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Research Article

Post-harvest Handling, Storage and Processing of Sisal (*Agave sisalana*) Fibres in the Hhohho District of Swaziland

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Abstract: The aim of this study was to establish the current practices and problems encountered in product development using sisal fibres with the view to explore the use of enzymes in releasing and softening the fibres. Associations making products of sisal fibres were identified in the Hhohho region of Swaziland and Participatory Rural Appraisal (PRA) tools and questionnaires were utilised in obtaining results for this study. Findings revealed that plant fibre production in the country was mainly done by unemployed rural women who used sisal plant leaves and employed crude decortication methods. The majority of the women (67%) were married, 48% were still highly productive as they were in between the ages of 16 and 35 years. About 31% of them were illiterate, with only 34% gone as far as primary education. The majority of the women (55%) were living on less than US $40.00/month which was too low considering the poverty datum line. A wide range of products were made and marketed abroad via an intermediate dealer. The study revealed that the women's efforts of making a living through handicraft were affected by the rough texture of sisal fibres, thus a need for research in modifying the texture of the fibres. The sisal project was found to be ecologically unsustainable because handcrafters relied on wild sisal and they lacked appropriate technology to increase productivity.

Keywords: *Agave sisalana*, decortication, livelihoods, natural dyes, plant fibres, rural women

INTRODUCTION

Fibres are elongated single-cell materials with tapering ends; they are basically units of matter characterized by flexibility, fineness and high ratio of length to thickness (Armstrong, 2010; Mwaikambo, 2006). They can also be chemically described as lignocellulosics, meaning that they are materials comprised primarily of cellulose, hemicellulose and lignin (Khalil *et al*., 2006; Reddy and Yang, 2005). Mwaikambo (2006) highlighted that cellulose was ubiquitous in the plant kingdom and that it was the commonest naturally occurring fibrous material. According to Madsen (2004) the exact structural organization of the chemical constituents of a plant fibre is a much debated subject; however, it is thought that hemicellulose polymers are bound to the cellulose micro fibrils by hydrogen bonds thus forming a layer around the cellulose fibrils and these cellulose/hemicellulose units are then enclosed by lignin polymers.

The use of naturally occurring plant fibres can be traced back to more than 10,000 years, as clothing made of flax fibres has been traced back to around 3000 B.C. (Mwaikambo, 2006). With such an increasing environmental awareness nowadays, natural plant fibres such as cotton, flax, hemp, etc., have lately received increased attention both industrially and scientifically (Han and Choi, 2010). The economic impact of natural fibre cultivation and beneficiation is well established and recognised as a key driver for sustainable growth through agricultural and industrial developments, particularly for developing nations (Anandjiwala, 2006).

Swaziland is facing a decline and non-reliability of rainfall which has subsequently lead to a decline in food production (Swaziland Annual Vulnerability Assessment and Analysis Report, 2009) and this decline in food production calls for alternative ways of ensuring food security. In fact there has been a decline in the production of the country's staple cereal, maize (*Zea mays*) over the years due to climate change (Oseni and Masarirambi, 2011). This coupled with rising world food prices and inflationary pressure (Ferreira *et al*., 2013) makes the food security situation precarious (Hinrichs, 2013). The plant fibre industry plays a

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notable role in alleviating a precarious food security situation; however the industry has not yet reached its maximum potential. Plant fibre production is mostly for the handicraft industry which is largely operated by unemployed rural women, who make and sell their products locally, in the region, or to export agents (intermediate dealers) that sell the products to America, Europe and Asia (Zwane and Masarirambi, 2009). Local handcrafters heavily rely on sisal fibres, however, as highlighted by Zwane and Cloud (2006) sisal fibres are believed to be brittle and have poor wearable properties, which in turn call for research in improving them.

There are many plants known to produce fibres and they include, flax, jute, kenaf hemp, cotton and sisal among others (Mwaikambo and Ansell, 1999; Akin *et al*., 2000; Foulk *et al*., 2002; Anandjiwala, 2006). In this study, *Agave sisalana* was studied because it was the main plant being used by the handcrafters. This plant belongs to the family of Agavaceae, a family described by Bogler *et al.* (2005) and Debnath *et al*. (2010) as a family of rossete-forming and often spiny plants centered in warm and dry areas of Mexico, the south-western USA and Caribbean basin. *A. sisalana* leaves are fleshy, finely fibrous and smooth with margins of mature leaves usually toothless while young ones have few minute teeth (Gentry, 1982). Sisal plant produces a 5-6 m inflorescence at about seven years of age, which can be delayed to 15-20 years by continued harvesting (Brown, 2002). Fibres are extracted from the plant leaves and harvesting, according to Brown (2002), can be done after two years of age and each plant produces about 220 leaves before bolting.

Extraction of fibres from *A. sisalana* leaves can be done mechanically by using rudimentary tools such as tin cans, floor polish container lids, aluminium containers and any other steel or metal materials or it can be modified and extracted faster by the use of a machine decorticator (Boguslavsky *et al*., 2007). Alternatively fibre extraction can be done chemically, in which case acids, alkalis and enzymes are used. Enzymatic extraction has not gained popularity in industries of developing countries, despite being eco-friendly (Anandjiwala, 2006). Enzymatic processing degrades the lignocellulosic complex in fibre swelling, lower the degree of polymerization and make fibres more pliable and softer (Zwane, 1997). For enzymatic fibre extraction, a combination of enzymes such as pectinases, hemicellulases and cellulases are generally used with a pre- or post-chemical treatment (Reddy and Yang, 2005).

The purpose of this study was to establish the current practices and problems encountered in the product development using plant fibres with the future view of exploring the use of enzymatic treatment of the plant fibres (*Agave sisalana*) for the development of environmentally friendly products. Attempts were made in this study to identify associations making products out of plant fibres in the Hhohho region of Swaziland, to determine the current practices and in product development, dye plants used and challenges encountered by the plant fibre processors.

METHODOLOGY

Study area: This study was done in Mayiwane and Gunwane. Both areas are found in the Upper Middleveld of Swaziland in the Northern part of the Hhohho region. Geographically, Mayiwane lies at 31°31'1" East of the Greenwich Meridian, 25°51'4" South of the equator and 462 m above sea level, while Gunwane lies at 31°20'48" East of the Greenwich Meridian, 25°52'46" South of the equator and 528 m above sea level. The two sites were selected because they were the identified handicraft associations in the Northern part of the country. Mayiwane and Gunwane were found to have soils that were suitable for the cultivation of *A. sisalana*, as sisal according to Nobel (1994) grows best on free-draining non-saline soils.

These two areas received an average annual rainfall that ranges between 800 and 1000 mm (Loffler and Loffler, 2005), which again is suitable for the growth of sisal as its optimum rainfall requirement falls around 1000 mm per annum (Lock, 1962). Mean temperatures in the Upper Middleveld are between 15°C (winter) and 24°C (summer). Both research areas are found in rural areas and like in many other rural areas in the country, the majority of the population is not employed but depends mostly on subsistence agriculture for food production. Mostly they grow maize which performs well and also sweet potatoes. Most of the households in these areas are taken care of by women, as their husbands go to search for jobs in urban areas or mines in neighboring country, South Africa (Loffler and Loffler, 2005).

Research design: There are two main methods of doing research, the quantitative and the qualitative. The main research method used in this study was the qualitative method. The choice of this method was influenced by the nature of the topic and the main objectives of the study. The interviewees included every individual who was a member of the associations. Additionally ex-members were also included here and treated as members to get reasons why they decided to leave the project.

Data collection: Data were collected using Participatory Rural Appraisal (PRA) techniques (Anyaegbunam *et al*., 2004). According to Alam and Ihsan (2012) PRA is a short-cut method of data collection, whereby information is owned and shared by local people with the help of outsiders (professionals) who go to the rural areas to facilitate rural people in collection, analysis and presentation of information. A

team of researchers started with key informants, whereby people who were known to be involved in sisal decortication and handcraft development were initially visited.

Findings from the key informants and community visits were then used in the development of a questionnaire which was then validated by three experts in Social Sciences and Agriculture Faculties of the University of Swaziland. A consent form was also developed to be used for introducing the research and asking the respondents to give information freely and without any coercion.

The population of women, from the communities and belonging to the association of producing sisal products was used in this study. Upon arrival the team read the consent form and asked the women if they were willing to participate in the filling of the questionnaires. The respondents were given the questionnaires and they responded with the help of the data collectors as some of them were relatively less educated.

Data analysis and presentation: The data collected were analysed using descriptive statistics with Statistical Package for the Social Sciences (SPSS) (SPSS, 2008) software package, officially named IBM SPSS Statistics. Responses from the respondents were analysed with the use of frequency counts and also percentages. The analysed data were then presented using graphical techniques such as bar charts and frequency tables depending on the nature of the data.

RESULTS AND DISCUSSION

Demographic information: There were 52 respondents interviewed in this study. It was found that sisal fibre production was mostly done by females as 51% of the respondent were female and 64% of them were married while 15% were widowed, 15% were single (Table 1). The cottage fibre industry has previously been reported to be dominated by women (Compton, 1976; Dlamini and Rycroft, 1981). However some men were also involved in various fibre handling, processing and storage phases.

The majority of the women were still in the productive range as 27% of them were between the ages of 26-35 years, 23% were between ages of 36-45 years, about 14% were between ages of 46-55 years and about 14% were over 56 years (Table 2). About 20 % were below 25 years of age.

Literacy rate: The study showed that about 31% of the respondents did not get any formal education, with 34.6% going to as far as primary education and 34.6% obtaining a secondary education (Table 3). It was also noted that most of those who received secondary education dropped at lower secondary.

As far as employment was concerned it was found that 54% of the women were unemployed, 34% doing household work and only 6% employed. Most of the women (37%) were making a living with a monthly income of less than $40 (Table 4) meaning that they lived on less than $1.50/day which is below the UN poverty datum line. However, there was a small portion (4%) of the respondents who were living on an income of over $130/month. Seventeen per cent of the respondents did not respond to this question, probably because they were ashamed or they were thinking that they might lose donations after disclosing their income.

In Swaziland, it is believed that if you own livestock, especially cattle and goats, you are considered a rich person. Our findings showed that most of the households did not have cattle and goats, as reflected in 57% of the households did not have cattle while 63% did not have goats (Table 5). About 32% of the respondent households only had between 1-10 of both cattle and goats and 3% had between 11-20 of

Table 1: Marital status of respondents

Marital status of respondent	Frequency	Percentage (%)	Cumulative percentage
Single	8	15	15
Married	33	64	79
Widowed	8	15	94
Separated	1	2	96
Cohabiting	2	4	100
Total	52	100	

Table 2: Age of respondents

Age of respondent (years)	Frequency	Percentage (%)	Cumulative percentage
25 and below	12	23	23
26-35	14	27	50
36-45	12	23	73
46-55	7	13.5	86.5
Over 55	7	13.5	100
Total	52	100.0	

Table 3: Literacy rate of the respondents

Education status of respondent	Frequency	Percentage (%)	Cumulative percentage
Primary education	18	34.6	34.6
Secondary/High school education	18	34.6	69.2
No formal education	16	30.8	100.0
Total	52	100.0	

Table 4: Monthly income of respondents

Monthly income (USD)	Frequency	Percentage (%)	Cumulative percentage
40 and below	19	37	37
41-70	10	19	56
71-100	5	10	66
101-130	7	13	79
Over 130	2	4	83
No response	9	17	100
Total	52	100	

Table 5: Livestock owned by respondents

	Households keeping livestock (%)		
Number of each livestock	Cattle	Goats	Chickens
0	57	63	16
1-10	33	31	42
11-20	2	4	25
Over 20	8	2	17

Fig. 1: The crude extraction tool (spade) and a man using the tool for fibre extraction

Fig. 2: Pictures showing sisal fibres being dried inside a house and under shelter to avoid change of colour

both cattle and goats. A small portion (8%) of the households was considered rich, because they had over 20 cattle. The livelihood asset that was found to be in abundance was chicken. Most of the respondents kept them, with an exception of 16% of the households. Seventeen per cent of the respondents' households had over 20 chickens (Table 5).

Fibre extraction: It was found that all the women were only using sisal (*Agave sisalana*) as their fibre production plant, they did not know century plant (*Agave americana*), even those who knew the plant did not know if it produced fibres. However Zwane *et al*. (2011) previously reported that the century plant (*Agave americana*) presented the greatest opportunity whereby it could be used in various ways including the fibre industry leading to subsequent attainment of food security in Swaziland. They obtained the sisal from nearby abandoned homesteads and they used the leaves to extract fibres. The extraction was through the use of crude decortication methods, which were time consuming and exposed them to sisal juice which caused serious itching upon contact with skin (Fig. 1).

All the respondents reported that it took one week maximum storage time before extraction, after which extraction became hard as sisal started drying out. After extraction the respondents said they dried the fibres

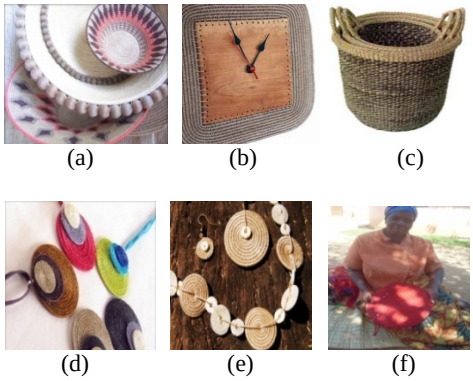

Fig. 3: Products made by respondents, a) sisal bowls, b) wall watch made of sisal and wood, c) Sisal baskets, d) and e) sisal jewelry (earrings and necklaces) and f) one of the respondents making a table mat

inside the house or under shelter as it got spoiled by direct sunlight (Fig. 2). They responded that extended storage of sisal fibres resulted in spoilage where the sisal lost its whiteness to cream white to reddish in colour due to possible fungal infection.

Dyes and dyeing: In terms of dyes and dyeing we found that about 76% of the respondents did not dye their fibres while 24% dyed. Of the 24% who dyed fibres, 33% used synthetic (commercial) dyes, 17% used natural dyes while 50% used both natural and synthetic dyes. Some of the plants which were used for dyeing sisal fibres are shown in Table 6. Similar plants from which natural dyes were extracted were reported previously (Ngubane and Khoza, 1996; Khoza and Ngubane, 1996). Natural dyes should be preferred in this day and age when planet earth is threatened with potentially irreversible climate change. Swaziland is relatively very rich in biodiversity including diverse flora and fauna.

It was also found that the sisal fibres processors were also using tea (*Camellia sinensis*) to dye fibres, which gave a khakhi colour to the dyed product.

Products made of sisal fibres: It was found that many products were made from sisal fibres and that products ranged from door mats, table mats, sleeping mats, cordage, dishes and bowls, baskets and washing baskets, wall watches up to a wide range of jewelry (necklaces, ear rings, bracelets, etc) (Fig. 3).

Table 6: Plants used to produce natural dyes

Botanical name	siSwati name	Common name	Part of plant used	Colour of dye
Allium cepa	*Anyanisi*	Onion	Leaves	Khakhi-brown
Berchemia zeyheri	*Umneyi*	Pink ivory	Bark	Pink
Bidens pilosa	*Chuchuza*	Blackjack	Leaves	Yellow-green
Calpunia aurea	*Umphendvulo*	Wild laburnum	Leaves	Brown
Searsia dentate	*Inhlangushane*	Rhus	Fruits	Yellow
Schotia brachypetala	*Vovovo*	Weeping boerbean	Bark/Roots	Yellow
Sclerocarya birrea	*Umganu*	Marula	Bark	Red
Szyzygium cordatum	*Umcozi*	Water berry	Bark/Fruit	Purple
Terminalia sericea	*Umhonono*	Silver cluster-leaf	Bark	Lime
Trichilia emitica	*Umkhuhlu*	Natal mahogany	Bark	Brown

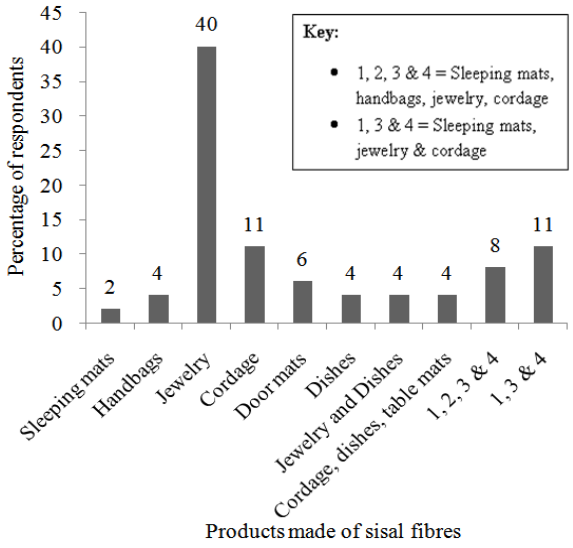

Fig. 4: Products made by respondents

It was found that of all the products, a bigger portion of the woman, 40% made jewelry and 4% made hand bags which meant they were greatly affected by the coarse nature and harshness of sisal fibres because these products need to be soft (Fig. 4). We also found that some women had skills of making more than one product, 11% made sleeping mats, jewelry and cordage while 80% made sleeping mats, hand bags, jewelry and cordage.

Marketing of products: In terms of marketing and market opportunities it was found that, all the women were selling their products to an intermediate dealer, a monopoly that negatively impacted their efforts of making relatively more money. As a result 62% of them were unsatisfied with the returns they got from their work. However, 72% of the women said the project had improved their household food security and some even reported that they educated their children from the money they got from the sisal project. Almost all of them were found to be making the products for trade purposes mostly yet they also needed them for their domestic uses. One of the two associations interviewed was more organized, had scheduled meetings and a working hall, while the other one worked under a tree. There is need for vigorous market research locally, regionally and internationally. A potentially very big market exists on the African continent. However it is important to approach the markets in Africa with caution because they have been reported not to be homogenous (Gbadamosi, 2013). Aggressive advertising of the fibre products may be part of the solution. Advertising is a critical element of business conduct affecting consumer valuation of promoted goods, market structure, firm profitability and social welfare (Giannakas *et al*., 2012).

Challenges faced by respondents: This study found the following challenges that were encountered by the sisal fibre producers:

- The industry was ecologically unsustainable because women relied on wild raw material (sisal), meaning it can be limited at any time if the industry was to expanded due to raw material shortage.
- Lack of technical knowhow of women in product development as the intermediate dealer only trained them in what was wanted at any particular time.
- Lack of appropriate technology for decortications to increase productivity of fibres.
- Constraints in terms of limited market opportunities, as the intermediate dealer wanted the women to sell their products to their company only.

CONCLUSION

It was found that the women involved in sisal fibre production were doing a great job in providing food security to their households and educating their children. It was observed that in worst case scenarios, even those women who were married, their husbands were not employed and thus depended on the sisal fibre home industry. Achieving greater equity in agriculture requires investment to bring modern technology and education to rural areas. The women's efforts of making a living through handicraft production were affected by the rough texture of sisal fibres; so there was a need to take the project further to bio-processing of the fibres, thus modifying fibre texture. The respondents' fibre storage methods, business conduct and knowledge of laws on natural products were poor. Therefore, it was observed that there was need for financial and training support from government and Non-Governmental Organizations (NGOs) to expand their industry so as to be able to supply bigger companies which will compete for their products. The export market remains a big untapped market with a great potential.

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