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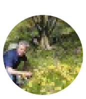

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African seed oils of commercial importance — Cosmetic applications

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Abstract

Seed oils have been used for centuries by rural communities as food, medicine, for cosmetic applications and as fuel. Recently there has been a renewed interest in these non-timber forest products (NTFPs) specifically for use in cosmetic formulations. The cosmetic industry remains under immense consumer pressure to produce innovative products for this lucrative industry. Like the pharmaceutical industry, the wellness industry turns to nature for guidance, inspiration and as a source of novel compounds to produce new consumer products. Furthermore, discerning consumers of cosmetic products are nowadays informing themselves of the validity of scientific claims made on various products. The seed oils extracted from several plant species are popularly included as ingredients in cosmetic products due to their high fatty acid composition. The information on African seed oils is scattered in literature and often published in obscure and dated manuscripts. With an emphasis on (but not restricted to) cosmetic applications the botanical aspects, uses, physico-chemical properties and oil composition as well as biological activity of six commercially important species are coherently united and reviewed in this paper and include; *Adansonia digitata* (baobab), *Citrullus lanatus* (Kalahari melon), *Schinziophyton rautanenii* (manketti/mungongo), *Sclerocarya birrea* (marula), *Trichilia emetica* (mafura butter) and *Ximenia americana* (sour plum).

Keywords: *Adansonia digitata*; *Citrullus lanatus*; Commercial importance; Cosmetic; Seed oils; *Schinziophyton rautanenii*; *Sclerocarya birrea*; Skin; *Trichilia emetica*; *Ximenia americana*

1. Introduction

The multibillion dollar natural products industry (food, beverages, cosmetics, herbal medicines, pharmaceuticals) has grown enormously with an annual growth rate of 15–20%. In 2005, it was valued at US$65 billion/year with a US$1 billion/year growth in the global sales of natural and organic cosmetics specifically for the wellness industry (Nemarundwe et al., 2009). Natural cosmetics specifically exhibited an increased revenue of 20.9% partly due to increased wariness towards the chemicals contained in some commercial products. The personal care category showed high growth of 12.7% with $2.35 billion in sales (Sustainable Business, 2006). However, the formal natural products trade, commonly referred to as non-timber forest products (NTFPs), in southern Africa was estimated at only US$12 million per year. There is growing consumer interest in natural and/or organic cosmetics with the major markets being Europe and North America. As a result, there has been a remarkable growth in the sales of natural organic cosmetic care products in retail outlets, pharmacies and skin care clinics worldwide (Antignac et al., 2011; Nemarundwe et al., 2009). A survey conducted in the United States indicated that there has been an increase in the number of adults using herbs to treat medical and cosmetic conditions from 3% in 1990 and 12% in 1997 to 21% in 2001 (Bent and Ko, 2004). In 2002, it was estimated that a total of 38 million people in the United States used herbal therapies (Tindle et al., 2005).

Oils extracted from plant sources have a rich history of use by local people as a source of food, energy, medicine and for cosmetic applications. It has been used in the production of lubricants, soaps and personal care products, as well as in the topical treatment of various conditions such as hair dandruff,

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muscle spasms, varicose veins and wounds (Zimba et al., 2005; Chivandi et al., 2008). In recent years, demand for seed oils as ingredients for food, cosmetics and biofuel has greatly increased as industry seeks natural alternatives. The global production of seed oils increased dramatically, creating pressure on countries providing the raw material to meet the growing demand. In 2004–2005, the global production of seed oils was approximately 113 million metric tonnes (MMT). Currently, the global supply is obtained from only about 15 plant species out of nearly half a million known to man, highlighting the greater potential (Mitei et al., 2008).

This continued commercial interest may also have socio-economic and ecological impact. The use of non-timber forest products has been boosted as a result of renewed interest in natural health and beauty products. However, the men and women (mainly) who collect the materials usually receive only a small fraction of the final selling price of the product. Rural women are especially involved in the harvesting of raw materials such as seeds from indigenous trees as they provide food and income to care for their families. The seeds are used to obtain oils of specific interest to cosmetic industries (IFAD, 2008; Nemarundwe et al., 2008), as many are rich in fatty acids which have been shown to be beneficial to the skin (Lautenschläger, 2003). Commercialisation of these oils can have a great economic impact for local communities and significantly contribute to household economy (Juliani et al., 2007). However, the emphasis should be not only on increasing livelihoods but also on encouraging communities to manage

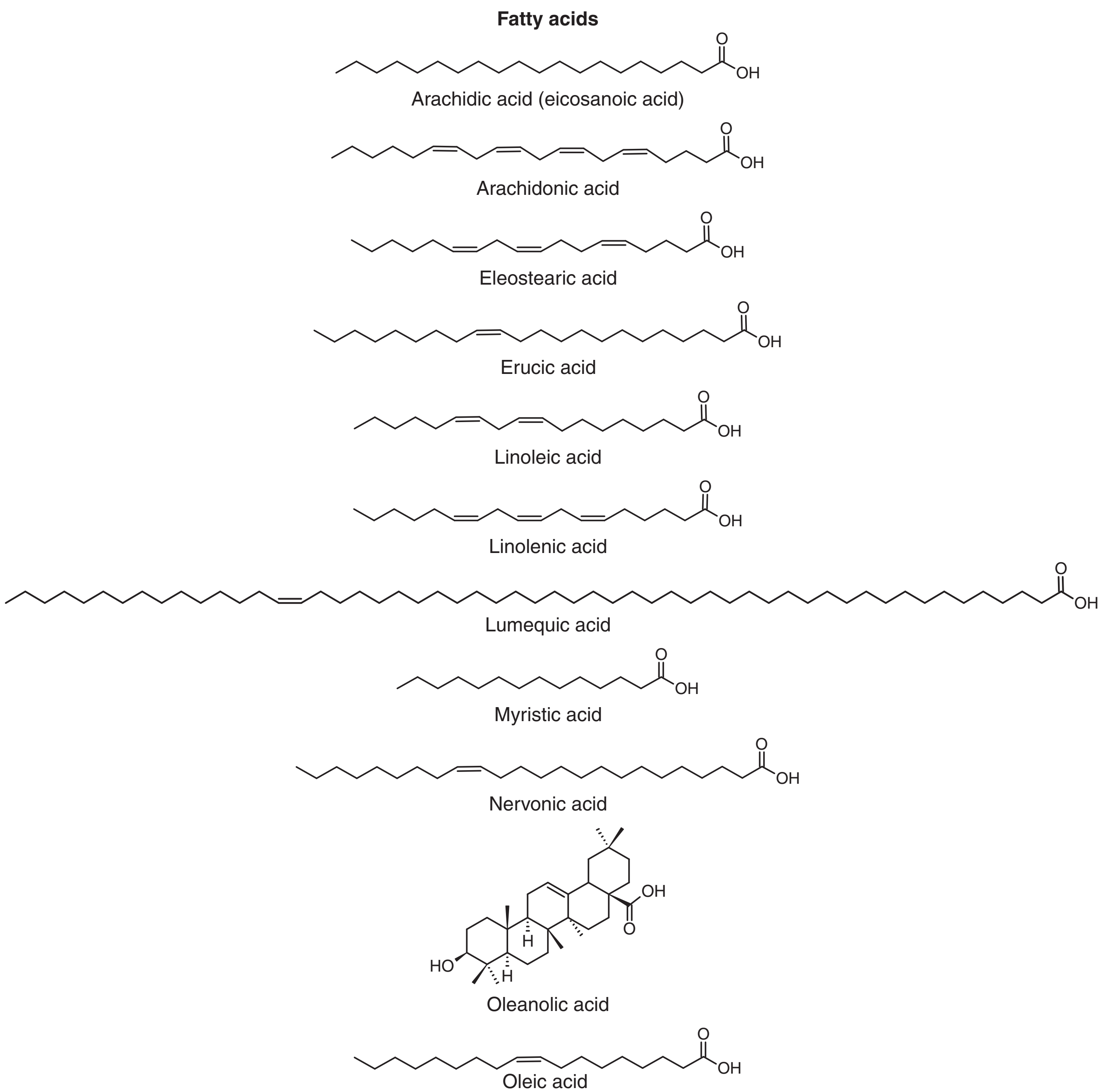

Fig. 1. Chemical structures for compounds isolated from seed oils.

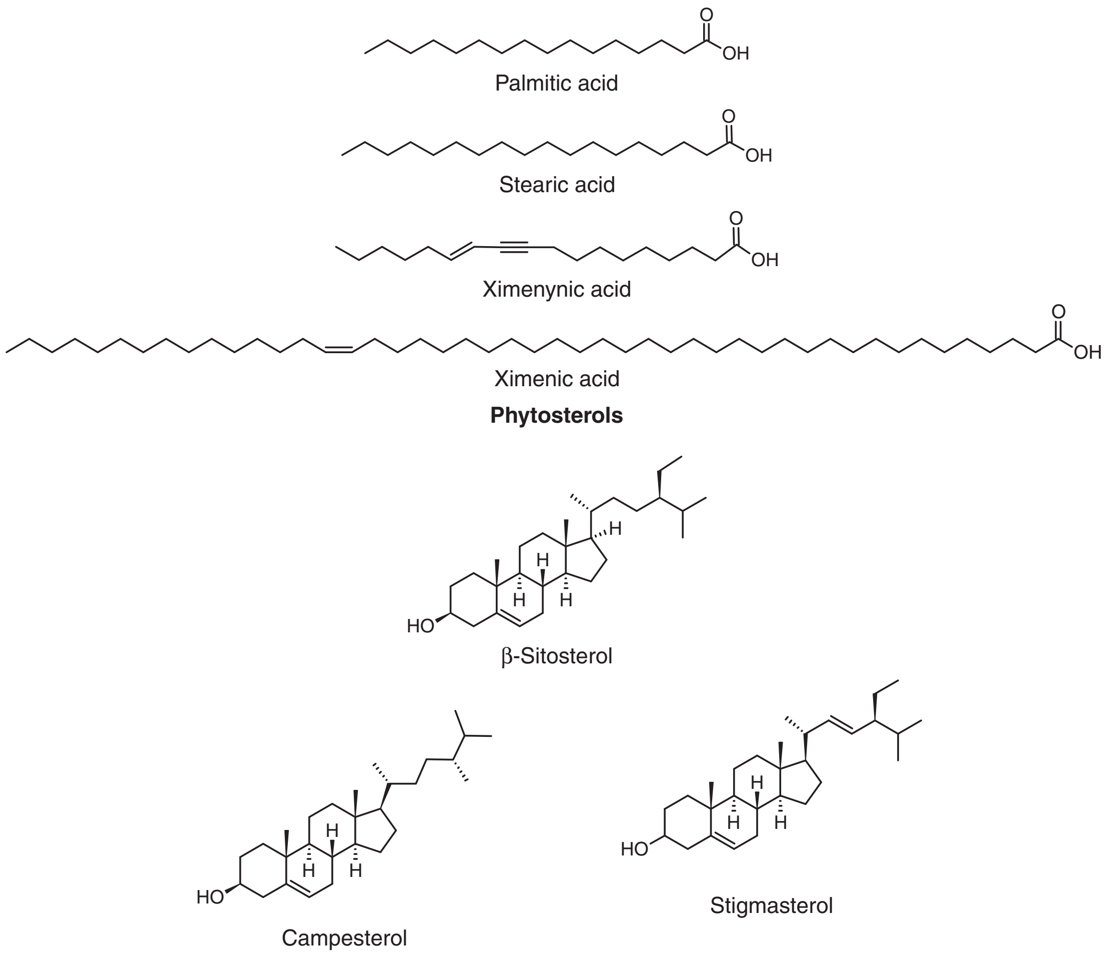

Fig. 1 (*continued*).

their resources effectively and protect the environment. Creating markets for these non-timber forest products may play a role in conservation as increased economic importance of natural resources may reduce destructive timber harvesting (Nemarundwe et al., 2008). It is evident that commercialisation and formal trade agreements will have a positive impact on rural communities, conservation, and the natural products industry as a whole.

2. Fatty acids in cosmetics

Natural seed oils used in cosmetics contain a range of fatty acids which contribute several beneficial properties in cosmetic and personal care products. Fatty acids are divided into saturated acids (e.g. palmitic; stearic; arachidic) and unsaturated acids (e.g. oleic; linoleic). Palmitic, oleic and stearic acids are synthesised in the body but linoleic acid is not and a deficiency will cause various signs. The skin dries out and becomes scaly, nails crack, and hairloss as well as transepidermal water loss increases. Linoleic acid is the most frequently used fatty acid in cosmetic products as it moisturises the skin, aids in the healing process of dermatoses and sunburns and is used for the treatment of *Acne vulgaris* (Lautenschläger, 2003). Plants containing linoleic acid may be beneficial in acne lesion reduction as the anti-inflammatory effects have been shown to inhibit *Propionibacterium acnes*. Many plants containing high levels of linoleic and linolenic acids are used in the treatment of acne, though clinical evaluation is lacking (Kanlayavattanakul and Lourith, 2011). Oleic acid is reported to be an effective percutaneous absorption enhancer. It markedly enhanced the penetration of tenoxicam, a non-steroidal anti-inflammatory drug (NSAID), by as much as 15% and is reported to increase diffusivity and partitioning as well as the fluidity and flux by interaction with subcutaneous lipids (Larrucea et al., 2001). Another study investigated the permeation enhancing effects of various fatty acids using diclofenac as a model drug. Of the unsaturated fatty acids, oleic acid exhibited the best permeation enhancing effect, while amongst the saturated fatty acids, palmitic acid had the most potent skin permeation enhancing effect (Kim et al., 2008). Skin permeation enhancement effects were also recorded for linoleic, lauric, myristic and stearic acids (Ren et al., 1994; Santoyo et al., 1995), all of which are present in various seed oils which are described in the following sections. The chemical structures of selected fatty acids are shown in Fig. 1.

3. Species discussion

3.1. *Adansonia digitata*

3.1.1. Botanical aspects

A. digitata L., commonly known as "baobab" (Malvaceae) (or bottle tree, upside-down tree, and monkey bread tree), is regarded as the largest succulent plant in the world. It is an extremely large deciduous tree easily distinguishable by its huge trunk with a diameter of 10–12 m and a height of up to 25 m. The hand-shaped leaves are present only 3 months per year whilst the white pendulous flowers are seen in October to December. The large egg-shaped fruit capsule, covered by velvety hairs, contains numerous seeds (Fig. 2A) and can reach 12 cm or more. The fruit pulp (white in colour), clustered around the seeds and fibres can be removed from the shell and it is very rich in vitamin C. It is estimated that it takes 8 to 23 years before the baobab can produce seeds and the mature plant can produce more than 30 kg of fruits (Ibiyemi et al., 1988; Gebauer et al., 2002; Drake 2006).

In southern Africa, baobab is commonly found in Malawi, Zimbabwe, Mozambique and South Africa especially in the warm parts of the Limpopo Province, while in West Africa, it is found in Mali, Benin, Senegal, the Ivory Coast, Cameroon and Burkina Faso. In East Africa, the plant is found in countries such as Kenya, Uganda and Tanzania. It is believed that the centre of origin of the genus *Adansonia* is Madagascar. Seven out of the eight known species are found on the island of Madagascar and six of them are endemic (Drake, 2006). Baobab trees are restricted to hot, semi arid regions, dry woodlands and places with low rainfall (less than 1500 annually) (Gebauer et al., 2002). The slow growth of the baobab is mainly attributed to the low amount of rainfall received (Venter and Venter, 1996).

3.1.2. Traditional and modern day uses

Baobab plant parts are used in Africa as a panacea (to treat various diseases) and the seed oil is used alone or in combination with other plant parts to treat various conditions such as fever, diarrhoea, coughs, dysentery, haemoptysis and worms (Watt and Breyer-Brandwijk, 1962; Aké Assi, 1992). The oil is used in wound care therapy and bath oil preparations, as a moisturiser and massage oil, and hot oil soaks are used for hair and nail conditioning (Wren and Stucki, 2003; Zimba et al., 2005). Baobab oil has been included in a few patented compositions. In one case, baobab oil may be included as a carrier/vehicle in a dermatological/cosmetic preparation containing an extract from baobab leaves (Engels, 2009). Another patent for an oil absorbent wipe intended for use on the skin or hair, lists baobab oil as a possible ingredient (Seth et al., 2004).

3.1.3. Physico-chemical properties and oil composition

The physico-chemical properties of all the oils are summarised in Table 1. The semi-fluid slightly scented golden-yellow oil (Fig. 2E) is generally obtained by pressing the seeds followed by filtration. Baobab oil is extremely stable with a highly variable shelf life estimated to be between 2 to 5 years. The high saponification value of baobab oil is comparable to some of the edible oils such as marula oil, groundnut oil and palm oil (Eromosele and Eromosele, 1993; Mariod et al., 2004). The iodine value of the oil is 87.9 g/100 g and therefore it is classified as a non-drying oil (Nkafamiya et al., 2007). In relatively small quantities of up to 20%, the oil may be incorporated into another carrier oil or base (Wren and Stucki, 2003).

The oil contains saturated (33%), monounsaturated (36%) and polyunsaturated (31%) fatty acids (Baobab Fruit Company). Palmitic and oleic acids are major constituents of the oil (Andrianaivo-Rafehivola et al., 1993) and investigation of the oil stability index (OSI) revealed results comparable to olive oil and evening primrose oil. Baobab oil displayed the slowest rate of oxidation (8.2 h) compared to olive and evening primrose oil, 5.4 and 3.1 h, respectively (Arch personal care products). The seed oil composition is presented in Table 2. β-Sitosterol (≈80% of the total sterols) is one of the major sterol constituents present in baobab seed oil. Other sterols include campesterol (8.3%) and stigmasterol (2.9%) (Fig. 1) (Baobab Fruit Company).

3.1.4. Biological properties

β-Sitosterol is a known anti-oxidant able to reduce DNA damage and the level of free radicals, in addition to possibly increasing the level of typical anti-oxidant enzymes. Peanuts display anti-oxidant activity on DPPH radical scavenging and this activity was correlated to the high amount of oleic acid contained in the skin (Talcott et al., 2005). It can be speculated that the high proportion of monounsaturated oleic acid is key to the anti-oxidant capacity of the oil. Several fixed oils such as almond oil (*Prunus dulcis* (Mill.) D.A.Webb), sesame oil (*Sesamum indicum* L.), avocado oil (*Persea americana* Mill.), apricot kernel oil (*Prunus armeniaca* Blanco), rapeseed oil (*Brassica napus* L.), linseed oil (*Linum usitatissimum* L.), sunflower seed oil (*Helianthus annuus* L.), and palm oil (*Elaeis guineensis* A. Chev.) have been included in cosmetic preparations as moisturisers or emollients (Lubbe and Verpoorte, 2011). In recent years, baobab oil has been added to the list of fixed oils commonly included in cosmetic products. Baobab oil will not burn the skin when applied as such, and it is said to be non-irritating as well as non-sensitising (Wren and Stucki, 2003). Like avocado oil, baobab oil is highly penetrating, deeply nourishing and softens dry skin. It is known to restore and re-moisturise the epidermis (PhytoTrade Africa).

Several vitamins, including vitamins A, D, E and 'F', are present in baobab oil (Nkafamiya et al., 2007). Vitamins A and 'F' are polyunsaturated fatty acids and these acids are directly implicated in the rejuvenation and renewal of cell membranes, while vitamin E is a superior anti-oxidant, with an anti-ageing effect. Baobab oil is ideal to help treat dry and damaged skin, is used for intensive hair care and its soothing properties are helpful for eczema and psoriasis treatments. Baobab oil is considered to be a natural source of vitamin D3 which increases calcium absorption and decreases blood pressure in the elderly (Wasserman, 2004). The oil is said to alleviate pain from burns and regenerates the epithelial tissues in a short time, thereby improving skin tone and elasticity (Murunga Products).

Fig. 2. (A) Fruit and seeds of *Adansonia digitata*; (B) *Citrullus lanatus* fruit; (C) seeds of *Ximenia americana*; (D) women gathering fruits of *Sclerocarya birrea*; (E) pressed oil and seeds of *Adansonia digitata*; (F) seeds of *Trichilia emetica*; and (G) seeds of *Sclerocarya birrea* (photographs courtesy of PhytoTrade Africa).

3.2. *Citrullus lanatus*

3.2.1. *Botanical aspects*

C. lanatus (Thunb.) Matsum. & Nakai commonly known as Kalahari Tsamma melon, is one of the species of the Cucurbitaceae family (Schippers, 2000). *C. lanatus* is a trailing herb of up to 10 m long with broad leaves and yellow flowers (Sodeke, 2005). The green or yellow fruits are soft and fleshy with a length of 9.7–25 cm and width of 6.1–16 cm (Fig. 2B). Fruit of wild plants is small with a diameter of 15–20 cm, while cultivated fruits are larger with a diameter of 30–60 cm. In addition, they vary from pale yellow or light green (wild form)

Table 1
The physico-chemical characteristics of the seed oils of *Adansonia digitata*, *Citrullus lanatus*, *Schinziophyton rautanenii*, *Sclerocarya birrea*, *Trichilia emetica* and *Ximenia americana*.

Species name	*A. digitata*	*C. lanatus*	*S. rautanenii*	*S. birrea*	*T. emetica*	*X. americana*
Colour	Golden yellow	Pale yellow	Light yellow	Clear pale	Yellow golden brown	Pale yellow
Refraction index						
20 °C	1.50	–	1.48	1.46	–	2.47
25 °C	–	1.47	1.48	–	1.45	2.47
Density						
(g/cm^3) at 20 °C	–	0.906	0.907	–	0.906	–
(g/cm^3) at 30 °C	–	–	–	0.900	–	0.963
Acid value						
(%)	–	–	1.60	–	–	–
(mg KOH g^{-1})	0.33	1.10–5.12	0.36	5.10–33.70	3.82	1.50
Peroxide value						
(mg/kg)	–	2.30–7.51	9.00	–	12.85	–
(mequiv/kg)	–	–	2.51	–	–	29.40
Unsaponifiables	–	–	0.58–0.74	0.70–3.10	–	1.4
Saponification value (mg KOH g^{-1})	165.00–250.00	173.20–204.44	185.26	162.70–193.50	190.00–210.00	165.20–182.30
Iodine value						
(Wijs)	–	119.8–125.0	121.8–129.0	–	–	77.4–85.0
(%)	87.9	–	–	64.2–100.3	60.0–80.0	149.8
Specific gravity 25 °C	–	0.93	3.85	0.90	0.90–0.91	0.90
References	Nkafamiya et al. (2007)	Nyam et al. (2009) and Anhwange et al. (2010)	Zimba et al. (2005) and Chivandi et al. (2008)	Ogbobe (1992) and Mariod et al. (2004)	Personalcaremagazine and Scatters oil	Puntambekar and Krishna (1937), Ligthelm et al. (1954), Eromosele and Eromosele (2002) and Eromosele and Paschal (2003)

Table 2
The fatty acid composition (%) of the seed oils of *Adansonia digitata*, *Citrullus lanatus*, *Schinziophyton rautanenii*, *Sclerocarya birrea*, *Trichilia emetica* and *Ximenia americana*.

Fatty acid		*A. digitata*	*C. lanatus*	*S. rautanenii*	*S. birrea*	*T. emetica*	*X. americana*
Saturated							
Myristic	14:0	0.78	0.78	0.03	–	–	–
Palmitic	16:0	18.0–30.0	8.8–15.7	9.6–10.8	9.0–12.0	43.0–53.0	3.31
Stearic	18:0	2.0 –9.0	5.6–13.8	3.04–7.7	5.0–8.0	3.0	4.0–15.4
Unsaturated							
Oleic	18:1	30.0–42.0	13.03–17.1	15.2–19.2	70.0–78.0	51.0	54.0–72.1
Linoleic	18:2	20.0– 35.0	56.8–70.8	36.6–49.5	4.0–7.0	16.0	1.34–10.0
α Linoleic	18:3	1.0–3.0	0.46–1.1	–	0.1–0.7	–	–
Linolenic	18:3	–	0.46–1.6	16.7	–	16.0	10.31
Erucic	22:1n9	–	–	21.5	–	–	3.46
Arachidonic	20:4	–	–	–	0.3–0.7	–	0.60
References		Andrianaivo-Rafehivola et al. (1993) and Wren and Stucki (2003)	Mabaleha et al. (2007), Oluba et al. (2008), Ziyada and Elhussien (2008), Nyam et al. (2009), Mariod et al. (2009) and Gaw et al. (2010)	Zimba et al. (2005), Juliani et al. (2007) and Chivandi et al. (2008)	Mariod et al. (2004), Zimba et al. (2005) and Ojewole et al. (2010)	Engelter and Wehmeyer (1970), Khumalo et al. (2002) and Van der Vossen and Mkamilo (2007)	Ligthelm et al. (1954), Badami and Patil (1981), Eromosele and Eromosele (2002), Řezanka and Sigler (2007) and Saeed and Bashier (2010)

to dark green (cultivars), with or without stripes and the pulp varies from yellow or green (wild forms) to dark red (cultivars) (Jeffrey, 1978). The fruit contains smooth compressed seeds "pistachio" of a black or yellowish white colour (Sodeke, 2005).

C. lanatus is native to the western Kalahari region of Namibia and Botswana, where it occurs in several morphological forms together with other *Citrullus* species. Its centre of origin has been traced to both the Kalahari and Sahara deserts in Africa (Jarret et al., 1996) but more than 3000 years ago *C. lanatus* cultivation became widespread in Mediterranean Africa, the Middle East and West Asia, and it grows abundantly in Sudan (Jarret et al., 1996; Schippers, 2000). *C. lanatus* reached China around the 10TH century and Japan in the 16TH century and it was introduced to the Americas in early post-Columbian times. It is commonly found on river banks, dry lakes, drainage areas or disturbed areas (Jarret et al., 1996).

3.2.2. Traditional and modern day uses

Jack (1972) cited that *C. lanatus* seeds are comprised of 50% oil and 35% protein, hence the seeds have both nutritional and cosmetic values. The fruits and/or seeds are used in different ways in different countries. In the Kalahari region in Africa, *C. lanatus* is used as a source of drinking water. In Zimbabwe the cooked melons are mixed with cooked beans or cowpeas. The rind of some cultivars is made into a pickle or a sweet preserve in the United States and in the south of France, the preserved melon is popular for jams. The seeds are commonly roasted and salted for nutritional purposes and the pulp used as soup thickener in Sudan, Egypt and Western Africa. The residue from oil extraction is made into balls that are fried to produce a local snack in Nigeria (Van der Vossen et al., 2004).

The seed oil, known since the time of ancient Egyptians, was used to care for the skin to maintain its healthy appearance and aid in its regeneration (Athar and Nasir, 2005). This moisturising oil has a light texture and is therefore a highly suitable emollient in cosmetic care formulations. The high essential fatty acid content aids in nourishing the skin and restoring the elasticity (Murunga Products). In addition, the oil has traditionally been used for making soap in Namibia. Tar extracted from the seeds is used for the treatment of scabies and for skin tanning. In Central America and India the oil extracted from the seeds is applied to herpes lesions, venereal sores, stubborn leg ulcers and the face to treat acne vulgaris (Van der Vossen et al., 2004). Traditionally, it has been used medicinally as a diuretic, for treating urinary diseases and fever (Cho et al., 2004). A patent has been filed which mentions the use of the oil in a self tanning formulation but it is listed amongst numerous other possible ingredients (Ehlis et al., 2009).

3.2.3. Physico-chemical characteristics and oil composition

Kalahari melon seed oil is light yellow in colour and rich in essential fatty acids (Cho et al., 2004). The oil has a very low saponification value (Taiwo et al., 2008). According to Anhwange et al. (2010) an oil with an iodine value that ranges between 100 and 150 has good properties of absorbing oxygen on exposure to the atmosphere. This makes *C. lanatus* oil, with an iodine value of 119 Wijs, useful for soap manufacturing due to its thick, sticky consistency which doesn't form a hard dry film. Furthermore, the saponification value indicates the average molecular weight of the oil (Booth and Wickens, 1988). A high saponification value implies a greater proportion of fatty acids of low molecular weight. The values compared favourably with the saponification values of olive oil which ranges between 185 and 196 (Anhwange et al., 2010). The peroxide value is the measure of oxidative rancidity of oil. Oxidative rancidity is the addition of oxygen across the double bonds in unsaturated fatty acids in the presence of enzymes (Ekpa and Ekpa, 1996). The odour and flavour associated with rancidity are due to the liberation of short chain carboxylic acids. High peroxide values are associated with a higher rate of rancidity. Variation of peroxide value could be due to the level of unsaturated fatty acid content, since the rate of auto-oxidation of fats and oils increases with increasing levels of unsaturation. The generally low peroxide values of oils from the Cucurbitaceae family indicate that they are less liable to oxidative rancidity at room temperature (Odoemelam, 2005; Anyasor et al., 2009). Specific gravity and the refractive index indicate the purity of oil and the results indicated that the oil is of high purity (Anhwange et al., 2010).

Phytochemical analysis of the fatty acid content of the oil revealed that linoleic acid is present in the highest concentration followed by oleic, palmitic and stearic acids. A low presence of myristic, linolenic and lauric acids was also demonstrated (Oluba et al., 2008). Furthermore, *C. lanatus* oil contains a high level of γ-tocopherol (70.56 mg/100 g) as the major component followed by α-tocopherol (25.94 mg/100 g). These high values of α- and γ-tocopherol provide anti-oxidant properties as well as a reasonably good shelf life and could signify potential use of the oil for industrial, nutritional, pharmaceutical and cosmetic purposes (Nyam et al., 2009).

Amongst the phytosterols, β-sitosterol (485.49 mg/100 g) was the key phytosterol extracted from *C. lanatus* seed oils followed by campesterol (130.41 mg/100 g) and stigmasterol (25.87 mg/100 g) (Fig. 1). The main phenolic acids present are gallic, protocatechuic, *p*-hydroxybenzoic, vanillic, caffeic, syringic (trace), *p*-coumaric and ferulic acids (Nyam et al., 2009). These key secondary metabolites exhibit highly efficient peroxyl-radical scavenging activity and may have beneficial pharmacological effects (Larson, 1988; Halliwell, 1994; Manach et al., 1998). Low levels of trace elements including calcium, magnesium, copper, cobalt, iron, manganese and zinc are present in the oil. Some trace elements in oils are pro-oxidant and it is important to remove them from the oil during the processing (Ojieh et al., 2008; Ziyada and Elhussien, 2008).

3.2.4. Biological properties

C. lanatus is a popular fruit endowed with high natural anti-oxidant capacity, an aspect which is an important qualitative factor for cosmetic uses. Interest in *C. lanatus* seed oil by the cosmetic industry, especially European companies, has led to the formulation of moisturising and skin rejuvenating products (Nyam et al., 2009). Fatty acids, mainly linoleic acid followed by oleic, palmitic and stearic acids, isolated from seed oil of the Cucurbitaceae family have been used in medicine for their anti-inflammatory properties (Nesterova et al., 1990; Akhtar et al., 1980). The high vitamin E level in *C. lanatus* could be considered for pharmaceutical and cosmetic use due to its protective nature against oxidative stress (Nyam et al., 2009). Despite the vast nutritional and medicinal significance of *C. lanatus* oil, little detail on its cosmetic benefits is available.

3.3. *Schinziophyton rautanenii*

3.3.1. Botanical aspects

S. rautanenii (Schinz) Radcl.-Sm., formerly known as *Ricinodendron rautanenii* Schinz, is part of the Euphorbiaceae family. This large deciduous, dioecious tree, known as mungongo in Zambia and manketti in many other African countries, reaches a height of up to 7–15 m. It has thick whitish, pale grey or pale brown bark, dark-green leaves, and small whitish-yellow flowers appearing in October to December. The egg-shaped green fruits, 3.5 cm long and 2.5 cm wide, are covered in fine small hairs. The young fruits fall from the tree in April to May and ripen to red-brown on the ground causing the flesh to become soft. About 20% of the fruit consists of the pulp layer which has a full sweet flavour comparable to the taste of dates. The large seed forms 70% of the fruit. The shell is very hard and tough, and it is traditionally broken between two rocks to remove the kernel(s). The creamy yellow flesh encapsulating the seed has nutritional value (57% lipid; 26% protein) and may be eaten raw or roasted (Graz, 2002; Juliani et al., 2007).

The tree is found growing in a rough band across the subtropical latitudes of southern Africa, from the border of northern Namibia and Angola, stretching through southern and Western parts of Zambia, the Okavango of Botswana, northwest and central Zimbabwe, central Mozambique and the Limpopo Province of South Africa. Its preferred habitat is wooded hills as part of the savanna woodlands and the deep sands of the Kalahari. It is adapted to withstand several years of drought and temperatures that range from −5 °C in winter to well over 40 °C in summer (Graz, 2002; Juliani et al., 2007).

3.3.2. Traditional and modern day uses

The seed oil is used by local communities as a source of nutrition in food preparation (soups), and in personal care products due to its healing and nurturing properties. A hair lotion prepared with the oil is used to revitalise, strengthen and detangle hair and it is used as a body rub during dry winter months. It protects the skin by acting as a cleanser, moisturiser and emollient (Graz, 2002; Juliani et al., 2007). The fatty acid profile of manketti oil resembles that of maize oil (*Zea mays*), indicating that it may be used in a similar way in food products (Mitei et al., 2008). Patents have been filed for manketti oil-containing products as a possible component in topical formulations forming part of the base as opposed to the active ingredient. This includes an antiparasitic formulation and a soap bar for microdermabrasion (Lucka and Mullen, 2010; Razzak, 2010). It has also been included in nutritional food supplements including a gluten-free food product and a health food containing beneficial lipids (Bhagat, 2009; Stratakis, 2011).

3.3.3. Physico-chemical properties and oil composition

The thin oil is ideal for the aromatherapy and cosmetic industries as it has a light texture and is easily absorbed into the skin. Manketti seed oil consists mainly of fatty acids including linoleic, oleic, palmitic, linolenic, and erucic acids, with lesser quantities of myristic and myristoleoic acids. In addition, it is rich in vitamin E (565 mg/100 g of the kernel) which provides excellent oxidative stability and a long shelf life (Zimba et al., 2005; Juliani et al., 2007; Chivandi et al., 2008). The physico-chemical properties of the oil are shown in Table 1 and the chemical composition of manketti seed oil is indicated in Table 2.

3.3.4. Biological properties

The presence of Vitamin E, linoleic and eleostearic acids renders the oil useful for skin protection and hydration, for the treatment of eczema and atopic disorders where it may assist with reduction of inflammation and promotion of cellular repair and tissue generation. It may also be useful in the reduction of itching, redness, scarring and the prevention of keloids (Zimba et al., 2005). Reactive oxygen species produced as a result of exposure of the skin to ultraviolet B (UVB) light may cause skin damage. Skin supplementation with anti-oxidants may play an important role in the reduction of photodamage and photoaging due to free-radical oxidative stress. Topical tocopherol (vitamin E) may protect the skin against such photoaging due to its anti-oxidant action after ultraviolet radiation-induced free-radical formation (Jurkiewicz et al., 1995; Saral et al., 2002).

3.4. *Sclerocarya birrea*

3.4.1. Botanical aspects

The marula tree (*S. birrea* (A. Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro) (Anacardiaceae) is an important food, commercial, cultural and ethnomedicinal plant in Africa (Ojewole et al., 2010). This medium size deciduous tree can grow up to 18 m in height. It is leafless for several months (winter) of the year (Ogbobe, 1992), flowers from September to November and bears fruits from January to March (Ngorima, 2006). It produces edible yellow oblong shaped fruits (3–4 cm in diameter) with a plain tough skin and a juicy mucilaginous flesh (Ogbobe, 1992). The seed encloses 2–3 soft white edible kernels (Fig. 2G), which are rich in oil and protein (Mizrahi and Nerd, 1996).

This tree is distributed throughout Africa with its southern most location in the lowlands of KwaZulu-Natal (South Africa) from where it extends northwards through tropical Africa into Ethiopia and Sudan. In southern Africa, the tree is also found in Swaziland, Botswana, Angola, Zimbabwe and Namibia and Malawi (Ngorima, 2006). In West Africa, the tree is found in Gambia, Nigeria, Cameroon and the Central African Republic. The tree grows in various woodland habitats and on sandy loam soils, but is more often found in semi-arid and savannah regions of sub-Saharan Africa (Borochov-Neori et al., 2008).

3.4.2. Traditional and modern day uses

In southern Africa, the oil obtained from marula kernels is used for different purposes. Women in the Limpopo region of South Africa use the oil to massage babies and as body lotion massaged onto the skin of their face, feet and hands. Local populations in southern Africa, particularly in South Africa, have been using marula oil for several years to protect against dry and cracking skin, and as a shampoo for dry, damaged and fragile hair (Athar and Nasir, 2005). The oil is used as a base oil for soap and as nose-drops for infants (Zimba et al., 2005). The moisturising capacity is so effective that in some rural areas, the oil is used to treat leather and preserve meat (Mariod et al., 2004). Marula oil, amongst numerous other oils, is listed as a possible ingredient where its reaction with glycerine in the presence of a basic catalyst results in retention of the unsaponifiable portion of the oil. The resulting reaction products are to be used in cosmetic and personal care applications (Hein et al., 2009). As for manketti oil, it may also be included in the soap base used to manufacture a soap for microdermabrasion according to the patent filed by Lucka and Mullen (2010).

3.4.3. Physico-chemical properties and oil composition

Marula oil is a clear, pale, yellowish-brown colour and has a pleasant nutty aroma. The oil is classified as medium rich and is silky to the touch with an excellent 'slip factor' making it ideal as massage oil. Like many other fixed oils (e.g. baobab seed oil; olive oil), marula oil is rich in monounsaturated fatty acids which makes the oil very stable (Hore, 2004; Mariod et al., 2004; Zimba et al., 2005; Kleiman et al., 2008). Some physico-chemical properties of marula oil are presented in Table 1. The oxidative stability of marula oil is very high (induction period of 32 h) when compared to other fixed oils such as olive oil (4.6 h), sunflower oil (1.9 h) and cottonseed oil (3.1 h) (Burger et al., 1987).

The fatty acid composition of marula oil which is comparable to that of olive oil is presented in Table 2 (Burger et al., 1987). The oil is particularly rich in oleic acid and can be considered an excellent source of natural oleic acid. A study conducted by Ogbobe (1992) revealed that the oil was rich in stearic and palmitic acids (50.8 and 22.6%, respectively). Mariod et al. (2004) who investigated the composition of selected Sudanese oils found that the marula oil contained, in addition to saturated and unsaturated fatty acids, tocopherols, sterols, procyanidine, gallotannin. The tocopherol content of the oil (mainly dominated by γ-tocopherol) amounted to 13.7 mg/100 g oil. The total content of sterols was 287 mg/100 g oil with β-sitosterol (Fig. 1) being the main compound comprising about 60% of the total sterols. The study also revealed the presence of 5-avenasterol (4.8 mg/100 g) in high levels (Mariod et al., 2004). The presence of other fatty acids in the oil including caproic and arachidonic acids was also confirmed. Marula oil is similar to olive oil in terms of the high content of oleic acid. Therefore it can be used as starting material for the production of cocoa butter equivalents that can be used in the food and cosmeceutical industries (Zimba et al., 2005).

3.4.4. Biological properties

Marula oil has been shown to improve skin hydration and smoothness as well as reduce skin redness (Gruenwald, 2006). Oleic acid is known to exert good anti-oxidant activity and as marula oil is reported to contain a high content of this acid it could be expected to also exhibit antioxidative properties. However, there is limited scientific evidence to substantiate this. The free radical scavenging property of the oil is mainly attributed to the unsaponifiable fraction which varies from 3800 to 4300 mg/kg (PhytoTrade Africa). Clinical tests (including skin hydration, 'transepidermal water loss' and 'increase in skin smoothness') to determine its potential use as an ingredient in cosmetic formulations have been completed with moderate success for marula oil (Houghton, 1999). Easy absorption, a high proportion of oleic acid, as well as the presence of linoleic acid (4–7%) all contribute to rendering the oil ideal for topical application.

3.5. Trichilia emetica

3.5.1. Botanical aspects

The genus name "*Trichilia*" is derived from Greek "tricho" referring to the 3-lobed fruits and the epithet "*emetica*" refers to the emetic properties of the tree (Allaby, 1998; Orwa et al., 2009a). *T. emetica* Vahl (Meliaceae), also known as the Natal mahogany, is an evergreen tree reaching 20 m but occasionally even up to 35 m in height (Allaby, 1998, Orwa et al., 2009a). It has red-brown or grey-brown bark and the leaves are dark glossy green on the upper surface and covered with brownish hairs on the lower surface. The flowers are small, creamy to pale yellow-green, and fragrant. The furry, rounded, red-brown fruit capsules (±3 cm across), contain 3–6 shiny black seeds (1.4–1.8 cm) with a large fleshy scarlet or orange-red aril (Fig. 2F) (Orwa et al., 2009a).

T. emetica is widely distributed and grows naturally throughout sub-Saharan Africa extending from KwaZulu-Natal in the south, through Swaziland, Mpumalanga and Limpopo Provinces (South Africa), into Zimbabwe and northwards into Cameroon, Sudan and Uganda (Germishuizen and Meyer, 2003). It has a preference for areas with a high rainfall and well-drained rich alluvial or sandy soil and is therefore abundant along coastal areas (Cronquist, 1981; Orwa et al., 2009a).

3.5.2. Traditional and modern day uses

T. emetica is a coveted multipurpose tree which has been used throughout Africa for several centuries. The seeds are rich in fat and produce good quality oil used for cosmetic purposes such as in the manufacturing of natural soaps (Von Breitenbach, 1965; Orwa et al., 2009a). Women in Gazaland applied the oil for cosmetic purposes and used it in combination with *Cyathula natalensis* Sond. to treat leprosy (Hutchings et al., 1996). In Senegal, *T. emetica* is used to treat a range of skin ailments (Oliver-Bever, 1986). *T. emetica* oil is rich in essential fatty acids and has nourishing, revitalising effects on the skin and hair. "Mafura" butter is used for soap production, lip balm therapy, cosmetics and candle making (Van der Vossen and Mkamilo, 2007). In some instances, *T. emetica* oil is combined with coconut oil to provide emollient and moisturising effects. *T. emetica* oil is listed as a possible active from a botanical source included in a patent filed by the Estee Lauder Companies Inc. describing a powder make-up product containing 'skin treatment actives'. Another species included as a possible active is *S. rautanenii* kernel oil which was described earlier (Mercado et al., 2010).

3.5.3. Physico-chemical properties and oil composition

Originally the oil was used as a starting material in lipase catalysis for the production of cocoa butter equivalents. The pressed seed yields two types of oil, "mafura" oil (solid butter) from the fleshy seed envelope and "mafura" butter from the kernel (Van der Vossen and Mkamilo, 2007). Gas chromatography was used to analyse methyl esters of the glycerides of *T. emetica* to determine the fatty acid profile of the oil. It was determined that the oil is rich in fatty acids containing high proportions of palmitic and oleic acids, with lower proportions of linoleic, linolenic and stearic acids indicated in Table 2 (Engelter and Wehmeyer, 1970; Khumalo et al., 2002; Van der Vossen and Mkamilo, 2007).

3.5.4. Biological activity

There is a paucity of scientific studies related to the use of *T. emetica* seed oil. However, it is known to be rich in palmitic and oleic acids which have proved to be good skin permeation enhancers (Kim et al., 2008). In a previous study anti-oxidant activity was correlated to a high oleic acid content and it may be plausible to predict that the high levels of oleic acid in *T. emetica* seed oil will exhibit good anti-oxidant properties (Talcott et al., 2005).

3.6. Ximenia americana

3.6.1. Botanical aspects

The genus *Ximenia* (Olacaceae) consists of eight species of small trees and thorny shrubs (Uiras, 1999) of which two occur in southern Africa. *Ximenia americana* L. (sour plum) is a thorny bush-forming shrub or small tree that can grow up to 7 m high. The trunk is rarely thicker than 10 cm with dark brown to pale grey smooth to scaly bark, and it has small, pale grey-green hairless leaves. The flowers are fragrant and can be white, yellow-green or pink. The young oval green fruits turn yellowish or orange-red upon ripening. They contain a juicy pulp with an almond acid taste and have one light-yellow woody seed with a fatty kernel and brittle shell (Fig. 2C). The seed, 1.5 cm long and 1.2 cm thick, forms a large part of the fruit which is 3 cm long and 2.5 cm thick (Orwa et al., 2009b; Maikai et al., 2010). *X. americana* bears fruit and flowers throughout the year, seemingly not governed by climatic regimes (Orwa et al., 2009b).

This drought-resistant, mostly solitary tree grows at low altitudes in a wide range of habitats including, savannahs, dry woodlands, dry forests, and along coastal areas or on river banks (Orwa et al., 2009b). It has a wide geographical distribution throughout many countries in Africa, Central and South America, as well as Australasia. Consequently it has many vernacular names including: kleinsuurpruim (Afrikaans), sour plum/tallow wood (English), cerise de mer (French), habbuli (Fulani), and mtundakala (Swahili) amongst several others (Orwa et al., 2009b; James et al., 2008).

3.6.2. Traditional and modern day uses

The leaves and twigs are used as traditional medicine to treat fever, headaches, toothache (mouthwash), angina, and constipation. The roots are used to treat skin problems, leprotic ulcers, mouth ulcers, haemorrhoids, abdominal pains, dysentery, guinea worm and venereal disease (Orwa et al., 2009b; James et al., 2008; Maikai et al., 2010). However, the use of *X. americana* is not restricted to medicinal applications and it is also considered a food source rich in vitamin C which can be consumed raw or used to produce juice, jams and alcoholic drinks. The bark and roots contain high levels of tannin and are used to tan leather. The yield of oil from the seed is high and has been applied as an emollient, conditioner, skin softener, body and hair oil as well as included as an ingredient in lipsticks and lubricants. In addition it is used in soap manufacturing and as a vegetable butter (Řezanka and Sigler, 2007; Orwa et al., 2009b). Patents have been filed for the possible inclusion of the oil in a moisturising lotion (Piterski, 2004) and a ximenynic acid rich formulation said to have beneficial effects on skin ageing amongst others (Eggink et al., 2004).

3.6.3. Physico-chemical properties and oil composition

The physico-chemical properties of the pale yellow *Ximenia* seed oil are indicated in Table 1. Essential oils can be extracted from the heartwood and flowers and the bark contains about 17% oils. Analysis of the seed oil revealed that the major components were oleic, hexacos-17-enoic (ximenic), linoleic, linolenic and stearic acids together with smaller quantities of triacont-21-enoic (lumequic), octadec-11-en-9-ynoic (ximenynic), arachidonic, erucic, and nervonic acids (Fig. 1). Fatty acids with more than 22 carbon atoms, termed very long chain fatty acids, are rarely found naturally. *Ximenia* oil contains very long chain fatty acids with up to 40 carbon atoms (Ligthelm et al., 1954; Badami and Patil, 1981; Eromosele and Eromosele, 2002; Řezanka and Sigler 2007; Saeed and Bashier, 2010). The fatty acid composition of *Ximenia* oil is shown in Table 2.

3.6.4. Biological properties

Scientific studies on the biological activities of the seed oil are not available. However, it is composed of several long chain fatty acids such as linolenic, linoleic, oleic and stearic acids shown to be beneficial upon topical application. Studies on ximenynic acid (Ximenoil®) have revealed improvement in blood circulation. Blood perfusion was increased in a group of female volunteers ($n=40$) applying a cream containing 0.5% ximenynic acid. The greatest effect of 50% increase was seen after 60 min especially on cellulitic areas were blood perfusion is usually very low (Indena).

4. Conclusions

Seed oils obtained from plant sources have been commonly used for topical skin application since ancient times. However, during the last century, synthetic substitutes have become available and have been used to replace natural seed oils. Due to toxic effects of synthetic oils, there is a growing trend to replace them and revert to the use of natural oils in the cosmetic and pharmaceutical industries (Shackleton et al., 2006). However, this does not imply that all natural oils are safe. Toxicity data is not readily available and it is imperative that these studies be conducted for any product intended for human use, whether consumed orally or applied topically. There is increasing consumer demand for high-quality cosmetic products of natural origin which industry is responding to. Seed oils are ideally suited to satisfy this need due to their high fatty acid content. Fatty acids have been shown to have beneficial effects when applied onto the skin as such. In addition, the oils may be used as a carrier/vehicle for other active ingredients. The presence of certain fatty acids has also proved to enhance skin permeation of co-administered molecules. The concept of developing cosmetics derived from African seed oils and integrating the traditional use component is extremely attractive to international companies as it has strong marketing potential. However, this review has identified a general lack of good scientific information on the cosmetic application of these oils that will corroborate the traditional use. The fatty acids identified have been tested mostly in a solitary fashion and the application of the crude oil may reveal synergistic effects.

The current major concerns for the use of seed oils as ingredients in natural cosmetic products are conservation aspects as well as trade agreements with local communities to prevent exploitation. One of the key objectives of the convention on biological diversity (CBD) is access and benefit sharing (ABS). ABS relates to the sharing of benefits derived from the use of genetic resources and associated traditional knowledge. In October 2010, the Nagoya protocol on “access to genetic resources and the fair and equitable sharing of benefits arising from their utilisation” was adopted. It was designed to create incentives to conserve biodiversity, ensure sustainable use of the biological resources and enhance sustainable development and quality of human life. It sets the framework on which national law can be based and provides legal clarity for the providers and users of genetic resources and associated traditional knowledge (Secretariat of the CBD, 2011).

Prior to the adoption of the Nagoya protocol there was uncertainty as to whether plant-based cosmetic oils were included in the ABS framework. However, the Nagoya protocol makes it clear that ‘genetic resources’ can include ingredients pending interpretation by States when they enact their National regulations on ABS. Those involved in the cosmetics sector should be aware of these procedures when dealing with plant-based resources. With increasing interest and demand for natural cosmetic ingredients the role of the CBD and the Nagoya protocol is likely to increase along with a focus on the positive role that utilisation of these genetic resources play in economic development, livelihoods and biological diversity (Secretariat of the CBD, 2011).

The collection of seeds and nuts contributes to the livelihood of a large number of people and commercialisation of these oils is starting to provide economic opportunities. Consider for example the marula trade in Namibia in southern Africa. It provides an income for many families of US$15 to US$166 per household per year for fruit collection and fruit processing respectively with members of the Namibian based women's co-operative (Eudafano) earning US$23 to US$65 per year. The marula fruits are processed into oil and sold to the European cosmetic market (Shackleton et al., 2006). There are an estimated 2.5 million households that harvest marula and a potential output of about 877 200 tonnes of products derived from the fruit. Optimal production/processing can bring an annual turnover of about US $263 million to the whole southern African region (Ngorima, 2006). Data on the current and potential trade of products from Southern African Developing Countries (SADC) was published in 2006. The current trade value in 2006 and potential trade value, respectively, of each of the species are indicated in brackets: *A. digitata* ($11 203 928; $961 358 568), *S. birrea* ($425 000; $263 001 008), *X. americana* ($58 500; $37 566 884) and *C. lanatus* ($58 500; $21 126 226). The current trade value (2006) was not available for *T. emetica* and *S. rautanenii* but it was envisaged that potential trade value could be $501 665 697 and $19 677 684, respectively (Ariyawardana et al., 2009), indicating the great potential financial benefits from the commercialisation of these resources. After fair-trade agreements have been initiated and finalised, the focus should shift to increasing the oil pressing efficiency and scientific proof of the benefits of these oils as cosmetics in order to provide good quality natural export products from Africa for the global cosmetic industry. Steps have already been taken to optimise oil extraction in the case of Kalahari melon. Supercritical fluid extraction was optimised and used to extract oil with a high content of an important cosmetic ingredient, tocopherol, as compared to traditional extraction methods (Nyam et al., 2010). The setting of specifications for herbal cosmetic medicinal products derived from seed oils should be part of an overall control strategy which includes control of raw materials in process testing, process evaluation/validation, stability testing and testing for consistency of batches. Specifications should provide assurance that an appropriate and acceptable quality of the product is achieved and maintained. Quality assurance is most important especially considering that all six oils are freely commercially available as a general internet product search revealed.

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