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Proximate, mineral, fibre, phytate–phosphate, vitamin E, amino acid and fatty acid composition of *Terminalia sericea*

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ABSTRACT

Terminalia sericea is widely distributed in the African Savannah bushveld. It is one of the indigenous fruit bearing trees put to multiple uses. Research has focused on the phytochemical composition of its root, bark, and leaf extracts that are used in ethnomedicine neglecting the potential of its seed. This study purposed to determine, by chemical analyses, the nutritive value of *T. sericea* seed. 78.8% of the seed was found to be crude protein (46.2%) and lipid (32.6%). Ash made up 6.90% of the seed mass. Linoleic and oleic acids constituted 68.63% and 14.05%, respectively, of the seed oil. Phosphorus (1121.75 ± 10.39 mg 100 g^{-1} DM) and glutamic acid (8.07 ± 0.13 g 100^{-1} DM) constituted the most concentrated mineral and amino acid, respectively. *T. sericea* seed could be utilized as a protein source in feeds and foods and could also be exploited as a non-conventional plant oil source of oleic acid and linoleic acid.

1. Introduction

Terminalia sericea, also known as the Silver leaf tree, family Combretaceae, is widely distributed in tropical Africa where it is found scattered in most of the savannah woodlands of east, central and southern Africa occurring as a dominant or co-dominant species in mixed forests and in some warm temperate regions (Hutchings et al., 1996). The tree thrives in most soil types with good drainage but is more abundant in areas with deep sandy soils and moderate rainfall (Coates-Palgrave, 1988). Palmer and Pitman (1972) point out that the tree is drought tolerant, moderately adapted to saline soils and tolerates some degree of frost.

T. sericea occurs as a shrub or bush that grows on average to a height of 6 to 9 m although some trees may reach a height of 23 m (Coates-Palgrave, 1988). The stem and branch barks are reddish-brown in colour (Drummond, 1981). *T. sericea* leaves which are obovate-elliptic and covered in silvery hairs are crowded at the end of the branch and are bluish-green above and paler below (Drummond, 1981). The pale-yellow to creamy-white flowers are in auxiliary spikes. Its winged oval fruit is pinkish on maturity turning dark with advancement in age and contains a single seed.

In communities where it is found, *T. sericea* is of multipurpose value. It is used as a fuel source (fuel wood and charcoal), for fencing posts, for carving of hand tools and in construction (Eckman and Deborah, 1993). In sub-Saharan Africa *T. sericea* contributes to both domestic and wildlife production through the provision of browse especially during the hot dry season (Katjiua and Ward, 2006). *T. sericea* is also widely used in ethnomedicine. The root bark extracts are used to treat diarrhoea, colic, pneumonia and bilharzia while its leaf extract is used in the management of stomach disorders (Coates-Palgrave, 1988).

The use of *T. sericea* in ethnomedicine is premised on its reported biological activities that include being antifungal and antibacterial (Fyhrquist et al., 2004) and the ability to inhibit topoisomerase II (Wall et al., 1996). The enzyme topoisomerase is critical for chromosome structure and segregation and plays a role in DNA replication, recombination and transcription in cells (Osheroff et al., 1991). Phytochemicals including resveratrol-3-*O*-β-rutinoside, a stilbene glycoside, and oleanane-based pentacyclic triterpenes and their glycosides have been isolated from *T. sericea* (Joseph et al., 2007). Resveratrol and its derivatives are considered protective against coronary heart disease (Jeandet et al., 1991). A *T. sericea* derived sericoside has been patented and is used in skin lightening preparations in Japan (Maeda and Fukuda, 1996).

Recently our laboratory has focused on characterizing the potential of seeds from indigenous fruit bearing trees as feed and food ingredients and as sources of oils, essential fatty acids and industrial raw materials (Chivandi et al., 2008; Chivandi and Erlwanger, 2011; Chivandi et al., 2011a, 2011b). While a substantial amount of research has been carried out on the phytochemical composition and biological activity of the root, bark and leaf extracts of *T. sericea*, a dearth of information exists on the chemical composition and nutritional

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value of *T. sericea* seed hence the major objective of this study was to chemically characterize the potential of *T. sericea* seed as a feed and or food resource.

2. Materials and methods

2.1. Seed source and processing

Fresh ripe *T. sericea* fruits were collected from Gweru District, Zimbabwe (latitude 19°28′S; longitude 29°45′E). Gweru District is characterized by basalt and granitic soils, an average annual rainfall of 643 mm and an average annual temperature of 28 °C (Moyo, 2006). Two kilograms of ripe fruit was harvested from each of ten randomly selected trees between August and October 2010. The seeds were manually extracted from the tough fruit coat, dried in the shade and stored in dark sample bottles at 4 °C in a refrigerator until the time of assaying. Before the chemical assays, the seeds were crushed using a blender (Waring; Lasec Pty Ltd, Johannesburg, South Africa) to produce a fine composite powder from which the various assays were done.

2.2. Chemicals and reagents used for the assays

All the chemicals and reagents used were of analytical grade. The chemicals and reagents unless otherwise stated were obtained from Sigma-Aldrich Chemie (Steinheim, Germany).

2.3. Proximate determinations

The proximate, mineral, amino acid, fibre and phytate–phosphate determinations were performed at the Agricultural Research Council's Irene Analytical Services Laboratories, South Africa. Dry matter was determined as outlined by the Official Methods of Analysis of Analytical Chemists (AOAC) (2005). The other proximate components organic matter, crude protein, ether extract, and ash were determined as outlined by the Official Methods of Analysis of Analytical Chemists (AOAC) (1995). The gross energy value of the seeds was determined using an MC-1000 Modular Calorimeter (Energy Instrumentation, Centurion, Republic of South Africa) equipped with a personal computer (PC) and MC1000 software.

2.4. Calcium, magnesium and phosphorus determination

Prior to the determination of the mineral concentration in the seed samples, 0.5 g of the crashed composite sample was digested in concentrated nitric acid and perchloric acid at 200 °C to generate the digest solution (Zasoski and Burau, 1977). From the digest solution an aliquot of the digest solution was used for the inductively coupled plasma optical emission spectrometric (ICP-OES) determination of calcium, magnesium and phosphorus on a Varian Liberty 200 spectrometer (Varian, Perth, Australia) as described by Huang and Schulte (1985).

2.5. Amino acid assay

The concentration of each of the assayed amino acids was determined as described by Einarsson et al. (1983). Briefly, the assay involved acid hydrolysis with 6 M HCl at 110 °C for 24 h and pre-column fluorescence derivatization of amino acids with 9-flourenylmethyl chloroformate. The amino acids were extracted with pentane, and separated by gradient elution on a chromatograph. The chromatograph consisted of a SpectraSystem P4000 Quaternary HPLC (Rigas Labs S.A., Thessaloniki, Greece) equipped with a SpectraSystem FL3000 fluorescence detector and Rheodyne 7125 valve with 20 μl injection loop. The eluent was varied with a concave curve from sodium citrate buffer (pH 2.95)–acetonitrile (70:30) to sodium citrate buffer (pH 4.5)–methanol–acetonitrile (14:6:70) and a flow-rate of 1.4 ml min^{-1}. An OmniSper 5 C18 150 × 4.6 analytical column and guard-column were used for separation of the amino acids. Identification of the amino acids was done at an excitation wavelength of 264 nm and an emission wavelength of 340 nm. A PC equipped with TSP software was used for quantification. Quantification was performed by using an external calibration procedure.

2.6. Fibre determinations

The neutral detergent fibre (NDF) and acid detergent fibre (ADF) components of the seed were determined as described by van Soest et al. (1991). In summary, NDF determination involved refluxing a 0.5 g sample for 1 h in 100 ml of neutral detergent solutions of sodium lauryl sulphate and ethylenediamine-tetraacetic acid to which heat-stable alpha-amylase (20 350 IU ml^{-1}) (dietary fibre kit, Sigma-Aldrich) was added. After refluxing for 1 h, the mixture was filtered; the residue was dried and weighed. ADF was determined by refluxing for 1 h a 0.5 g sample in acid detergent solution (20 g cetyl-trimethyl ammonium bromide dissolved in 1 l N H_2SO_4). After refluxing, the mixture was filtered and the residue was dried and then weighed.

2.7. Phytate–phosphate determination

Phytate–phosphate content of the seed was determined colorimetrically as described by Wheeler and Ferrel (1971). In summary, samples were treated with 3% trichloroacetic acid followed by addition of ferric chloride (2 mg ferric iron per ml in 3% trichloroacetic acid) and the precipitate dissolved in 3.2 N nitric acid. After addition of 1.5 M potassium thiocyanate the absorbance was read at 480 nm using a Perkin Elmer Lambda25 UV/Vis Spectrometer (PerkinElmer, California, USA) equipped with a desktop computer and Lambda25 software.

2.8. Fatty acid profile determination

Fat was extracted from the respective seeds by the Soxhlet method. Methyl esters for capillary gas chromatography were prepared according to the method of Christopherson and Glass (1969). Briefly, the fat extracts were trans-methylated with 2 M methanol–sodium hydroxide. The resulting fatty acid methyl esters were extracted in heptane, filtered and dried under nitrogen. The fatty acids were separated by a temperature gradient over 45 min on a gas chromatograph (GC) with nitrogen as carrier gas on a DB-23 capillary column (90 cm × 250 μm × 0.25 μm) (Supelco, Sigma-Aldrich). The gas chromatograph consisted of a HP6890 GC (Hewlett Packard, Bristol, United Kingdom) with flame ionization detector (FID). Both the detector and injector temperatures were set at 300 °C. A PC equipped with Chemstation software was used for quantification. Nonadecanoic acid (C19:0) was used as internal standard.

2.9. Vitamin E and squalene determination

Lipid extracts used in the assays were prepared using standard lipid extraction procedures (Bligh and Dyer, 1959). After evaporation to dryness, the lipids were re-dissolved in an equal volume of the respective running solvent; methanol:water (95:5) for vitamin E and, hexane:propan-2-ol:water (98:2:0.02) for squalene prior to injection into the HPLC system. Assays for vitamin E were done as described by De Leenheer et al. (1985) and Gratzfeld-Huesgen et al. (1992) whereby, following the dissolution of the lipid extracts into the running phase solvent, the sample was injected into the HPLC system (LKB Bromma 2150 HPLC; LKB, Bromma, Sweden). The mobile phase ran at 2 ml/min. Vitamin E was separated using methanol:water (95:5) and a C18, 15 cm × 4.6 mm ID, 5 μm particle size column; and detection at 290 nm by a Lambda-Max Model 481 LC spectrophotometer with vitamin quantification using an HP 3390A integrator. Squalene

was assayed as described by Sulpice and Ferezou (1984). The sample was injected into an HPLC system (LKB Bromma 2150 HPLC). The mobile phase ran at 5 ml min^{-1} with squalene separation using hexane: propan-2-ol:water (98:2:0.02) and a silica gel C18, 25 cm × 4.6 mm ID, 5 μm particle size column (Phenomenex, Torrance, USA); and detection at 215 nm by a Lambda-Max Model 481 LC spectrophotometer (Millipore Water Corporation, Ontario, Canada) with squalene quantification using an HP 3390A integrator (Hewlett Packard, Bristol, United Kingdom). Authentic vitamin E and squalene standards were used to identify and quantitate vitamin E and squalene, respectively.

3. Results and discussion

Table 1 shows the chemical composition of *T. sericea* seed, while the amino acid composition of *T. sericea* seed and fatty acid profile of the seed oil are shown in Tables 2 and 3, respectively. Protein and lipid combined made up 78.8% of the seed mass thus constituting the bulk of the organic matter of *T. sericea* seed. The seed had a gross energy value of 21.96 ± 0.01 MJ kg^{-1} DM.

3.1. Proximate, mineral and fibre composition

Soyabean meal (SBM), cotton seed cake (CSC), and sunflower seed cake (SSC) constitute the major plant-derived protein sources in feeds (Storebakken et al., 2000; McDonald et al., 2002). The crude protein (CP) content of CSC and SSC depends on the degree of decortication. Decorticated sunflower seed meal has a reported CP content range of 24–40% (Jabbar et al., 2009) while the CP contents of undecorticated and decorticated CSCs are 21.3% and 45%, respectively (McDonald et al., 2002). Solvent extraction produced SBM has a CP content of 45% (FAO, 1993). Full-fat *T. sericea* seed's CP content of 46.2% (Table 1) is comparable to the 45% CP solvent extracted SBM (FAO, 1993) and generally higher than that of CSC and SSC. Defatting *T. sericea* seed could result in a seed meal that has CP content much higher than that of SBM, particularly when considering the higher oil content of *T. sericea* seed (Table 1). *T. sericea* seed meal could potentially be used to partially or completely substitute SBM as a protein source in feeds and foods.

The lipid yield from *T. sericea* seed at 32.6% following solvent extraction (with a 2:1 chloroform:methanol mixture) was much higher than the 15–25% lipid yield from soyabean seed (Cheftel and Cheftel, 1977) but comparable to lipid yield from sunflower (35–40%) and cotton seed (35–40%) (Manga et al., 2000). Thus *T. sericea* seed could be exploited as a non-conventional plant oil source which could provide a cover for the cost of processing the seed into a protein concentrate. Maize, the major energy source in feeds and foods has a gross energy (GE) value of 17 MJ kg^{-1} (Fagbenro, 1999) that is lower compared to the 21.96 ± 0.01 MJ kg^{-1} we found for full-fat *T. sericea* seed. The higher GE in *T. sericea* seed could be ascribed to the seed's higher lipid content compared to maize grain. This means that *T. sericea* could also be exploited as an energy source in feeds and foods. However, there might be a need to de-fat the seed prior to utilization in order to guard against possible rancidity as a result of the seed's high oil content.

Table 1
Proximate, mineral, vitamin E and squalene and fibre composition of *Terminalia sericea* seed.

Proximate component (g kg^{-1} DM)	Mean ± SD
Dry matter	953.03 ± 0.92
Organic matter	884.08 ± 3.22
Crude protein	462.32 ± 5.49
Lipid yield	325.61 ± 14.00
Ash	68.95 ± 2.30
Mineral (mg 100 g^{-1} DM)	
Calcium	795.20 ± 17.82
Magnesium	560.70 ± 6.68
Phosphorus	1121.75 ± 10.39
Vitamin E and squalene content (μg g^{-1})	
Vitamin E	48.70 ± 6.08
Squalene	nd
Fibre fraction and phytate–phosphate (g kg^{-1} DM)	
Neutral detergent fibre	223.30 ± 2.16
Acid detergent fibre	90.27 ± 4.68
Phytate–phosphate	1.02 ± 0.00

Data presented as mean ± SD; n = 3.

Table 2
Amino acid profile (g 100 g^{-1}) of full-fat *Terminalia sericea* seed.

Amino acid	Mean ± SD
Alanine	3.68 ± 1.70
Arginine	7.56 ± 0.21
Aspartic acid	3.49 ± 0.26
Glutamic acid	8.07 ± 0.13
Glycine	2.14 ± 0.01
Histidine	1.25 ± 0.09
Hydroproline	0.32 ± 0.08
Isoleucine	1.59 ± 0.23
Leucine	2.43 ± 0.19
Lysine	1.60 ± 0.21
Methionine	0.65 ± 0.11
Phenylalanine	1.91 ± 0.03
Proline	1.88 ± 0.13
Serine	1.62 ± 0.01
Threonine	1.76 ± 0.26
Tyrosine	2.34 ± 0.02
Valine	1.79 ± 0.31
Total	44.08

Data presented as mean ± SD; n = 3.

Table 3
Fatty acid profile of *Terminalia sericea* seed oil.

Fatty acid	%
Saturated	
C12:0 (lauric acid)	0.04
C14:0 (myristic acid)	0.12
C16:0 (palmitic acid)	9.22
C17:0 (heptadecanoic acid)	0.15
C18:0 (stearic acid)	6.18
C20:0 (arachidic acid)	0.57
C21:0 (heneicosanoic acid)	0.04
C22:0 (behenic acid)	0.15
C24:0 (lignoceric acid)	0.04
TSFA	16.51
Monounsaturated	
C14:1n7 (myristoleic acid)	0.04
C16:1n7 (palmitoleic acid)	0.11
C17:1n8 (cis-10-heptadecanioc acid)	0.04
C18:1n9 (oleic acid)	14.05
C20:1n9 (cis-11-eicosenoic acid)	0.14
TMUFA	14.38
Polyunsaturated	
C18:2n6 (linoleic acid)	68.63
C18:3n3 (α-linolenic acid)	0.41
C20:2n6 (all cis-11, 14-eicosadienoci acid)	0.06
TPUFA	69.10
cis fats	82.68
Omega-3	0.41
Omega-6	68.63
Omega-9	14.05
TPUFA:TSFA	4.19:1
n3PUFA:n6PUFA	0.01:1

TSFA: total saturated fatty acids; TMUFA: total monounsaturated fatty acids; TPUFA: total polyunsaturated fatty acids; n3PUFA: omega-3 polyunsaturated fatty acids; and n6PUFA: omega-6 polyunsaturated fatty acids; data presented as a mean of assays done in duplicate.

The 6.90% mineral content reported for *T. sericea* seed in the current study is higher than the mineral content of *Kigelia africana* seed (Chivandi et al., 2011b) and *Mimusops zeyheri* seed (Chivandi et al., 2011a), indigenous fruit-bearing trees found in the same eco-environment as *T. sericea*. However the mineral content of full-fat *T. sericea* seed (6.90%) is generally comparable to the 7.48% mineral content reported by Hadjipanayiotou and Economides (2001) for soyabean. When comparing individual mineral elements, the calcium content of *T. sericea* seed (795.20 ± 7.82 mg 100 g^{-1} DM, Table 1) is much higher than the 48.3 ± 12.9 mg 100 g^{-1} DM reported by the FAO (1992) for maize grain. Maize grain has reported magnesium and phosphorus contents of 107.9 ± 9 mg 100 g^{-1} DM and 299.6 ± 57.8 mg 100 g^{-1} DM, respectively (FAO, 1992) that are lower than the 560.70 ± 6.68 and 1121.7 ± 10.39 mg 100 g^{-1} DM magnesium and phosphorus contents, reported for full-fat *T. sericea* seed in the current study (Table 1). Using *T. sericea* seed to substitute maize as an energy source in feeds could result in savings on the calcium, magnesium and phosphorus component of the mineral supplement due the higher concentration of these minerals in *T. sericea* seed compared to maize grain.

SBM, the major protein source in animal feeds has neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents of 15.74% and 10.70% (Hadjipanayiotou et al., 1985), respectively. The respective NDF and ADF contents of maize grain are 10.80% and 2.8% (FAO, 1992). Compared to that of SBM, the NDF content of *T. sericea* seed (22.33%; Table 1) is moderately higher. The ADF content of *T. sericea* seed (9.03%; Table 1) is lower compared to the ADF concentration in SBM. High fibre content usually limits inclusion levels of potential protein and energy sources in monogastric animal feeds (due to physiological limitations to digest highly fibrous feeds). Although the NDF content of *T. sericea* seed is moderately higher compared to that of SBM, it could help provide the necessary bulk critical for maintenance of normal gastrointestinal motility. The relatively lower ADF content of *T. sericea* seed could mean that its use in monogastric animal feeds could be without challenges of the fibre content.

3.2. Amino acid content

When compared to the amino acid profile of soyabean (Kapsiotis, 1968; Cerny et al., 1971) the concentration of both non-essential and essential amino acids in *T. sericea* seed is lower. In comparison to the amino acid profile of SBM, the individual amino acid concentration (essential and non-essential) in *T. sericea* seed is in the range of 70–90% of that in solvent extracted SBM (FAO, 1993). The concentrations of the essential amino acids (EAAs) arginine, histidine, isoleucine, leucine, lysine and valine in solvent extracted SBM are 3.45%, 1.41%, 1.98%, 3.29%, 2.90%, and 2.15%, respectively (FAO, 1993). The reported respective concentrations of the corresponding EAAs in *T. sericea* seed were generally lower except for arginine (Table 2). The high oil/lipid content of full-fat *T. sericea* seed (Table 1) could be masking the potential of the seed to supply EAAs. Defatting *T. sericea* seed to about 1% residual lipid could produce a meal whose CP content and hence both non-essential and EAA concentrations could be comparable if not substantially higher to that of SBM.

T. sericea seed had a high concentration of arginine (7.56 ± 0.21 g 100 g^{-1} DM, Table 2) compared to the 3.45% arginine in SBM (FAO, 1993). Creager et al. (1992) reported an improvement in endothelium-dependent vasodilation subsequent to exogenous administration of L-arginine, the physiological precursor of nitric oxide (NO). Administration of L-arginine was noted to restore endothelium-dependent relaxation in hypercholesterolemic humans (Creager et al., 1992) while Jeremy et al. (1996) reported that administration of L-arginine decreased aortic lesion formation in cholesterol-fed rabbits all indicative of cardiovascular protection. Thus *T. sericea* seed, due to its high concentration of arginine, if used as a food ingredient or supplement, could potentially increase the body's physiological pool of L-arginine, the physiological precursor of NO, thus offering some degree of cardiovascular protection. However, the potential of *T. sericea* seed to offer cardiovascular protection when used as food supplement requires further investigation.

3.3. Fatty-acid profile and vitamin E content

The fatty acid profile of *T. sericea* seed oil is interesting from a nutritional and health view point. *T. sericea* seed with an oil yield of about 33% had 14% oleic acid (OA) in its seed oil. The OA acid content of *T. sericea* seed oil was lower compared to the OA range of 70–80% in *Sclerocarya birrea* (marula tree) kernel oil (Burger et al., 1987), 63% OA in *Ximenia caffra* kernel oil (Chivandi et al., 2008), 84.59% OA in *M. zeyheri* seed oil (Chivandi et al., 2011a) and 17.58% OA in *K. africana* seed oil (Chivandi et al., 2011b), all of which are indigenous fruit bearing trees that flourish in the same southern African eco-environment as *T. sericea*. Comparably, virgin olive oil contains 70–80% OA (Terès et al., 2008). Alonso and Martinez-Gonzàlez (2004) reported that long term intake of olive oil with its high OA content attenuated blood pressure and the risk of developing hypertension. The potential use of *T. sericea* seed oil as a dietary source of OA in the attenuation of hypertension and the development of cardiovascular disease requires further investigation.

Linoleic acid, an essential fatty acid (EFA), constituted 68.63% of the *T. sericea* seed oil (Table 3). Singh (2005) reported that EFAs, including linoleic acid, and their active metabolic substrates play a critical role in the maintenance of the structural and functional integrity of the central nervous system (CNS) and the retina, thus the use of *T. sericea* seed as a dietary supplement could increase the systemic pool of linoleic acid with potential benefits in the maintenance of the structural and functional integrity of the CNS and retina. Conjugated linoleic acid (CLA) refers to a group of dienoic derivatives of linoleic acid (Pariza et al., 2001) with bioactive properties including anti-atherogenic (Lee et al., 1994), anticarcinogenic (Chin et al., 1992) and immunity enhancement (Miller et al., 1994). The potential of *T. sericea* seed oil as a source of linoleic acid (a precursor of CLA) in anti-cancer and anti-atherogenic and immunity enhancement studies needs further interrogation.

In vivo, vitamin E functions as an anti-oxidant terminating the recyclable chain reactions of polyunsaturated fatty acid free radicals (Kamal-Eldin and Appelqvist, 1996) that are generated from endogenous oxidation of lipids. Mopping up of free radicals by vitamin E gives protection to membranes and cells against oxidative damage by the free radicals. Vitamin E is found in tissues of photosynthetic organisms (Sattler et al., 2004), thus its presence in *T. sericea* seed was not surprising. Compared to the 1.4 mg g^{-1} and 41.1 mg g^{-1} vitamin E concentration in *Sesamun indicum* (sesame) and *Helianthus annuus* (sunflower) seed oils, respectively, the *T. sericea* seed oil vitamin E concentration (48.70 ± 6.08 μg g^{-1}) is much lower. Despite the low concentration of vitamin E in *T. sericea* seed oil, the use of the seed and or seed oil as a dietary supplement could lead to an increase in the systemic anti-oxidant pool thus giving protection to the body. *T. sericea* stem bark extract showed anti-diabetic and anti-oxidant properties that were ascribed to β-sitosterol, β-sitosterol-3-acetate, lupeol and stigma-4-ene-3-one isolated from the extract (Nkobole et al., 2011). While the current study did not interrogate the polyphenolic and other phytochemical constituents of *T. sericea* seed, their presence in the seed would contribute positively to the potential health benefits of the seed.

4. Conclusion

Its high protein content, high energy density and, the linoleic acid-rich lipid make *T. sericea* seed a potential alternative dietary source of protein, energy, oil and linoleic acid. However before testing *T. sericea* seed's nutritive potential in vivo, the anti-nutritional factor content of the seed has to be determined. Furthermore, despite its

widespread distribution in sub-Saharan Africa, any possible future exploitation of *T. sericea* seed for its nutritional value would require the establishment of commercially viable tree stands and the breeding of high-yielding *T. sericea* provenances.

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