IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 8, Issue 6 (Sep. - Oct. 2013), PP 01-08
www.iosrjournals.org

Sisal and its Potential for Creating Innovative Employment Opportunities and Economic Prospects

P.Srinivasakumar [1*], M.J.Nandan [2], Dr.C.Udaya Kiran[1], Dr.K.Prahlada Rao[3]
[1]Research scholar[*], JNT University,Anantapur & Professor, Department of Mechanical Engineering J.B.Institute of Engineering and Technology, Hyderabad-500075 , India
[2] Sr.Scientist ,National Geophysical Research Institute (CSIR-NGRI), Uppal Road Hyderabad – 500 007 A.P, India
[3] Professor, Department of Mechanical Engineering, JNTUA College of Engineering, Anantapur-515002 ,India

***Abstract**: The tremendous potential of sisal (Agave sp.) as an important plant resource has not so far been fully exploited in our country. Sisal leaves yield quality fibres, which are utilized for conventional purposes like ropes, anchors, cordage and handicrafts. The superior engineering properties of sisal makes it an excellent green material for its application in major sectors like marine, automotive, construction and renewable energy etc. Preliminary investigations indicate that there is a great scope for the development of sisal based technologies for rural and engineering applications. The sisal fibre and its allied activities could augment employment opportunities for income generation in rural sector, whereas its engineering applications can generate substantial employment potential in semi-urban and urban areas. New opportunities for the use of sisal fibre as a reinforcing fibre in commodity papers potentially offers large markets and employment generation for rural area people in India.*

***Key words**: Sisal fiber, Sisal roofs, Automobiles, Renewable Energy, Employment, Cultivation, Sisal economy model.*

I. Introduction

Products from plants are assuming increasing importance to the economy and well being of any country. Utilization of plant resources for generating employment in rural areas is natural, cost effective and ecologically sustainable [1]. Since long time the mankind is associated with natural fibres and they have been used by them for various purposes and have been incorporated in their livelihood [2]. Be it basketry, mats or small useful products, appropriate use of the locally available material is always the solution. India has a vast resource of different natural fibers viz., jute, sisal, banana, coir etc., which are abundantly available with a production capacity of 400 million tonnes per year [17]. Among others, sisal [12] has an edge as it can be grown in wastelands; require minimum maintenance; withstand in many agro ecological conditions and produces continuous fiber for seven to eight years. It is usually grown on land that is unsuitable for any other agricultural activity apart from grazing. Other advantages are that the crop is drought resistant, does not require the use of fertilizers, herbicides or insecticides, can be inter-cropped and inter-grazed. For instance, in hundred years of commercial sisal growing in Tanzania there has not been a year when there was a drought to destroy sisal plants [25].

India possesses a large chunk of wastelands and practically, one of the viable cultivation on such a dry ecosystem is sisal. The leaves of sisal yield a strong fibre, which is primarily used for making ropes, cordage and twines. Its potential can be visualized from the fact that a quantity of 1000 Kg sisal leaves are estimated to produce 30 Kg fibre, 1 Kg hecogenin (a steroid used in pharmaceuticals), 3.75 Kg wax and 33 Kg paper [19]. Sisal fibre is a very strong, lustrous natural fibre and can take the wear and tear equivalent of coir. The huge advantage of sisal fibre over coir is that it is a white material which takes the dye very well and is softer than coir. Apart from the traditional applications sisal finds its way in environment friendly engineering materials due to low density, high specific strength and biodegradability. Sisal and allied activities like cultivation, fibre extraction, value addition etc. are labour intensive, low-tech and has high potential for employment generation. The tremendous potential of sisal as a resource has not so far been fully exploited in our country for value addition and as a source of employment generation in rural and semi-urban sectors. Preliminary investigations indicate that there is a great scope for the development of sisal based technologies for rural and engineering applications [20].

II. Historic Presence

Sisal is native of Central America and its origin can be traced back several centuries. The name “Sisal” comes from a harbor town in Yucatan, Mexico [2]. Currently there are around 275 varieties spread throughout the tropical and sub-tropical areas of the world. The sisal industry is concentrated in mostly tropical regions of Africa,Central and South America and Asia. It is produced in some of the poorest areas of the world and in many cases it is the only source of income and economic activity in those areas. Normally, raw fibre was produced in the tropical, predominantly developing countries and shipped to the developed economies in Europe, North America, Japan, Australia and New Zealand for transformation into products for consumption in those markets and re-exports. However this feature has been changing with fibre producers also processing the fibre in their own countries. Many countries are putting efforts to revitalize the sisal industry and transform it from maturity and traditional production and products to a more modern and vibrant industry. As the sisal has been predominantly produced in poor countries, resources for research and development have been limited.

In India *Agave* plant was brought by the Portugese in the fifteenth century and first time cultivated in Goa and later on in Orissa[11] and now found throughout the country. The major species of agave available in India are *A. sisalana, A. mexicana, A. americana, A. cantala,* and *A. veracruz*. Among the agaves, the most prevalent is *Agave sisalana,* commonly known as sisal, which *is* a xerophyte and can survive on poor soils in drought prone tropical regions. In India the plant is spread in many states viz., Madhya Pradesh, Chhattisgarh, Orissa, Uttar Pradesh, Rajasthan, Andhra Pradesh, Tamilnadu, Karnataka, Maharashtra and Bihar**.**

III. Production

Sisal occupies 6th place among fibre plants, representing 2% of the world's production of plant fibres [18]**.** The total annual production of sisal fibre varies, depending on demand, climatic conditions and cultivation. In recent years annual production of sisal in the world has been recorded as 250 thousand tones as shown in Fig.1[29]. The main producers are Africa, Angola, Ethiopia, Kenya, Madagascar, Mozambique, South Africa, Tanzania, Latin America, Brazil, Haiti, Jamaica, Venezuela and China [4]

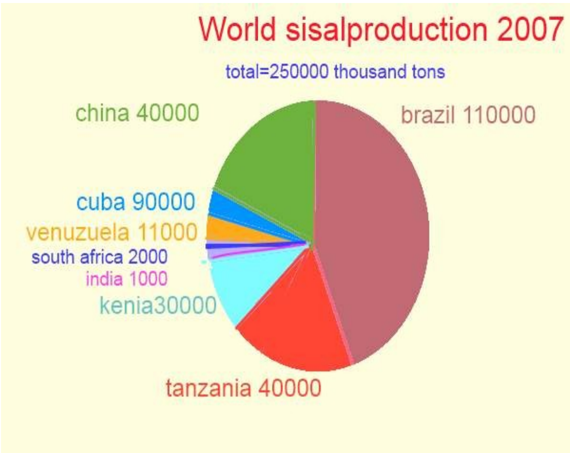

Fig.1: World Sisal Production 2007
(www.**waterwereld.nu/sisal**.php)

In India, sisal is not cultivated and the sector is unorganized. It is currently found on embankments, bunds and roadsides, serving the purpose of soil conservation and protection as hedge plantation. The standardized and optimized data on sisal cultivation practices is not available for different agro-ecological regions of India. A high yielding sisal hybrid (*Leela*) has been developed at Sisal Research Station, Bamra, Orissa in 1985 which has a yield potential up to 25 q/ha. Considering its employment and income generation potential, the District Rural Development Agency (DRDA), Koraput, Orissa implemented an integrated "Sisal plantation, fiber extraction and rope making" programme under Jawahar Rojgar Yojana (JRY) in the year 1995 [16]. Though its adoptability to most of the soils and agro-ecological zones is well known for quite a long period, its optimum results in terms of its fibre yields, its lifetime with respect to its environment is not exactly known.

IV. Cultivation And Harvesting

Sisal is a perennial hardy plant, which unlike the other fibres is not a seasonal crop as shown in Fig.2. It can establish and easily grow in all states of India covering sub humid to arid and semiarid regions. It can also survive in almost all soil types and its input costs are least for its survival, regeneration and maintenance on sustainable basis. Sisal tolerates prolonged droughts and high temperatures also. It is a stoloniferous plant, which produces shoots from the stolons, known as suckers or bulbils, which can be used for propagation. The suckers / bulbils are grown on in nurseries until they are about 50 to 70 cm high and then planted in the main field[27].

With good growing conditions sisal plant forms an inflorescence after 6 - 9 years after having produced 250 - 300 leaves, and then dies. Leaves are around 120 cm in length and are arranged spirally around the thick stem. The root system is shallow but extends up to 3.5 m from the stem. The leaves have a thorn at the tip and grow up to a height of 3 - 4 ft and yield valuable fibre. More usually plants are harvested after 24-36 months. About 50 leaves, each weighing up to 1 kg may be cut per plant per year. The ripest lower leaves are cut first and this continues periodically over the next four years. On an average, over the first four years, two cuttings are made annually. In following years only one cut is made per year, until the flower stalks begin to develop. A total of about 300 leaves may be harvested during the economic life of each plant.

Fig.2: A typical view of sisal plant

V. Fiber Extraction

For extraction of the fiber, two methods are employed, viz., the retting process and the mechanical method. The retting process is a biodegradation process involving microbial decomposition of sisal leaves, which separates the fibre from pith. The fibres are washed and processed further. This process takes 15-21 days for a single cycle of extraction and degrades the quality of fibre. At the same time this process is water intensive, unhygienic and not eco-friendly. In the mechanical process, the fibre is extracted by rasping the leaves with a raspador[20]. Raspador is a rotating drum mounted on an axle having blunt blades, fitted obliquely about 10 cm apart on its periphery as shown in Fig.3. The leaves are fed into the slit of the raspador and pulled out. In this method almost the entire extraneous matter is removed leaving only the fibre strand. Decorticated fibres are washed before drying in the sun or by hot air. Proper drying is important as fibre quality depends largely on moisture content. Artificial drying has been found to result in generally better grades of fibre than sun drying. Dry fibres are machine combed and sorted into various grades. Appearance, color and physical properties [28] are the main features to decide the quality standards of sisal fiber as shown in Table 1.

Fig.3: Raspador Machine for sisal fiber extraction

Table 1: Quality Standards of Sisal long fiber

	Excellent	**First grade**	**Qualified grade**
Length (cm)	≥ 95	≥ 85	≥ 70
Bungle strength (N/g)	≥ 880	≥ 830	≥ 780
Trash content (%)	≤ 2.5	≤ 3.5	≤ 5.0
Colour	White or milky white with luster	White	Yellow or Yellowish-brown
Spot	Nil	Very few	Very few

VI. Fiber Properties

The important chemical components [20] of the sisal fibre are shown in Table 2. Based on the composition, it can be inferred that the sisal fibre is harder (greater rigidity and lower flexibility) and coarser than other bast and leaf fibres because of the high lignin and pectin content. Apart from this, the superior engineering properties (diameter 50–200 μm; microfibril angle 10–22^0, Ultimate Tensile Strength of 468–640 Mpa; Modulus of 9.40–15.80 Gpa and elongation of 3–7%) makes it an excellent material for manufacturing high strength textile and reinforcement in composites for various applications[2].

Table 2: Chemical composition of sisal fiber

S.No.	Chemical Components	% by weight
1.	Cellulose	55-65
2.	Hemi-cellulose	10-15
3.	Pectin	2-4
4.	Lignin	10-20
5.	Water soluble materials	1-4
6.	Fat and wax	10.15-0.3
7.	Ash	0.7-1.5

VII. Use Of Sisal And Its Waste

Long fibers (> 90 cm long) are used for ropes and binder twine. Besides rope making, there are also other usage in making of brushes, dusters, door-mats, carpets, bags, fishing nets, belts, chappal stripe, hats, dolls, Christmas trees etc. It is also used for cigarette papers and filters, filter papers, tissues papers, tea bag etc. whereas unbleached pulp can be used for electrical cable and telephone cable insulation and in making cement bags and sacks etc. (Singh and Sasmal 1994: 245) . The sisal pulp (about 95 percent) left after fiber extraction is mainly used for making paper / paperboards, hecogenin (a cortico steroid), wax and bio gas [3].

There is a dire need to widen the product base. Traditional products of twines, ropes, carpets and bags need to be sustained and improved to combat competition. But efforts have to be intensified to produce and market those products where sisal has technological, environmental, geographical and cost advantages. There is a wide range of products like geo textiles, buffing cloth, bonding, construction materials, handicrafts, furniture, padding and mattresses can be made with sisal fiber[8,25]. In recent years sisal has also been utilized as a strengthening agent to replace asbestos and fiberglass and is increasingly a component used in the automobile industry, where its strength, naturalness and environmentally friendly characteristics are greatly appreciated. Attempts were made to prepare Corrugated sisal cement roofing sheets at AMPRI, Bhopal using hand lay up technique as shown in Fig.4 [6,22].

Fig.4: Sisal fiber cement roofing sheet (with courtesy from : AMPRI ,Bhopal)

It is discernible that there is a huge quantity of sisal waste (95% of the leaves by weight) can be effectively utilized for composting, vermi-composting [21] and extracting other valuable products as shown in Table 3. The pilot scale demonstrations show that it is a valuable feedstock for biogas plants to cater to the local and rural energy requirements. One tonne of sisal pulp can generate 54.3 m^3 of biogas by the methanogenesis (Oudshoorn 1995). Sisal leaves are known to contain wax (0.38%) and hecogenin (0.10%). Indian Institute of Science (IISc), Bangalore has developed technologies for the production of hecogenin from the sisal waste (Murthy et al. 1981: 228). Hecogenin is a pharmaceutical raw material for the manufacture of carticosteroids, which is currently imported at a cost of Rs. 800 per Kg. These expected spin-offs in the form of secondary / allied activities which are labour intensive and have wide range of applications in rural and small-scale industrial sectors.

Table 3: Spin-offs from Sisal Waste

S.No.	Spin-off	Application	Potential
1.	Manures	Agriculture	Variable
2.	Vermicompost	Agriculture / Horticulture	Variable
3.	Hecogenin	Pharmaceuticals	1.00 Kg / tonne
4.	Wax	Industrial	3.75 Kg / tonne
5.	Biogas	Rural energy	54.3 m^3 / tonne
6.	Electricity	Rural energy	1.0 MW from 4500 ha

VIII. Engineering Applications

During the past several years, the soft, durable and biodegradable natural fibers have established a positive and highly regarded name for themselves as they are considered as future biorenewable materials. Due to the lightweight, high strength to weight ratio, corrosion resistance and other advantages, natural fibre based composites are becoming important composite materials in various engineering applications [7]. In case of synthetic fibre based composites, despite the usefulness in service, these are difficult to be recycled after designed service life. However, natural fibre based composites are environment friendly to a large extent [8].

Due to superior mechanical properties and recyclable nature, sisal fiber can be used as a potential input material for making composites for application in buildings, automobiles, railways, geo-textiles, marine, renewable energy and packaging industries etc. Sisal fibre reinforced composite building materials like; wood substitute products, panels, doors, corrugated roofing sheets and instant houses suitable for disaster (floods / tsunami / earth quake) prone areas would be made which attract prospective entrepreneurs and stake holders due to its durability and cost effectiveness [5]. Asbestos fibres being carcinogenic, sisal fibre cement corrugated roofing sheets, which are eco-friendly, can be an effective alternative[1,6,13.22].

Present scenario indicates that the use of plant fibre (sisal / flax / hemp etc.) based automobile parts like trim parts, various panels, seat backs, shelves, brake shoes etc., are picking up momentum worldwide. Reduction in weight, consumption of less energy for production and decreased cost of the components as experienced elsewhere, attracts the automobile industry to employ sisal fibre composite parts [14]. The conservative estimates indicate that about 6,000 TPA plant fibre based composite parts can find their way into passenger cars and multi utility vehicles. Railways are also a potential application area where in it is estimated that about 350 TPA fibre composites are required to manufacture doors, luggage racks, panels, partitions, seating etc[13]. Packaging materials for bags, boxes, crates, containers, which is now made up of wood, can be replaced by cost-effective sisal reinforced composites. Boats can be made by replacing the conventional polymer composite fibres with sisal as reinforcement. The market potential of geotextiles for roads, paved road networks and railway applications in India is estimated to be 2,72,500 tonnes, of which a considerable portion can be earmarked for sisal-based textiles.

To make fuel, the residual biomass is fed into a digester along with cow dung [25]..A sisal waste fed biogas power plant was established at Hale by M/s Katani Ltd in Tanzania.as shown in Fig.4 [30]. The bacteria in the dung feed on the crop residues to produce biogas which is then used to generate electricity, used as fuel for transport, cooking and lighting, or for powering farm machinery. Liquid effluent from the process is high in nitrogen, potassium and calcium and is sold as fertiliser to be used on the next generation of sisal crops. The effluent is also used as a nutritious animal feed, which is proving particularly popular with livestock keepers with limited access to grazing lands.

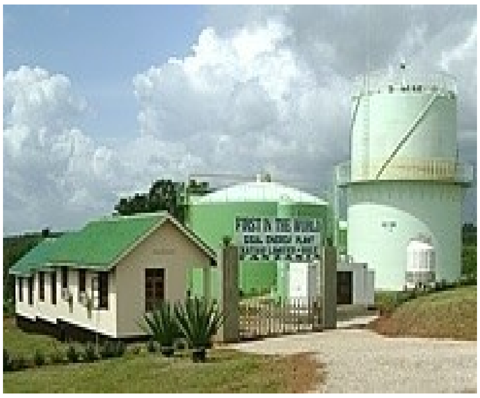

Fig. 4: The Hale biogas plant uses sisal waste to produce electricity established by M/s *Katani Ltd, Tanzania.*

IX. Employment Potential

India's villages are mainly dependent on agriculture for much of their sustenance. Drought is a common event across much of India and the country needs creative solutions and technological innovations to start a revolution which can take its villages fast forward in time by creating them economically viable units and growth engines.

Presently sisal and their allied activities is an unorganized sector localized mostly in rural and tribal areas. The sisal fibre and its allied activities like cultivation; fibre extraction, processing and making value added products could augment the employment opportunities for income generation in rural sector [24]. The engineering applications of sisal fibre like buildings, automotives, railways etc. are the prospective areas where it can generate enormous employment potential in semi urban and urban areas. Sisal plantation activity alone has an annual employment potential of about 113 man-days per hectare[16]. For instance, the state of Madhya Pradesh has 14.17 lakh ha. barren and uncultivated wastelands, out of which 3.00 lakh ha (20%) can be targeted for sisal plantations, which can generate enormous employment potential (339 Million Man days) for exclusively cultivation and fibre extraction as shown in Table 4. Apart from this fiber is an input material for various rural applications involving cordage, mats, handicrafts and other utility items, which can augment the employment opportunities for income generation in rural sector.

Table 4. Employment potential from sisal cultivation

	Sisal Cultivation Area (ha.)	**Production (Tonnes/Yr)**	**Mandays (Per Year)**
Unit area	1.00	2.5	113*
Current Status - India (Unorganized Sector)	10,100	25,250	11,41,300
Potential (Madhya Pradesh)	3,00,000	7,50,000	3,39,00,000

X. Sisal Economy Model (Sem)

The increasing petroleum prices and environmental consciousness are forcing the major economic markets like marine, automotive, construction etc. towards natural fibers. Sisal is considered to be the best because of its strength, durability, and ability to stretch, affinity for dyeing and resistance to weather conditions. The recyclable and sustainable nature of the sisal fiber makes it competes directly with fiber glass. It is expected that within a few years fiberglass will make way for composite materials made out of both natural and man made fibres instead of 100% non-recyclable synthetic materials[9]. Daimler Chrysler now uses sisal in door panels, ceilings and dash boards of Mercedes Benz A and C class models. Brazil alone consumes 12,000 tons of sisal in the automobile industry where it has applications in seat cushions, insulation parts, door trim panels and dash boards. Considering the great economic potential of sisal, countries like South Africa, China, Tanzania, Chad etc. are commercially growing sisal and improving their production levels.

India is a developing country and is suffering from unemployment and daunting economic problems of poverty and lack of economic empowerment. The commercial cultivation of sisal in the unproductive lands will become a basis to create sustainable rural economy as the crop is labor-intensive agriculture activity. Taking this into concern a model on sisal economy is proposed to accelerate rural economic growth of our country. The model called Sisal Economy Model (SEM) has the potential for achieving the multi-faced goals of sustainable development. The approach is to demonstrate how rural masses can organize themselves to succeed in creating

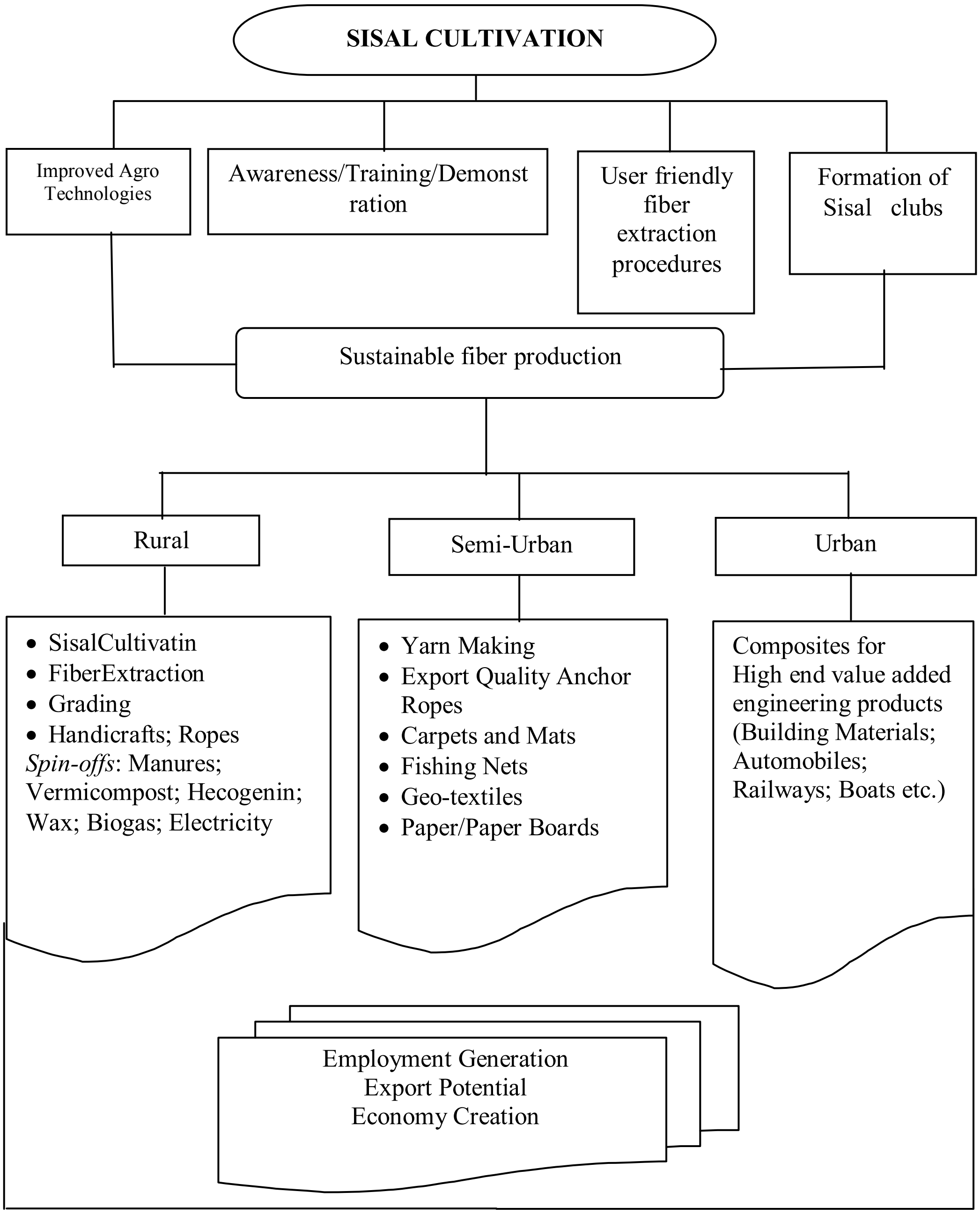

Fig.5: Sisal Economic Model

sisal economy for our country. The goal of SEM is to create a win-win situation combining economics, technology, ecology and society and to set up an exemplary rural economic model as shown in Fig.5 of our country.

The Association of Small Farmers of the municipality of Valente (APAEB Valente); Sindifibras and Madikwe sisal projects of Brazil and Dailmer Chrysler Sisal Fiber Project of South Africa are the best examples of the Sisal Economy Model.

In order to produce, transform and commercialize sisal, SEM is targeted to evolve with know-how, processes, technologies, machinery and products. The entire value chain from the farm and factory through process and product development, regulatory analysis, and life cycle evaluation to financing and market development. Dealing with this complexity demands an interdisciplinary approach and real-life expertise in agronomy, biology, fiber availability, textile technologies, product development, market structures, and economic trends etc.

XI. Conclusions

- Sisal is native of Central America and its origin can be traced back several centuries.
- Since long time the mankind is associated with natural fibres and they have been used by them for various purposes and have been incorporated in their livelihood.
- Due to superior mechanical properties and recyclable nature, sisal fiber can be used as a potential input material for making composites for application in buildings, automobiles, railways, geo-textiles, marine, renewable energy .
- New opportunities for the use of sisal fiber as a reinforcing fiber in commodity papers potentially offers large markets and employment generation for rural area people in India.
- Sisal plantation activity alone has an annual employment potential of about 113 man-days per hectare.
- In Madhya Pradesh 3.00 lakh ha (20%) has been used for sisal plantations, which can generate enormous employment potential (339 Million Man days) for exclusively cultivation and fibre extraction.

Acknowledgement

The authors would wish to thank the Council of Scientific and Industrial Research (CSIR), New Delhi for financial support in the form of RSP-002 project and Director, Advanced Materials and Processes Research Institute (AMPRI), Bhopal for guidance and support.

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