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Alcides Leão [a] , Silvia Maria Sartor [b] & José Cláudio Caraschi [c]

[a] UNESP - Sao Paulo State University, College of Agricultural Sciences, Botucatu, São Paulo, Brazil

[b] UNIMONTE - Santos, São Paulo, Brazil

[c] UNESP - Itapeva, São Paulo, Brazil

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Natural Fibers Based Composites – Technical and Social Issues

Alcides Leão
UNESP – Sao Paulo State University, College of Agricultural Sciences, Botucatu, São Paulo, Brazil

Silvia Maria Sartor
UNIMONTE – Santos, São Paulo, Brazil

José Cláudio Caraschi
UNESP – Itapeva, São Paulo, Brazil

Brazil is the only country in South America to have an automotive supplier sector based on natural fibers. New opportunities are arising due to an increase demand by the car makers in applying natural fibers in their parts. Several crop fibers have been developed in Brazil. Among them can be listed caroá, piaçava, pupunha, mutum and others of regional application. For the automotive industry, which requires large quantities with uniform quality, the alternatives are sisal (170,000 ton/yr), curauá (150 ton/yr in 2003), malva, 200 ton/yr; Brazil is the single largest producer country of sisal, and commercially, the only one in curauá. For South America, the alternatives are fique in Colombia, abaca in equator, flax in Argentina and curaua in Venezuela. It must be understood by the target countries of drugs, is that crop fiber can be an economic alternative to coca in the Andes region, therefore an instrument of land reform and drug reduction plantations. Several companies have a strong program of apply natural fibers based components in their products: Volkswagen do Brazil, DaimlerChrysler, General Motors do Brazil. Among their suppliers can be listed companies such Pematec (curaua), Toro (sisal, coir and jute), Incomer (sisal and jute), Ober (jute, curauá), Indaru (jute and sisal), Antolin (imported kenaf,) Tapetes São Carlos (sisal), Poematec (coir) and Art-Gore, with "Woodstock" wood and natural fibers). Figures about production and demand are discussed in the paper.

Keywords: composites; curauá; jute; natural fibers; rural development; sisal

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Address correspondence to Alcides Leão, UNESP – São Paulo State University, College of Agricultural Sciences, Botucatu, SP 18603-970, Brazil. E-mail: alcidesleao@fca.unesp.br

INTRODUCTION

Environmental and economical concerns are stimulating research in the development of new materials for construction, furniture, packaging and automotive industries. Particularly attractive are the new materials in which a good part is based on natural renewable resources, preventing further stresses on the environment by depleting dwindling wood resources from forests. Examples of such raw material sources are annual growth native crops/plants/fibers, which are abundantly available in tropical regions. These plants/fibers (like jute and sisal) have been used for hundreds of years for many applications such as ropes, beds, bags, etc. If new uses of fast growing, native plants can be developed for high value, non-timber based materials, there is a tremendous potential of creating jobs in the rural sector. These renewable, non-timber based materials could reduce the use of traditional materials such as wood, minerals and plastics for some applications.

The Northeast Region of Brazil has a land area of over 1.5 million km^2 and extends over tropical and equatorial latitudes from 18′S to 1′S. Although representing only about 18% of the national territory, it is the home of approximately 35% of Brazil's 180 millions inhabitants [1]. The Northeastern region of Brazil, in the States of Bahia, Paraiba and Rio Grande do Norte are responsible for 100% of the Brazilian sisal production. Reflecting this wide diversity of moisture conditions are natural vegetation patterns ranging from tropical rainforest ("Atlantic Rain Forest") to semi-arid thorn scrub ("Caatinga"). The caatinga system has been under severe pressure due to the lack of economical alternatives to support the population living in those areas and sisal crop fibers can be the one.

BACKGROUND

The Northeast Region was the heart of the colonial settlement, and was the richest of the country in the XVII century, due to its sugar exports to Europe. Thus, insufficient and irregular rainfall together with the economic decline experienced by the loss of competitiveness of the region agricultural monoculture in the world market, in XIX and XX centuries, only contributed to worsening the local conditions. The Northeast is the poorest region in Brazil. It has the highest infant mortality rates in the country, around 50–60 (estimated per 1,000 live births). The HDI range from 0.668 to 0.557. The per capita varies from US$1,232 to US$1,005. Inequalities within the region are also significant, and it has been estimated that the rural income in the semi-arid region is below US$ 200 per year. Nowadays the Northeast Region exemplifies the extreme case

of a large and persistent pocket of poverty within a dynamic and rapidly developing country. In parts it shares a similar profile to Sub Saharan African Countries such as Sudan and Botswana.

Approach Used for Development of Natural Fiber in Industrial Applications

The aim of the natural fibers, mainly sisal in the Brazilian context is to use several strategies toward bringing income and labor positions in the poorest regions of Brazil and other countries. These points have been under discussion in several countries. Muhlbauer [2], under the patronage of Daimler Chrysler organized a workshop in Philippines about the sustainability of natural fibers, mainly abaca. Daimler Chrysler [3] have set up several initiatives to develop the natural fibers in their vehicles. Sherman [4] described the fashion of natural fibers in the auto industry, what have resulted in a steady growth in the German market of 25% per year. Following this trend, Ford as well have moved toward green materials [5]. Mueller [6] compared several natural and synthetic fibers evaluating its properties, such as cotton, flax, hemp, jute, kenaf, ramie, sisal and e-glass. The recommendations for the growth of the natural fiber market goes through:

1) Development of agricultural and industrial research which will lead to a fuller utilization of the sisal plant as a whole, in view of its productive and industrial chain;
2) Incentives to the sisal expansion production;
3) Development of industrial applications of sisal fibers as well as the utilization of sisal by-products, enhancing the plant utilization, such as:
   - Animal forage aiming to produce high value nutrients from mucilage;
   - Inputs for the human and veterinary pharmaceutical industry;
   - Inputs for the automotive industry and furniture;
   - Inputs for the civil construction industry;
   - Inputs for reinforced plastic industry;
   - Inputs for production of cement-matrix and polymer-matrix based composites; and
   - Development of sisal handcraft by less developed communities.

Brief Description of the Sisal Shrinking Market Problem

Cultivation of annual subsistence crops, and in some instances other perennials, during the annual rainy season by small farmers is also

common. Sisal crops represents an alternative due to its high drought resistance. Unfortunately the markets was shrinking due the man made fibers competitors. The sisal is a gender fibrous plant *Agave*, very rustic, original of Mexico and introduced into the Brazilian Northeast in 1903. *Agave sisalana*, perrine, is practically the only cultivated variety commercially in Brazil, supplying fibers for the agricultural and textile threads production, carpets, blankets for isolation thermal-acoustic, among others uses. The national production, agro industry of the sisal is of extreme importance for representing one of the only economic options for the rural and urban population of semi-arid region, responsible for the generation and maintenance of about 800 thousand direct jobs in than 40 municipalities and rural population, constituted largely by small producers.

However, although Brazil is nowadays sisal fibers world biggest producer, with about 200 thousand hectares of planted area, accounting for the production of about 175,000 tons per year of fiber, since decade of 80's its production comes falling due to drought long periods, lack if incentives resultant of the Brazilian fiber low prices in the external market; the low technological level of the sector, and non existence of integrated research and extension programs.

The cultivation traditional systems, extraction, sisal benefit and industrialization have result in workers under high degree to the occupational risks, sub-utilization of the plant resources, fiber low quality, low productivity and low profitability. Although the region's situation is quite difficult, there is a certainty that the present problems can be overcome and that the Northeast development potential is quite high. However, for this potential to be materialized, it is necessary to have political decisiveness, financial resources and proper utilization of the technical-scientific knowledge available, to find the adequate solutions for the social conditions of the region. The state governments are struggling to revitalize the sisal, a culture that has considerable merit regarding the environmental and socio-economic conditions of Northeast Brazil. From an environmental standpoint, the recuperation of the culture, or even the establishment of new plantations, represents a concrete possibility to relieve pressure over the local vegetation ("*caatinga*"), traditional source of fuel not only to meet domestic needs of cooking but also to meet industrial ones as well, since the local people are selling fire wood from the *caatinga* due to lack of other economical alternatives. Indeed, as an agricultural biomass, sisal boles and poles could be used as supplements or even as substitutes for fuel wood or timber from native forests. On the other hand, the use of these two by-products as a raw material for a biogas plant will produce an improved conditioner and fertilizer to the soil. Not to mention that

the use of chipped old boles and poles spread over the top of the soil will ensure both agricultural production and environmental stability by restoring and/or improving organic matter content, reducing surface runoff, improving water infiltration and decreasing evapotranspiration. Mulching of sisal residues can be a very useful tool helping to prevent soil erosion in and regions.

The existing sisal industry utilizes only 4% of the plant leaves, with the balance being thrown away as waste products. It is important to stress, on the other hand, that a number of small farmers use the mucilage to feed their livestock, particularly during long dry periods. Additionally, it is well known that 24% of the sisal's total weight may be used in animal diet, representing 70% of the cotton's nutritive value.

In view of the above, it is believed that the best way to promote social and economic development of the sisal culture in the Northeast is to achieve a more efficient use of the plant, focusing on its composites which, in a future perspective, may represent its own economic redemption. Also considered important for the revitalization of this culture is the adoption of new production methods and practices in order to obtain new products for the sisal productive chain. Social reasons may, in fact, be the overriding justification for encouraging the revitalization and/or expansion of the sisal culture in Brazil's Northeast Region. Once this program is well established it is expected that it may be replicated to other regions or countries with similar physical and socio-economic conditions.

Among the direct benefits to be obtained with the sisal revitalization and the development of new areas can be listed:

- Alternative to the deforestation, replacing native solid wood as a source of firewood for cooking, preserving the forests in a semi-arid region;
- Use of by-products, such as mucilage, to feed the goat population, with high net gain in milk to be delivered to the infant poor population;
- Use of short fibers to produce composites in polymeric matrix and cement, to produce tiles, bricks, etc, replacing the asbestos fibers;
- Use of medicines from the sisal juice in drugs (anti-inflammatory and anticoncepcional), and in agrochemicals, such as insecticides and others.

The following steps are considered to develop the sisal demand:

– Revitalization of crop yields at levels of 1980/95, 1200 kg/ha/year, increasing the nowadays levels, 1995/2000, of 600–700 kg/ha/year. With the revitalization of the sisal crop, from an

adequate management, in terms of harvesting age, etc..., it is possible to obtain an income increase of about 30% [7];
- The Brazilian fiber shows low uniformity and quality in function, mainly, of the decortication process. A better fiber qualification will allows the industry to pay higher prices for the leaves producer, which is the main target of the sisal applications;
- Development of a defiberization machine looks to preserve the fiber quality as well to reduce the losses and be harmless to the operator health, in opposition to the nowadays available machines, responsible to thousands of mutilations in the sisal areas. An ideal machine, will result in a fiber with better quality, without mechanical damages, using prior world experiences;
- Development of a processing machine, (brushing machine) with a better capacity of remove fines and impurities from the thread still presents after the decortication. The equipment would have large application in other producer regions around the globe;
- Development of composites based on cement aiming to replace the asbestos fibers, scheduled to be banned of civil construction in year 2005. Among the applications can be listed tiles, roof, shingles, bricks, water containers, pipes, etc.... The producer regions have been using the sisal fiber since 1960, with some parts still in perfect conditions;
- Development of polymeric composites, for applications mainly in the automotive industry, furniture and appliances, replacing the conventional plastics. The sisal fiber is replacing the curauá fiber as the world priority by Mercedes Benz in the application as reinforcement agent for interiors and even exterior parts;
- Replacement of the conditions of exporting just raw-materials, with low aggregate value, one of the basic causes of the high numbers of poverty in the region of Northeast of Brazil. Based in this fact, it has been devoted efforts in the development of small capacity machines and equipments compatible to the production of the goods in small agroindustries, aiming to bring up the income index from the rural works at a level compatible to the world average standard of living, reducing, this way the rural exodus;
- Utilization of by-products, e.g., mucilage, for animal feed in the semi-arid regions, where the goat population represents one of the best alternatives for milk enrichment for human needs, mainly for the poor infants and their families, as well meet supply. It is an important tool towards the social program, that helping to reduce drastically the mortality and under-nutrition levels, mainly at the children population;

- The majority of the States in the Brazilian Northeast is developing several programs of replacement of cattle by the goat industry. To feed the herds, it will be used sisal mucilage in concentrate as a constant quality source to supplement the animal deficit;
- Development of technical standards to utilize sisal flowering poles as a replacement of solid wood in civil construction applications, such as lumber and poles. These materials, treated conveniently present a life span of about thirty years;
- Use of sisal crop as an instrument of land reform in rural communities for "landless workers," in Northeast states, where even, the biggest sisal farm in the world was used to land reforms.

A valorization of the fiber, through prior actions, will be an alternative to land reform in non-productive areas. One of the most serious problems in Brazil in the last decades is the uncontrolled migration from the rural areas to other regions or cities. Due to the fact that sisal is the only alternative to the region, it can a key factor do keep the man in the region, with the adoption of new technologies. In this case, it will be adopted the concept of productive chain, resulting in higher aggregate value moving away the subsistency economy, which is deleterious to the region (very sensitive region), to a market economy.

As a result of the actions mentioned before, it will be established conditions for:

1. Reduction in the rural exodus;
2. Possibility to have development associated with environmental preservation;
3. Possibility to develop rural communities in consistent way, helping the federal program of land reform;
4. In parallel form, the development of a project of handcraft, prevailing the concept of handcraft made of sisal fibers, associated with the care of the region cultural inheritage;
5. Development of new processes or products.

As for the socio-economic aspects of the sisal production, there are a number of benefits from the crop in the Northeast. Despite the shrinking of the world market for natural fibers due to competition from polypropylene and other man-made fibers, it is estimated that 0.7–0.8 million people are still depending direct or indirectly on this crop. It is an important commodity, considered as a labour-intensive a crop, each hectare employs – including the fibres extraction

operation – an average of 7 to 8 people/ha, even so 3 people/ha all year round regardless of water shortages.

The sisal industry had suffered a setback in terms of production. In the sixties the level was above 772,000 tons a year, but the levels fell to below 300,000 tons a year in the late nineties. Production has fallen due to increase competition from synthetics and change in the technology of hay baling. The demand for sisal fibre has thus dropped and the sisal estates were forced to run at low production levels. In the early nineties concern was raised as to the ultimate future of the sisal industry. Measures were undertaken to explore other uses of sisal fiber which, mainly composites, will increase the demand and therefore revive the otherwise collapsing industry.

SISAL IN COMPOSITES APPLICATIONS

The production of raw fiber is a very labor intensive operation and it is estimated that about 3 to 4 million of rural jobs have been lost in the last 35 years. The average annual exports of sisal and henequen (raw fibers and manufactures) between 1995 and 1999 was 202,600 tons of which 163,900 tons or 81% was exported by developing countries. The average exports for the period 1965/1974 was 767,200 tons or about 278% higher. This decline in the demand in the last 35 years strongly affected the exports of raw fiber. The annual average of 515,600 tons in 1965/74 was reduced to 70,660 tons in 1995/99 or nearly 86%. On other hand the exports of manufactures presented a reduction of about 47.5%. Beside the loss of market share to synthetics, changes in the baling technologies also contributed for further reduction in the demand.

The forecast for other traditional products of sisal such as padding, sacks, bags, carpets, pulp for specialty papers is envisaging a very low growth rate in the next 10 years. There is a wide range of new sisal products like pulp for commodity papers, geo-textiles, buffing, construction materials, furniture, household appliances, padding, handicrafts, mattresses and in the automotive industry. If all these are developed to their potential the demand for sisal will increase five folds [8].

The sisal industry is facing problems in both, demand and supply sides. The problems related with the demand side are mainly of international nature. They are related to: trade issues as barriers to free trade; heavily subsidized synthetic substitutes in the beginning of their inroads in the sisal market; strong marketing of synthetics in developed countries which were the main importers of sisal products; changes in baling technologies and lack of market promotion of the sisal products. The problems related with the supply side are related with production and have been created as a consequence of the problems in the demand

side since the majority of the developing producer countries strongly relied in the export market as the outlet for their production. The problems in the supply side are: utilization of old and inefficient technologies in the whole chain of production resulting in low productivity, profitability and product quality; lack of resources for research and development aiming at to improve the competitiveness of traditional products, development of value added and new marketable applications and to identify potential uses for sisal wastes; and, lack of pro-active actions for evaluation of the potential markets and for promotion of sisal products in those markets. Some political decisions also contributed for making worse the situation in some countries.

The opportunities for the use of sisal in new products were presented in the seminar on "Alternatives Applications for Sisal and Henequen." The seminar conclusions indicated that there are opportunities for the use of sisal fibers in composites for automotive industry, pulp for commodity papers and geo-textiles [9]. Natural fibers composites have found an application in automotive industry, side by side to fibers that are grown in Europe such as flax and hemp, and others such as kenaf and jute. Composites of sisal might find more use within the sisal-producing countries, in furniture, household appliances and automotive industries in Mexico and Brazil. Pulp continues to represent a largely untapped potential market, but the realization of this potential would require very considerable investment in technical research, market development and in pulping capacity. Geo-textiles may offer one of the largest potential market, however, for this potential to be realized, suppliers would need to offer a service which matched that of synthetics, including the provision of technical data on properties of the product, and the offer of regular quantities at stable price [10]. Another potential utilization is the replacement of asbestos in fibrous-cement composites for civil construction industry in selected developing countries such as China and Brazil, where some studies are being conducted at laboratory and pilot scales [11,12]. For all the potential applications above mentioned, sisal will have to compete with others fibers. The market for these new products needs to be evaluated and an efficient promotion of the products is also required.

The measures to address the problems and opportunities of sisal shall be focused in:

a) evaluation of the markets for new value added products as well as identification of strategies to penetrate these market as well as marketing promotion of the products,
b) contribution in initiatives focused in the creation of an international information network among the producers, consumers,

traders, governmental and non-governmental organizations and international organizations in order to facilitate the exchange of information and experiences in new developments for the sector. Strengthening the research and development capabilities in Brazil will be an important measure for the sustainability of the sector.

On the other hand, it might be possible to retard the erosion of the market for the sisal traditional products provided that their competitiveness in relation with synthetics be enhanced. If actions for enhancing the competitiveness of sisal are taken in conjunction with market ones it might be possible to recovery some share in the world market for twines and cordage. It is important to note that the amount of polypropylene (PP) used in manufacturing sisal substitutes is only 1.7% of the world consumption of PP products and even if sisal would recover some shares in the future the impact in the total market for PP products would be practically insignificant. The rural population will benefit with the increase in jobs opportunities resultant from the increase in the demand of sisal fiber for new products. It is expected that the introduction of the new value added products in the market would generate a demand of sisal fiber of about 50,000 tons/year. Taking into consideration the current requirements of labor/ton of fiber of 5 persons/ton and a productivity of 1,000 kg/ha/year, it is estimated that the natural fibers, among them, sisal, would contribute for the creation of about 250,000 new jobs.

Information is recognized as a key issue in the sustainable development of all agricultural and industrial sectors and it seems opportune to create an international information network for facilitating the exchange of information among the stakeholders of the sisal sector in order to keep them abreast with the technical, economic, social and environmental developments in producing and consuming countries. Availability of local technical support for the small producers is also an important requirement for the long term sustainability of the sisal sector.

Only the classification waste yields 10,000 ton/year, which could be used in composites. The main target for the final products developed from sisal will be the automotive industry for composites based on cellulose matrix and cement matrix for the civil engineering industry. Although other sectors later on can be targeted as well, such as the replacement of any part made of plastic in the electronics and appliances industries. In the case of the automotive industry there is a clear potential to use natural fibers in Brazil. The Brazilian industry is responsible for the biggest output on cars, trucks and buses in Latin America, which amounts to about 2 million cars per year. It can be

mentioned three car makers that are the leaders in the nature fibers applications in Brazil, these include: General Motors of Brazil (GMB), Mercedes Benz of Brazil (MBB) and Volkswagen of Brazil (VWB).

The Brazilian potential is about 40,000 ton/year, with an average of 20–23 kg/auto/yr. Considering that the cost of production is very low, Brazil can be the of the biggest supplier in the world for natural fiber composites. The possibility that other producing countries instead just sell fibers change their emphasis to sell added value products as well is very important.

One of the most involved companies in natural based composites is Mercedes Benz of Brazil (MBB). The company, in partnership with UNESP, developed the tests to demonstrate that the coir rubberized mats produce a seat in a shorter time and have seven times more resistance than the poly-urethane foam seats.

The other development was the application of natural fibers in external parts, mainly front sections for the trucks. Just for the auto C-Class (Mercedes), it was observed an increase of 27% in last year, accounting for a remarkable consumption of 23 kg/auto/yr. For the trucks, there is the model HSK LS 1938, which uses several parts, such as the internal engine cover, insulation for the engine, sun-blades, interior insulation and the most challenging the bumper, which is still under development. For the truck model HPN L 1622, the list of parts includes internal insulation; wheel box; roof; and back cover (under development). Only for the truck lines, MBB will consume about 200 ton/yr of natural fibers. The technology being employed is RTM (Resin Transfer Mounding) for the external parts and Non-Woven, Thermoforming and Vacuum Forming for interior parts.

In the case of VWB, the production scale is much larger. Only for one model, Gol, the demand is about 5 tons/day of dry fiber. The projections are to rise to 16 kg/auto/year in two years, accounting for 7,000 kg/year in 2005 and increasing for the following years. The market in Europe grows about 25%/year. The technology used is Non-Woven and Thermoforming.

The GMB is developing, through UNESP (São Paulo State University) a substitution program to replace 100% non-engineering plastics, with 50/50 plastics and natural fibers using the process of extrusion and injection mounding technology. There is a potential of about 320 parts listed by GMB as replaceable by the natural fiber based composites, basically short fibers. The approach is to get initially the parts where colour is not a problem as well as the surface and finishing of the parts. In this case, the homogeneity of the fibers is a key requirement. The other car markers are moving in this direction as well.

Ford Motor Company completed one of the biggest plants in the world in Bahia, with a political compromise to use sisal in its components. Fiat have been using natural fibers in its cars through its suppliers, mainly Rieter-Elo, Toro and Pematec, three of biggest auto part suppliers in the Brazilian market.

One the most attractive points to use natural fibers in the car industry is the fact that its parts are becoming lighter, about 20%, which will result in a large economy (100 kg account for 1 liter of fuel every 100 km). Another point is the matter of green carbon. In this case, the main competitor (glass fiber requires 54,8 MJ/kg to produce the material and the natural fiber only about 9,7 MJ/kg).

The automotive market for natural fibers is blooming but some requirements must be filled:

- High quality fibers;
- Homogeneity;
- Continuity of supply;
- Mechanical integrity through better decortication methods; and
- Consistent supply at high quantities.

Other strategies applied will be the development of composites based on cement matrix to replace asbestos fiber, which will be banned in the Brazilian market in 2005. It will use low alkalinity cement matrix such as gypsum and cement powder from blast furnace for the production of shingles, stabilized soil and sisal residues. These products present a Blast furnace slag mortar reinforced with strand fibers with a mechanical strength of 4 MPa (corresponding to 500 N load, with a ductility of $0.60\,\mathrm{kJ}\cdot\mathrm{m}^{-2}$). Other characteristics obtained are thermal comfort and durability.

The application of sisal in cement matrix composites is justified by the fact that:

- In low cost houses the price of the roof and sealing material is unproportionally high and can reach values up to 20% of the total construction price.
- The asbestos fiber will be banned in 2005 and there will be a large market, mainly in cellulose fibers.
- The needs to enchance the performance of fibrous materials, through optimization of its mechanical, physical, chemical and micro-structures in the composites.
- Use of residue materials, of low cost and reduction of the polluting sources of air, water and soil (green carbon).
- Possibility of application of sisal short fibers.

- Prioritization of regions in the country that produce fibers and areas with bigger deficit of houses and with high social interest.
- In Brazil only, there is a deficit of 12 million houses. This deficit is noticed in the other producing sisal countries.

The third main application for sisal based composites will be the geotextiles. The application areas of geotextiles are protection of river banks, slopes in the roads, preventing erosion, road construction in secondary ways and grass revegetation. The technical functions are the retention offiness with the tailor-made porometry (size of openings); separation of the soil surface from the armour overlay; prevention of development of differential pore-water over-pressure across the geotextile; durability depending upon chemical treatments in the fibers, from months up to 4 years. In this case the biodegradability is very convenient. The desired properties are a gramature ranging from 600 to 900 g/m^2, thickness of 3 mm, strength higher than 30 kn/m, elongation of 10% at maximum, water permeability of 20–40 $L/m^2/s$. However, tailor made mats can be made toward specific sites. The market in Brazil is fully untapped and could represent an excellent perspective for geotextiles.

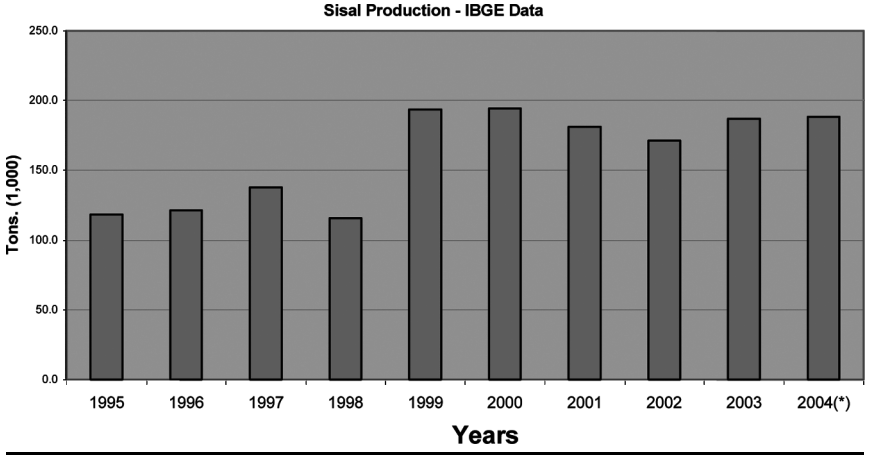
DISCUSSION

There is a markedly recovery of the sisal demand and consequently cultivation of sisal and other crop fibers in Northeast and Amazon regions. In 2005 there is a lack of leaves due to over-harvesting in 2004, related to a better agriculture prices (IBGE 2004), as can be observed by Table 1. The prices went from US$0.10/kg in 2003 to US$0.40/kg, which represents a significant income to the rural communities in the North (Amazon) and Northeast. The income rose from US$15/month to US$50/month based on the sisal crop.

CURAUA – *Ananas erectifolius* – is a hydrophylous species from the Amazon region. Its leaves are hard, erect and have flat surfaces. The leaves are about one meter long, or more, and 4 cm wide. The plant requires 2,000 mm or more of annual precipitation, preferring silil-humus soils, but also grows in clay-sillic soils. It is commonly used by the Indians as a favorite plant for fibers utilization for hammocks and fishing lines. Eight months old leaves can reach up 1.5 m in length, and 50–60 leaves per year. The dry fiber content in leaves is about 5–8%. It is considered the best natural fiber in the world [13].

Since the production of curauá is not enough to supply the automotive industry demand, other fibers are under utilization, mainly from the Amazon. Jute and malva are responsible to complete the demand.

TABLE 1 Sisal Production in Brazil

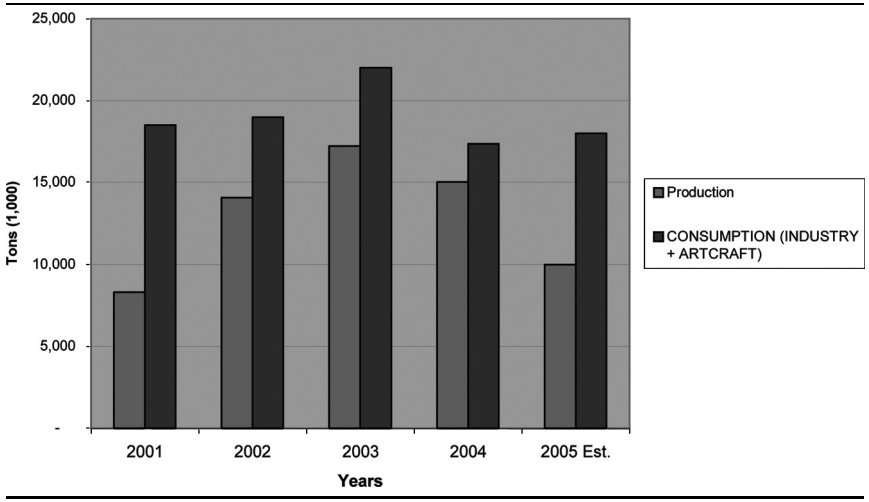


The region drought in 2004 have reduced the yield, but the increase in the cultivated area is noted (Table 2).

Therefore, more technological applications are a good option to make natural fibers to become more competitive:

- Higher quality (By definition MATERIAL means uniformity, homogeneity and replication, something that MUST be obtained from natural fibers based composites;

TABLE 2 Production and Demand for Malva and Jute



- Newer techniques specific for natural fibers such as feeders, extruders and injection molding;
- New machines for mats production giving low gramature and high uniform mats – The average machines in operation are very old and many are adaptations from other raw materials such as cotton;
- Environmental issues (Green Carbon, Rural Jobs, Recyclable, Renewable – The Carbon Relief Fund it is a powerful tool to increase the natural fibers applications;
- Social issues – poverty and drug relief crops in poor areas of Brazil, Colombia and other countries;
- Safety reasons in the car industry – The crash test must be favorable when compared to wood flour or other man-made materials;
- Specific niches for fibers according to its competitiveness;
- The natural fibers market represents only 1% of the polypropylene market (dumping) – probably it will be able to compete without any dumping practices;
- Political actions – standardization that will force the acquisition of natural fibers based product by the government – In any acquisitions bids the government will request some % of natural based products such as ropes, carpets, etc...;
- Active role in the standard organizations such as packaging, automotive engineers, etc... – not over establishing technical requirements, lowering limits or becoming adequate for the natural fibers;
- R&D – enhancement of mechanical and physical properties (mechanical stability, odor, impact, etc...) – odor is a key property to the auto industry and must be solved;
- New applications such as oil and heavy metals absorbents – selective absorbency;
- Reduce the overestimation of some properties such as impact resistance in the auto industry or packaging materials;
- Recyclability of parts made of natural fibers – the EU limits on incineration and consequently on application of natural fibers based parts; and
- Development of by products – it is very hard to be competitive with a raw material that only 4–6% is really used. The most part of sisal plant is discarded.

Natural fibers in motor vehicles is a tool transforming poverty into productivity, helping nature, creating jobs in poor regions, helping to conserve nature and, of course is also profitable – a perfect three-way contribution to sustainability. DaimlerChrysler has already shown how this approach can be successful in Brazil and South Africa [3].

CONCLUSIONS

The natural fibers tested showed a great potential for applications as reinforcement in composites based on polypropylene or used in cement matrix composites. Curauá was the best fiber among the tested with sisal in second place. Although these materials are subject to a number of material risks and uncertantities, such as government policies, market change, technological changes its role as a social tool toward development in economically deprived areas (e.g., Northeast of Brazil), is crucial, since reduce de rural exodus and brings an alternative to semi-arid regions. Short Fibers as sugar cane bagasse, coir and also can be used and grown in other regions of the country or even in the world. Recycled material (milk cartons) and other polyolefins are used in the composite matrix, favoring the greenness aspect of these composites.

Curaua is by far the best natural fiber for composites applications at the conditions tested at UNESP, but the others listed in this paper showed a quite similar behavior, indicating that price and availability will be the main aspect. The natural fibers tested showed a very high competitiveness with traditional materials, mainly wood and fiberglass based composites. The applications of the composites tested are ideal for sound insulation and non-structural parts for interiors in the automotive industry. Finally, natural fibers can be a business case for sustainability among other green materials and worldwide companies have moved in this direction [14].

SUMMARY

Brazil is the only country in South America to have an automotive supplier sector based on natural fibers. New opportunities are arising due to an increase demand by the car makers in applying natural fibers in their parts. Several crop fibers have been developed and grown in Brazil. Among them can be listed jute, malva, phormium, sisal, coir and mainly curauá, Other fibers of regional importance are used for handcracft and other small quantities applications, such as caroá, piaçava, pupunha, tucum, etc.... For the automotive industry, which requires large quantities with uniform quality, the alternatives are sisal (170,000 ton/yr), curauá (1,000 ton/yr in 2004), malva, 10,000 ton/yr, jute 12,0000 ton/yr and coir 15,000 ton/yr. The coir fibers are used only for rubberized mats in the car seat production lines (about 1,000 ton/yr). Brazil is the single largest producer country of sisal, the most cultivated fiber and that grows commercially curauá. For South America, the crop fiber alternatives are: fique in Colombia,

abaca in Ecuador, totora and puya in Bolivia and Peru, flax and phormium in Argentina, and curaua in Venezuela and Guiana. It must be understood by the target countries of drugs, that crop fiber can be an economic and social alternative to coca in the Andean region, therefore an instrument of land reform and drug reduction plantations. In Brazil, several automotive companies have a strong program of apply natural fibers based components in their products: Volkswagen do Brazil, Daimler Chrysler, General Motors do Brazil. Among their suppliers can be listed companies such Pematec (curauá), Toro (sisal, coir and jute), Incomar (sisal and jute), Ober (jute, curauá), Indaru (jute and sisal), Antolin (imported kenaf), Tapetes São Carlos (sisal, jute and coir), Poematec (coir and curauá) and Art-Gore, with their brand "Woodstock" (wood and natural fibers). Figures about production and demand and its social role in Brazil are discussed in the article.

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