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STERCULIA SETIGERA DEL. POTENTIAL DRYLAND RESOURCE FOR THE PRODUCTION OF GUM KARAYA IN ETHIOPIA: REVIEW

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ABSTRACT

The most important commercial gum resin product collected and exported from Ethiopia is frankincense obtained from *Boswellia papyrifera*. Deforestation, over-grazing, resettlement and improper tapping are among the major factors that degrade the species. Consequently, gum-resin producing enterprises have whown an increasing interest to find out other potential alternative species and products to exploit. The *Sterculia* (karaya) tree is a native of dry deciduous forests in tropical climates including Ethiopia. *S. setigera* exudes a water soluble gum, known as Gum Karaya or Gum Sterculia. The species is distributed in Senegal, in the Sudan-Sahel, in the Sudan-Guinea zones and East Africa. In Ethiopia the species is found in different dry land regions. However, gum Karaya is not produced so far. India is traditionally the largest producer and exporter of gum Karaya from *S. urens*, but nowadays increasing amounts of gum is entering international trade from Africa. Senegal is the leading exporter (around 1000 MT per year) of gum karaya from *S. setigera*. Of all the gum karaya produced, only 5% is used as a food additive; the remainder 95% goes to pharmaceutical products. In food industries, karaya is used in small amount as a texturiser and stabiliser in ice creams, and in ice sherbets to prevent the formation of ice crystals. Since Ethiopia has a species potential, gum karaya production shall be started in *Sterculia* forests by introducing appropriate tapping techniques. The Natural Gum Production and Marketing Enterprises thus will have an alternative commercial product for their business. This paper highlights the distribution of *S. setigera* in the country as well as the gum karaya's physical and chemical characteristics and quality. It also introduces appropriate tapping techniques that can be used for tapping and harvesting in Ethiopia.

Key words: Gum karaya, NTFPs, *Sterculia,* tapping.

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INTRODUCTION

Non-timber forest products (NTFPs) such as frankincense, gum, resins, edible fruits/plants, mushrooms, medicinal plants, spices and others. play an important role in the national economy of many countries. Sustainable forestry research and development programmes are being stepped up in order to ensure that these renewable resources continue to be available for use by current and future generations (Wubalem Tadesse et al., 2001).

Gums and resins form an important category of the NTFPs obtained from different tree species by naturally oozing or systematically tapping. Frankincense is one of the oleo-gum resins obtained from several species of *Boswellia* trees. Gum arabic is taken to refer to all gums collected from several *Acacia* species, which sometimes is referred to as "Acacia gum". Myrrh or oppoponax are used to refer to the various resinous products obtained from *Commiphora* species (Mulugeta Lemenih, 2005). Resin (terpentine oil) is obtained from different *Pinus* species (Wubalem Tadesse et al., 2001). Gum karaya is obtained from species in the genus *Sterculia* (Coppen, 1995; Girmay Fitwi, 2000). Gums and resins are considered as the byproducts or end products of certain metabolic pathways (Balakrisnan, 2003).

The industrial applications of gum and resins have expanded tremendously in recent years. They are used in many industries such as paper, textile, petroleum, pharmaceutical, cosmetics, food, varnishes, lacquers and soaps (Getachew Desalegn and Wubalem Tadesse, 2004; Wubalem Tadesse et al., 2007). Natural gums and resins are among dry land NTFPs resources in sub-Saharan Africa that contribute to improve the livelihoods of local communities in terms of food security, income generation and foreign exchange earnings. The use of natural gums for commercial purposes is an age-old activity in Ethiopia. Ethiopia was, and still is, one of the major producers and exporters of natural gums and resins from different indigenous tree species of *Acacia*, *Boswellia* and *Commiphora*, which are found in different dry agro-ecological zones of the country (Azene Bekele et al., 1993; Vollesen, 1995; Getachew Desalegn and Wubalem Tadesse, 2004).

Ethiopia's drylands, woodlands and bushlands (>3.5 million ha) are well endowed with native plant species in the genera of *Acacia, Commiphora, Boswellia* and *Stericulia*, important tree species known to produce about 300,000 ton of commercial gums and gum resins collectively. The major international commerce produced in Ethiopia is frankincense (Wubalem Tadesse et al., 2004). Export statistics showed that at the national level, between 2000 and 2008, Ethiopia exported 24,105 tons of natural gums (gum arabic, frankincense, myrrh and opopanax), which worth 23,846,000 USD with annual earning of 2,980,750 USD (Samuel Melaku, 2008). At the local level, communities in dryland areas

have been tapping and trading gums and gum resins as an effort to diversify their economic base and address the issue of food insecurity.

Sterculia setigera Del. exudes a water soluble gum, known as gum karaya or Gum *Sterculia*. Of all the gum karaya produced, 95% goes into pharmaceutical products and only 5% is used as a food additive (Coppen, 1995). Gum karaya is second next to gum Arabic. India is the major regular producer, overwhelmingly dominating international trade (Coppen, 1995). In Africa, Senegal is the biggest producer of karaya. Sudan also exports small amounts although it has the potential to produce and export much more. The United States consumes roughly 50% of the 4000-6000 tones gum karaya produced world wide and Western Europe around 30% (Coppen, 1995).

Industrial applications of gum karaya are similar to those of gum arabic, being used in food, pharmaceutical and toiletry industries. It stabilises salad dressings, cheese spreads and meat; prevents ice crystal growth in frozen foods; and improves the stability of whipped egg albumen and other protein foams (Hulse, 1996).

The most important commercial gum resin product collected and exported from Ethiopia is frankincense obtained from *Boswellia papyrifera* (Del.) Hochst. However, the resource potential of *B. payrifera* is decreasing at an alarming rate. Deforestation, over grazing, resettlement and improper tapping are among the major factors of the species degradation (Abeje Eshete et al., 2005). For instance, in Tigray National Regional State more than 177,000 ha of *Boswellia* forests are reported to have been destroyed in the last 20 years (Kindeya Gebrehiwot, 2003). Similar reports exist for Gonder (Abeje Eshete et al., 2005), and the Somali National Regional State (Mulugeta Lemenih et al., 2003). Assessment results of *B. papyrifera* population in the north and north-western parts of Ethiopia showed that lack of natural regeneration has led the species as one of the endangered species in Ethiopia (Kindeya Gebrehiwot, 2003).

Because of this, there is an increasing interest from gum and resin producing enterprises to find out other potential alternative species and products to exploit together with the endangered species products, frankincense (official request from stakeholder, Natural Gum Production and Marketing Enterprise). Therefore, tapping technique shall be introduced to the Ethiopian *Sterculia* species and the population status be studied. Hence, the main objective of this paper is to highlight the distribution of *S. setigera* in the country as well as the gum karaya's physical and chemical characteristics and quality. It also introduces appropriate tapping techniques that can be used for tapping and harvesting in Ethiopia.

rculia is a native of dry deciduous forests of tropical climates. It is udano-Sahel and in the Sudano-Guinea zones: Togo, eastwards to malia, East Africa, Angola (von Maydell, 1986), Gambia (Danso, a (Igoli et al., 2005), Senegal (Chikamai and Tchatat, 2004), lesen, 1995), Eritrea (Ogbagzhi, 2006), Kenya (Stiles, 1988), ania. Sudan has very large areas of *Sterculia* in Africa (Coppen, her species available in Ethiopia are *S. cinerea*, *S. africana*, *S.* and *S. stenocarpa* (Vollesen, 1995).

opia, it is found in association with *Acacia-Commiphora*-woodland, and and bush land, on rocky slopes or black cotton soil, dry riverine ng from 700 to 1900 m asl (Vollesen, 1995) and according to), it is a deciduous tree species of the savanna woodland and the and forest, from sea level up to 1500 m in altitude. The distribution (Table 1) in Ethiopia is in Tigray, North Gonder, Benshangul-Wello, Shewa, Kefa, and Sidamo regions (Vollesen, 1995; Girmay, n Tadesse et al., 2002; Getachew Desalegn and Wubalem Tadesse,

ated areas covered by natural gum and resin bearing species including *ia species* in the different administrative regions of Ethiopia

Regional te	Genus	Estimated Area (ha)
	Boswellia, Sterculia, Commiphora and Acacia	940,000
	Boswellia, Commiphora, Acacia and Sterculia	680,000
	Boswellia, Acacia, Commiphora and Sterculia	430,000
	Sterculia, Acacia and Commiphora	420,000
	Boswellia, Acacia and Sterculia	150,000
l-Gumuz	*Boswellia, Acacia and Sterculia*	100,000
	Boswellia, Acacia and Sterculia	70,000
	Commiphora and Acacia	65,000
		2,855,000

Fitwi (2000); * SNNP = Southern Nations, Nationalities and Peoples

It grows frequently on rocky areas of drier and steep slope hillsides in association with *Lonchocarpus, Pterocarpus* and *Anogeissus* tree species (Thirakul, 1993). It is characterised by easily recognisable simple broadly palmate leaves with 3-5 lobes or simply by its star-shaped fruits (Thirakul, 1993).

The bark is pale purple, grey-purple to whish greyish, smooth to very smooth, with white lenticels, flaking off in thin plates exposing the newly yellowish and pale red patches (Thirakul, 1993). Blazes are 1-1.5 cm thick. Blazing is exposing the resin canals of the inner bark by making wound/incision of a bark on the tree to a depth of 1-1.5 cm that may help to obtain optimum quantity of gum without causing damage to the trees (Murthy and Shiva, 1977). Even though literature on the bark thickness of *Sterculia* trees is not available, it is known to be about 2 cm (personal observation). Therefore, tapping with the above indicated depth may not cause damage to the trees.

In India, there are 12 gum karaya producing species, of which only *Sterculia urens* Roxb. species is tapped for gum harvesting (USAID, 2005). It occurs wild in many places on the dry, rocky hills and plateaus of central and northern regions, but it is also grown in plantations as a timber crop (Coppen, 1995).

Taxonomic and physiognomic characteristics

The genus *Sterculia* comprises about 300 species of which approximately 25 species are said to occur in South Africa's tropical forests (Vollesen, 1995; USAID, 2005). The genus *Sterculia* belongs to the family *Sterculiaceae* which is a source of important non-toxic edible gum. *Sterculia setigera* Del. tree (photo 1) reaches up to 15-20 m in height and 60 cm diameter at breast height (Vollesen, 1995).

Gum karaya sometimes known as gum Sterculia is the trade name for all the gum produced from *Sterculia* species (Coppen, 1995). The dominant gum karaya producing species in different countries are: *S. urens* (India), *S. setigera* (Senegal and Ethiopia), *S. quinqueloba* (Malawi and Tanzania), and others.

Production of gum karaya

As indicated above world wide production of gum karaya is currently at 4000-6000 tonnes per annum and is on a declining trend. India is the major regular producer, overwhelmingly dominating international trade in the gum produced from *S. urens* (Coppen, 1995). The market price for gum karaya ranges from USD 2250 to 6000 per ton (Coppen, 1995). Chikamai and Tchatat (2004) reported that commercial production of *S. setigrea* is taking place in Senegal which is the world's leading exporter (around 1000 tones per year). India was the leading

producer and exporter until the mid-1990s and it is believed that large quantities are consumed locally where domestic consumption is about double the volume exported (Chikamai and Tchatat, 2004).

Tapping

Indian experience exhibits that tapping is confined to trees with a minimum of 28.7 cm diameter at breast height (DBH) and the initial size of the blaze is limited to 15 cm tall, 10 cm wide and 0.5 cm deep. The tapping technique is accomplished by removal/incision of bark from the trunk (Coppen, 1995) with special tapping tool. Sixteen successive visits can be made to the tree at two-week intervals, removing a further 2 cm high section of the bark above the previous one at each visit, and leading to a maximum depth of the blaze of 2.5-3.0 cm. An additional blaze can be worked for every 16 cm DBH increment above 28.7 cm DBH, providing sufficient space is left between adjacent blazes. Tapping is best done during the hot season to maximise yields (Coppen, 1995). The gum begins to exude immediately and the exudation continues for several days. The maximum amount of exudation occurs within the first 24 hours. The gum is in the form of huge irregular tears (Photo 1). The best quality gum is collected during April, May and June. During this time, as the weather gets warmer the yield increases (Anonymous, 2007a).

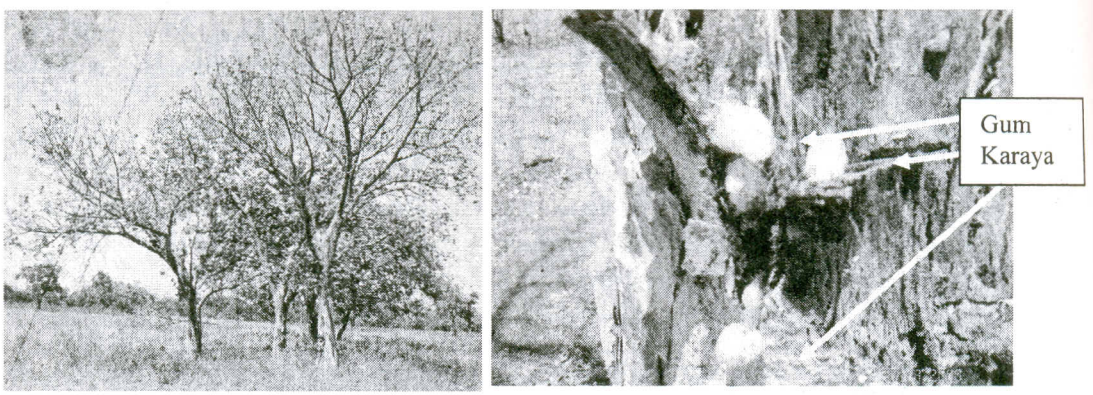

Photo 1. *S. setigera* trees (left) and gum karaya produced in Metema Wereda (North Gonder).

Due to the enormous socioeconomic importance gum karaya products, in India, researches are conducted by different researchers to improve the tapping techniques (Shiva et al., 2006) and they have designed special tools for tapping. According to Shiva et al. (2006) the newly designed tools have controlled the optimum depth of the blazes/incisions on the trees that may help obtain optimum

quantity of gum without causing damage to the trees. Average yield per tree is 1-5 kg (Coppen, 1995; Anonymous, 2007b) and according to USAID (2005) 4.3-7.2 kg during one year/season. It is hoped that the newly designed tools will prove useful in obtaining the sustained production of gums without causing mortality of trees. In India, as gum karaya is vital for tribal economy with respect to its trade value, there is a pressing need to develop a scientific and sustainable tapping method to increase the yield and quality and ensure the survival of the tapped trees (Shiva et al., 2006).

A simple and more safer technique of tapping with substantial increase in the yield is being developed using ethephon chemical to enhance gum yield and wound healing (Balakrisnan, 2003). After 45 days a thick wound tissue will develop at the injured region and almost replaces the damaged tissue when using this method. The wound is completely healed 60 days after tapping. While using this method the yield increases by approximately 20 to 30 times more than the control. There is also a marked difference in the yield among individual trees, presumably owing to heterozygosity. The systematic and scientific tapping technique using ethephon as a stimulating agent for gummosis or gumresinosis could ensure substantial improvement and sustainable production of these materials (Balakrisnan, 2003).

Experimental tapping of gum from *Acacia senegal* was carried out at the Central Arid Zone Research Institute (CAZRI), in India. An important finding of the CAZRI scientists has been the observation that gum exudation from most of the trees can be increased (nearly doubled), by injecting the plant hormone ethephone into the tree (Anonymous, 2004).

Characteristics and application of gum karaya

The exudates from *S. urens S. villosa* and S. *setigera* species are very similar in chemical composition and physico-chemical characteristics. Accordingly, in terms of current legal definitions of identity and trade specifications, exudates from any *Sterculia* or admixtures can be offered for sale (Coppen, 1995).

Physical properties

Appearance/grade of gum karaya

The highest grade sorts of gum karaya are white, translucent and almost free of bark. The lower grades vary from light yellow to brown and may contain as much as 3% of insoluble impurities. Powdered gum karaya is white to grayish white (Anonymous, 2007b).

Viscosity

The viscosity of gum karaya is largely dependent on its freshness, that is, why recently it was gathered from the trees. The thickening power (viscosity) is affected by conditions of climate and growth. Viscosity is also affected by storage. Powdered karaya will show a decrease in viscosity after storing over six months. Gum karaya sols are sensitive to alkali and attain their maximum viscosity at pH 8.5 and above (Anonymous, 2007b). Higher viscosities and pH stability over a wider range can be obtained by hydrating the gum prior to pH adjustment. In dry form, Karaya loses viscosity in storage, especially under high heat and humidity with the rate of loss being more for powdered material as compared to granules. To minimise this, storage under colder temperatures is advised. The viscosity loss of karaya dispersions in storage can be minimised by the addition of preservatives like benzoates, sorbates, phenols and related compounds (Anonymous, 2007a).

In dilute solutions of gum karaya, the viscosity increases linearly with concentrations up to about 0.5%, thereafter karaya dispersions behave as non-Newtonian solutions. At concentrations above 2-3% gum karaya forms thick, non-flowing pastes resembling spreadable gels. Heating under pressure gives smooth, homogenous solutions at concentrations as high as 18-20%. Heating gum karaya dispersions increases the solubility but results in permanently lower viscosities. The pH of a normal 1% dispersion is 4.6. Electrolytes such as sodium, calcium and aluminum chlorides and aluminum sulphate cause a viscosity drop as well as excessive acid or alkali (Anonymous, 2007a).

Chemical properties

Gum karaya is a complex polysaccharide of high molecular weight. A molecular weight as high as 9,500,000 has been reported. On hydrolysis it yields galactose, rhamnose and galacturonic acid. Gum karaya occurs as a partially acetylated derivative. The acid number has been found to vary from 13.4 to 22.7 (Lochhead, 2004) and general chemical specifications are presented in Table 2.

The variation in acid number is influenced not only by the source of the sample but also by its age. The gum has a peculiar property of splitting off free acetic acid and this loss is loosely correlated with the particle size. Trimethylamine has also been identified in the hydrolysis products. Gum karaya contains 12% to 14% moisture and less than 1% acid insoluble ash (Anonymous, 2007b).

Table 2. General chemical specifications

Actual Viscosity of a 1% Solution	
MAXIMUM LIMITS	
Arsenic (as As)	3 mg/kg
Ash (Acid-Insoluble)	1%
Heavy Metals (as Pb)	0.002%
Insoluble Matter	3%
Lead (Pb)	5 mg/kg
Loss on Drying	20%

Adapted from (Anonymous, 2008a).

Gum karaya occurs naturally as a complex, partially acetylated, branched polysaccharide of high molecular weight. It contains about 37% uronic acid residues and approximately 8% acetyl groups. Karaya is a calcium and magnesium salt, with a central chain of D-galactose, L-rhamnose and D-galacturonic acid units, with some side chains containing D-glucuronic acid (Anonymous, 2007b).

Grading /quality of gum karaya and prices

There are at least five Indian grades of karaya: HPS (Hand Picked Selected), Superior No.1 and No. 2, FAQ (Fair Average Quality) and Siftings. The first four grades are the main export grades (Tables 3 and 4). The main quality criteria at the sorting stage are colour and foreign matter, although even after grading the quality of consignments is often variable. The higher grades should be cleaner and paler than the lower ones, which may be dark brown in colour and have bits of bark present (Coppen, 1995).

Table 3. The grades and their technical specifications of gum karaya

Grade/specification	Colour	BFOM	Viscosity at 1 %
HPS	White	0.5 % max	>1000 cps
No.1	White with slight gray cast	0.75% max	>800 cps
No.2	Light tan	2% max	>400 cps
No.3	Tan	3% max	>300 cps

Adapted from (Anonymous, 2007a).

Note: BFOM -bark and foreign organic matter percent by weight (maximum)

Indicative FOB, Free on board (Shipping term), prices quoted by importers in London for Indian karaya (mid-1995) are in the range of US$ 2250-6000/tonne according to grade. FAQ gum is about US$ 3000/tonne. Senegalese gum has two grades, hand-picked and standard, which are generally inferior to the Indian export grades, and this is reflected in lower prices (Coppen, 1995).

Table 4. Grade designation and definition of quality of gum karaya (Crystals)

Grade Designation	Definition of quality			
	Special Characteristics			General characteristics
	Colour		Foreign matter, percent by weight (Maximum)	
	Summer Crop	Winter/Monsoon Crop		
I	2(a)	2(b)	3	4
No. 1	White with and yellow cast	Dull white	1.5	(1) Gum karaya Crystals Shall: be derived from the exudes of the plant *Sterculia urens*.
No. 2	Pale yellow to light tan and brown	Dull white to greyish to amber	3	(2) be reasonably dried, uniform in shape and size.
No. 3	Brown and dark brown with slight black cast	Dull yellow to brown dark	5	(3) be free from rodent excreta, rodent filth and hair, fungus attack, insect infestation.
No. 4	Dark brown to black	Dull brown to black	8	(4) have characteristic solubility.
No. 5	Black and mixed	Black and mixed	10	

Definition: Foreign matter shall include bark, leaves, dust, dirt, stones pieces or any other organic and inorganic matter other than gum karaya.
Adapted from (Anonymous, 2008b).

Traditional medicine

Various parts and products of *S. setigera* trees are used as a traditional medicine to cure different diseases in Africa (Igoli et al., 2005; Ogbagzhi, 2006). Stem bark is used to cure Diarrhea and leaves to cure poison (Arrow) in Nigeria (Igoli et al., 2005). Bark and leaves are used as a traditional medicine in Eritrea (Bein et al., 1996). Gum karaya is traded at the local market mainly for medicinal purposes in Eritrea (e.g. Barentu and Keren) (Ogbagzhi, 2006).

Other uses

The timber/lumber from the species is suitable for plywood cases, concealed items in carpentry=and insulation purposes (Thirakul, 1993). The tree species is also considered as a multipurpose tree species in agroforestry in dry land Africa (Rocheleau et al., 1988) and as a feed for animals (Yahaya et al., 2000).

CONCLUSIONS AND RECOMMENDATIONS

Gums and resins form an important category of non-timber forest products. Millions of people worldwide, especially in developing countries, depend on the collection of gums and resins for their livelihoods. Ethiopia is one of those countries which produces gum- resins for local markets and exports to the international market. Frankincense is the leading product exported from Ethiopia for centuries.

Even though *S. setigera* is distributed in various arid regions of the country, gum karaya has not been produced and marketed so far. Different countries in Africa produce and exports gum karaya from *S. setigera*. Senegal is the biggest producer and exporter of gum karaya, Sudan, Kenya and Malawi also produce gum karaya and export to the international market.

As stated above, Ethiopia has potential for commercialising the gum karaya product that can attract local and foreign investors, and hence contributing to the national economy. Therefore, gum karaya production shall be started in the country's *Sterculia* forests by introducing appropriate regeneration methods and tapping techniques. Tapping technique using ethephon chemical would be one solution to check and verify. However, the research work on appropriate tapping techniques shall precede commercial production and marketing. Thereby, the natural gum producing and marketing enterprises may have potential alternative commercial product for their business. Moreover, it may be an additional source of income for the people leaving neighborhood to the forests and may contribute to the sustainable utilisation of the forests and its environment. This can be

considered as one of the strategies for achieving food security, which is one of the millennium development goals of Ethiopia.

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