}) and petroleum ether extract exhibited LC_{50} value of greater than 1000 μg mL^{-1}. Recently, Omosa *et al.*[48] evaluated the cytotoxicity of dichloromethane and methanol (1:1) extract of *A. garckeana* stem bark using the resazurin reduction assay against CCRF-CEM leukemia cell line. The dichloromethane and methanol extract of *A. garckeana* stem bark displayed cytotoxicity towards leukemia CCRF-CEM cells with IC_{50} value of 85.0 μg mL^{-1} [48]. Compound gossypol 1 isolated from *Thespesia populnea* exhibited cytotoxic and elastase inhibitory activities[49,50]. These results obtained from cytotoxic evaluations indicate the possibility that some plant parts of *A. garckeana* may be toxic or contain some cytotoxic compounds. Previous research by Randel *et al.*[51] revealed that gossypol 1 is toxic to non-ruminant animals and this has limited the use of cotton seed meal as a dietary source of protein for mono-gastric animals.

CONCLUSION AND RECOMMENDATION

It was concluded that such detailed research will be important as an indication of the potential nutraceutical and economical utility of *A. garckeana* as an important source of bioactive phytochemicals, edible fruits and food additive. Some of the pharmacological properties of *A. garckeana* documented so far, may be attributed to various compounds including alkaloids, flavonoids and phenolics. The contemporary research done so far involving *A. garckeana* is promising as some of the nutritional, phytochemical and pharmacological evidence may be used to explain and support the documented ethnomedicinal uses, nutritional and nutraceutical values.

Further research on the phytochemistry, pharmacological properties, pharmacokinetics and clinical studies of *A. garckeana* will enhance the ethnopharmacology, nutritional and nutraceutical value of the species and also create awareness on the species' importance in improving human health in tropical Africa. There should be experimental animal studies, randomized clinical trials and target-organ toxicity studies involving *A. garckeana* and its derivatives. It will be important to investigate the isolation of the bioactive compounds, mechanisms of action and safety of such bioactive compounds. Such information may be useful for further studies on *A. garckeana* fruit for its applications in pharmaceutical industries. Further research on the antinutritive, enzymatic and molecular effects on human health will be needed to motivate further interest in the use of *A. garckeana* fruits.

SIGNIFICANCE STATEMENT

Azanza garckeana demonstrated several ethnomedicinal uses, nutritional and nutraceutical values throughout its distributional range in tropical Africa. The overall results suggest that *A. garckeana* parts contain nutrients, minerals phytochemical compounds that are useful for human health. *Azanza garckeana* fruits are a good source of flavonoids and tannins, indicating considerable potential of *A. garckeana* fruit as a resource for dietary health supplement.

ACKNOWLEDGMENTS

The author would like to express his gratitude to the National Research Foundation (NRF grant number T398) and Govan Mbeki Research and Development Centre (GMRDC, grant number C169), University of Fort Hare for financial support to conduct this research.

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