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ANALYSIS OF DIMENSIONAL AND DERIVED PROPERTIES OF SISAL LEAVES FIBER *(agave sisalana)* FOR COMPOSITES APPLICATION IN AUTOMOBILE ENGINEERING

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ABSTRACT

The fiber extracted from sisal (agave sisalana) leaves was studied for its dimensional and derived properties which aimed at evaluating the characteristic of fiber quality in relation to its application in automobile engineering. The dimensional properties evaluated were fiber diameter, which was found to range between (1.933um to 2.50um). Lumen width ranged between (1.00um to 1.50um), from wall thickness of (0.50um). Derived

INTRODUCTION

The importance of increasing wood consumption and raw materials availability for the paper industries have resulted in a renewed attention on the benefits inherent in several non-wood fiber plant with annual or biannual harvest(Jorge, *et al.,* 2011). Owing to their mechanical properties, good thermal insulation properties, low density, nonabrasive nature, easy availability from replenish able sources, cheaper prices and recyclability of natural fiber reinforced polymer composites have attracted the composite industry, both for structural and nonstructural applications. Glass fibers being non-degradable pose serious health and environment hazards. They can't be easily thermally recycled as they melt at very high temperatures and remain as a residue which can damage the furnace and are quite abrasive in nature. However the main focus of this review is to realize the potential of some unique natural fibers as a replacement for glass fibers, a key component in the automobile and structural composites.

properties computed includes runkle ratio, which was found to be within (0.867 to 1.784), slenderness ratio (106.3 to 128.3), and coefficient of flexibility of (56.01 to 74.55). Data obtained were subjected to statistical analysis and graphs were plotted using Matlab R2007b. Statistical package for social sciences (SPSS) was used to determine the significant different means, and the (ANOVA) tables were constructed from which observations and conclusions were made. The result shows that the fiber possess the high quality characteristic of tensile strength, density as well as moisture absorbency when compared with other leaves fiber of its category. Therefore, it is recommended for different applications in automobile industry such as car interior, bumpers, brake parts and others lining materials.

Keywords; Analysis, Dimensional and derived properties, Sisal leaves fiber, Composites application, Automobile engineering.

According to WHO Geneva (1998), apart from ropes, twines, and general cordage, sisal is used in low-cost and specialty paper, dartboards, buffing cloth, filters, geotextiles, mattresses, carpets, handicrafts, wire rope cores, and Macramé. Sisal has been utilized as an environmentally friendly strengthening agent to replace asbestos and fiber glass in composite materials in various uses including the automobile industry. The lower-grade fiber is processed by the paper industry because of its high content of cellulose and hemicelluloses. The medium-grade fiber is used in the cordage industry for making ropes, baler and binder twine. Ropes and twines are widely employed for marine, agricultural, and general industrial use. The higher-grade fiber after treatment is converted into yarns and used by the carpet industry. Other products developed from sisal fiber include spa products, cat scratching posts, lumbar support belts, rugs, slippers, cloths, and disc buffers. Sisal wall covering meets the abrasion and tearing resistance standards of the American Society for Testing and Materials and of the National Fire Protection Association. As extraction of fiber uses only a small percentage of the plant, some attempts to improve economic viability have focused on utilizing the waste material for production of biogas, for stock feed, or the extraction of pharmaceutical materials.

MATERIALS AND METHODS

Materials

The experiments was carried out in Biological department of Adamawa State University Mubi and the materials used were; Sisal (*agave sisalana)* leaves obtained locally in Digil, government reserved forest area, Mubi North local Government Area of Adamawa State, sisal fibre from the leave, NaoH, H_2SO4, potassium Sulphate, Safranin red, potassium chromate, HCl, HNO3, distilled water and water. Tools and equipment used was electronic oven dryer M/C NO.11/084 Mod., **M**otic electric microscope, weighing balance, veneer caliper, sharp knife, water bath and camera.

Methods

Dimensional analysis of the fibers

In accordance with Ververis *et al.,* (2004), Sharma *et al.,* (2011), for fiber length dimension, small silver was obtained and macerate with 10ml of 67% HNO3 and boil in a water bath (100$\pm$2°C) for 10minutes. The silvers were then washed and placed in a small flask with 50ml distilled water and the fiber bundles were separated into individual fiber using a small brush with a plastic end to avoid fiber breaking. The macerated fiber suspension was finally placed on a glass slide (7.5cm X 2.5cm) by means of a rubber pepette. For the fiber diameter, fiber lumen width and fiber cell wall thickness determination, cross sections was obtained from the same height as mentioned above and was stained with 1:1 aniline sulphite –glycerine /safranin red mixture to enhance cell wall visibility. Sisal fiber cell was viewed under calibrated motic electric microscope on ×10 objective lence.

Computation of fiber derived properties

The derived properties of sisal fiber were calculated at matured leaves stage using the measured fiber dimensional analysis as reported in Saikia *et al.,* (1997).

Coefficient of flexibility (c) = $\frac{Flw}{Fd} \times 100$ 1

Runkel ratio (r) = $\frac{2Fwt}{Flw}$ 2

Slenderness ratio (z) = $\frac{Fl}{Fd}$ 3

Where;
Flw = fiber lumen width (μm)
Fd = fiber diameter (μm)
Fwt fiber wall thickness (μm)
Fl = fiber length (μm)

Determination of the fiber Moisture absorption (Regain)

American society for testing and material (1997) standard testing method for moisture regain as reported by Brindha *et al.,* (2013) was adapted to determine moisture absorption of sisal fiber at matured stage. Sisal fiber samples were conditioned for 24hours at 27 $\pm$ 2°C and the weight to be taken as (L). The conditioned fiber sample was oven dried at temperature of 105°C for 4hrs and the weight was taken as (W). Moisture absorption percentage of the sample was calculated according to equation 3.4 below;

$$\text{Moisture Absorption \%} = \frac{L-W}{L} \times 100 \quad (4)$$

Determination of the Fiber Density

Technical Association of Pulp and Paper Industries (TAPPI) standard method was adopted as reported in Modibbo *et al.,* (2009). The density plant fiber at matured stage was determined by conditioning the fiber sample for 24hrs at 25°C before the test was carried. 2g of the sample was accurately weighed out for each fiber sample. The weight was immersed in toluene in a calibrated glass tube (30ml measuring cylinder) and volume of toluene displaced was determined and equal to the volume of sisal fiber immersed. The density of the fiber sample was calculated as follows;

$$\text{Density} = \frac{Mass\ of\ fibre}{Volume\ of\ fibre}\ in\ gcm-3 \quad (5)$$

RESULTS AND DISCUSSIONS

Results

The results of the analysis for dimensional and derived properties of sisal fiber were tabulated and discussed:

Table 1. **ANALYSIS OF FIBRE DIMENSIONAL PROPERTIES**

S/N	NO. of Replicates	FIBRE Length FL (µm)	FIBRE Diameter FD (µm)	FIBRE Lumen Width FLW (µm)	FIBRE Wall Thickness FWT (µm)
1	R_1	153.0	2	1	0.5
	R_2		2.5	1.8	0.5
	R_3		2	1	0.5
2	R_1	190.0	2	1	0.5
	R_2		2	1	0.5
	R_3		2	1	0.5
3	R_1	243.3	2	1	0.5
	R_2		2.3	1.2	0.5
	R_3		1.8	1	0.5
4	R_1	265.3	2.5	1	0.5
	R_2		1.5	1	0.5
	R_3		1.8	1	0.5

5	R_1	316.7	2	1	0.5
	R_2		3	2	0.5
	R_3		2.5	1.5	0.5

*R_1 R_2 R_3 Are Replicates Source: (Field Survey 2022)

Fiber diameter; The mean values of fiber diameter at different stages of fiber length as in Table 1 were 2.167μm, 2.00μm, 2.033μm, 1.933μm, and 2.50μm for the length of 153.0μm, 190.0μm, 243.3μm, 265.3 μm and 316.7μm respectively. The diameter at all stages of length evaluated were higher than that of corn husk fiber (Taiwo *et al.,* 2004). The result in figure 1 shows that the diameter increases with an increase in fiber length, and cellulose content also increase. This is nearly in agreement with the report of Sahin and Young, (2008) that, the chemical solution used to determined cellulose influence the percentage of cellulose content in plant fibers, and high percentage of cellulose in plant fiber produces fiber with lower diameter in micron. The analysis of variance test indicate that diameter investigated at stages of length were highly significant at p=0.05 level, table 2. And the coefficient of determinant evaluated were found to be R^2=0.90.

Table 2. Analysis of variance for fiber diameter:

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4567.484	4567.484	2.467667	0.256805
Residual	2	3701.864	1850.932		
Total	3	8269.348			

Fiber lumen width; The mean values of fiber lumen width of *agave sisalana* leave fiber evaluated at different stages of fiber length as in Table 5, were 1.267μm, 1.00μm, 1.067μm, 1.00μm and 1.50μm for the length of 153.0μm, 190.0μm, 243.3μm, 265.3μm and 316.7μm respectively. The result in Table 5 shows that, in all stages of fiber length investigated the lumen with was lower than that of rice husk fiber and wheat straw fiber Agu *et al.,* (2002). This is also lower than that of corn husk which has short fibers similar to various hard woods, whose length is <2mm, fiber diameter (21.89±5.1μm), lumen width (6.63±3.5μm) and cell wall thickness (7.63±2.3μm) Taiwo *et al.,* (2004). This is in contrast with the result reported by Sharma *et al.,* (2011) that, lager fiber lumen width produces better in beating of the pulp due to penetration of the liquid in fiber lumen, but in agreement with the report of Ogbonnaya *et al.,* (1997) that, fiber length, lumen width and wall thickness were not enough to justify the strength of the papers produced from the plant fibers. The analysis of variance test indicates that the values of fiber lumen width evaluated at all stages of length were significant at p=0.05 level, table 3. And the coefficient of determinant evaluated were found to be R^2=0.93.

***Table 3*: Analysis of variance for fiber lumen width**

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	5424.382	5424.3822	3.81332	0.1900849
Residual	2	2844.965	1422.4826		
Total	3	8269.348			

Fiber wall thickness; The mean values of fiber wall thickness of *agave sisalana* leave fiber evaluated at different stages of fiber length were the same at all stages investigated as 0.50±0.333 for length of 153.0µm, 190.0 µm, 243.3µm 265.3µm and 365.7µm respectively. The result in all cases were higher than that of castor plant fiber and cotton fiber (Maduako *et al.*, 2011), but lower than bambusa tulda (Sharma *et al.,* 2011). Istek, (2006) reported earlier that cell wall thickness governs the fiber flexibility, and thick walled fiber affect the bursting strength and folding endurance of the paper produced from the fiber. The analysis of variance test indicates that, the fiber wall thickness were not significantly different from each other for all stages investigated at p=0.05 level, table 4. And the coefficient of determinant evaluated was found to be not applicable at all stages investigated.

***Table 4*: Analysis of variance for fiber wall thickness**

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0	0	0	1
Residual	3	8269.348	2756.449		
Total	4	8269.348			

Table 5. MEAN VALUES AND STANDARD DEVIATIONS

Fiber Length FL (µm)	Fiber Diameter FD (µm)	Fiber Lumen Width FLN (µm)	Fiber Wall Thickness FWT (µm)
153.0	2.167 ± 1.444	1.267 ± 0.844	0.50 ± 0.333
190.0	2.00 ± 1.333	1.00 ± 0.667	0.50 ± 0.333
243.3	2.033 ± 1.356	1.067 ± 0.711	0.50 ± 0.333
265.3	1.933 ± 1.289	1.00 ± 0.667	0.50 ± 0.333
316.7	2.50 ± 1.667	1.50 ± 1.00	0.50 ± 0.333

Source: (Field Survey 2022)

Runkle ratio; The values of runkle ratio of extracted *agave sisalana* leave fiber at different stages of fiber length were found to be 0.867, 0.897, 1.040, 1.250 and 1.874 for the length of 153.0µm, 190.0µm, 243.3µm, 265.3µm and 316.7µm respectively. This is in agreement with Yang and Saheh, (1998) and Dutt, *et al.,* (2009), that, investigated on the fiber quality related to runkle ratio and reported that, fiber with runkle ratio less than 1 are good for paper making because they are more flexible, collapse easily and form a paper with large bonded area while fiber with runkle ratio more than 1 are stiff, difficult to collapse and form bulkier paper with less bonded area. It was observed that, from the result, the runkle ratio was slightly increase with increase in length of the fiber. And the coefficient of determinant R^2 =0.99.

Slenderness ratio; The mean values of slenderness ratio of extracted *agave sisalana* leave fiber at different stages of fiber length were found to be 106.3, 110.9, 112.4, 120.1 and 128.3 for 153.0µm, 190.0µm, 243.3µm, 265.3µm and 316.7µm respectively. This is higher than corn husk (Taiwo *et al.,* 2014). The result pointed out that *agave sisalana* leaves fiber have excellent slenderness ratio of greater than (>70) due to long length and thin cells of fiber. The slenderness ratio of fiber depends on length and diameter, short and thick fiber do not have good surface contact and fiber bonding (Obonnaya *et al.,* 1997). Maduoko, (2011) pointed out that, the higher the slenderness ratio, the stronger the resistant of tearing paper sheet. It has been observed that the slenderness ratio were ranged between 106.3 to128.3 in all stages of length investigated, and this is in line with the standard of technical association of pulp and paper industries (TAPPI, 1980). Also, in agreement with Xu *et al.,* (2006) that, the slenderness ratio of more than 33 for fibrous materials are considered good for pulp and paper production. And the coefficient of determinant evaluated were found to R^2=0.96.

Coefficient of flexibility; The computed values of coefficient of flexibility of the extracted *agave sisalana* leave fiber at different stages of fiber length were found to be 56.01, 59.04, 62.35, 72.72 and 74.55 for 153.0µm, 190.0µm, 243.3µm, 265.3µm and 316.7µm respectively. The values at all stages of length were higher than cotton fiber (Maduako, *et al.,* 2001). The values also fall within the standard rating of elastic fibers in accordance with Ogbonnaya *et al.,* (1997), and Namessan, (2008) who earlier pointed out that, flexibility coefficient of fiber makes fiber processing easy without breakage, and the fiber with low coefficient of flexibility will have negative effect on the tensile and bursting strength as well as folding endurance. It has been observed that fiber at all stages of evaluated were highly flexible and satisfies the requirement for suitability in pulp and paper making. This is in agreement with Bektas *et al.,* (1999) that, reported earlier that, there are four (4) groups of fiber; High elasticity fiber having coefficient of flexibility >75, elasticity fiber with coefficient between 50-75, rigid fiber between 30-50 and high rigid fiber with <30, in accordance with elasticity rating. Rigid fibers do not have efficient elasticity, therefore unsuitable for paper production, but suitable for fiber plates, rigid cardboards production as well as automobile interior parts. It has been observed from the result the coefficient of flexibility of *agave sisalana* leaves extracted fiber increases with increase in length of the fiber. And the coefficient of determinant were found to be R^2=0.89.

Table 6. ANALYSIS OF OTHER PHYSICAL PROPERTIES

1	**153.0**	**R_1**	**3.0**	**0.667**
		R_2	**2.5**	**0.669**
		R_3	**3.5**	**0.665**
2	190.0	R_1	4.0	0.703
		R_2	3.9	0.668
		R_3	2.1	0.501
3	243.3	R_1	3.9	0.669
		R_2	2.6	0.603
		R_3	2.5	0.591
4	265.3	R_1	3.0	0.665
		R_2	2.7	0.612
		R_3	3.8	0.664
5	316.7	R_1	4.0	0.740
		R_2	3.2	0.660
		R_3	2.2	0.431

*R_1 R_2 R_3 Are NO. Of replicates Source: (Hussaini *et al.,* 2018)

Moisture absorption; The mean values of moisture absorption evaluated at different stages of fiber length presented in Table 6, were 3.0%, 3.0%, 3.0%, 3.2% and 3.1 for length of 153.0μm, 190.0μm, 243.0μm, 265.3μm and 316.7μm respectively. It was observed that the moisture absorption at all stages investigated were lower than cotton fiber (Naveen *et al.,* 2014), flax (Brindha, *et al.,* 2013), and *Agave Americana* with moisture absorption ranged between 8-9% (Ashish *et al.,* 2015). This is in agreement with the report of (Saheb, 1999) that, fiber with low moisture absorption capacity will be suited for different application as composite due to its moisture resistance. And the coefficient of determinant evaluated were found to be R^2=0.60.
Density; The density values measured at different stages of length were 0.667g/cm^2, 0.654g/cm^2, 0.621g/cm^2, 0.647g/cm^2 and 0.610g/cm^2 for length of 153.0μm, 190.0μm, 243.0μm, 265.3μm and 316.7μm respectively. The result revealed that the density of sisal fiber ranged between 0.610 ±0.407 to 0.667±0.445, which is lower than that of jute, kenaf, okra and baobab (Modibbo *et al.,* 2009). The results are in agreement with the studies investigated on natural fibers by (Pai, *et al.,* 2015) and reported that, good quality natural fibers most possess good thermal insulation properties, low density, noon abrasive nature, easily available from replenish able sources, recyclable in nature and sustained good application as composite for structural and non-structural applications. It was observed that from the result that fiber density decrease with an increase in fiber length. And the coefficient of determinant evaluated were found to be R^2=0.75.

MEAN VALUES AND STANDARD DEVIATIONS

FIBRE LENGTH	Mean Moisture absorption (%)	Mean Density g/cm^3
153.0	3.0 ± 2.000	0.667 ± 0.445
190.0	3.0 ± 2.000	0.654 ± 0.436
243.0	3.0 ± 2.000	0.621 ± 0.414
265.3	3.167 ± 2.111	0.647 ± 0.431
316.7	3.133 ± 2.089	0.610 ± 0.407

Source: (Field Survey 2022)

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Agave sisalana leaves fiber extracted from the leaves obtained locally from Maiha L.G.A of Adamawa state, were studied for its characterization for engineering application. The fiber was extracted using water retting procedure and treated with alkaline (NaOH).
The following conclusions were drawn;
The dimensional properties evaluated were fiber diameter, which was found to range between (1.933um to 2.50um). Lumen width ranged between (1.00um to 1.50um), from wall thickness of (0.50um). Derived properties computed includes runkle ratio, which was found to be within (0.867 to 1.784), slenderness ratio (106.3 to 128.3), and coefficient of flexibility of (56.01 to 74.55). The fiber runkle ratio in some stages of length (153.0 and 190.0) were less than one (<1) while slenderness ratio in all stages of fiber length were greater than seventy (>70) which is considered good for paper production. It was found that the fiber has moisture absorption of 3.1 % and the density of 0.64 g/cm^3, this can be used in many applications due to its moisture resistance ability. The results obtained shows that the fiber exhibit high tensile strength and can be used in the production of nets, brake part, interior gaskets, carpets, rugs, door mats and other woven objects.

Recommendations

Based on this study conducted for dimensional and derived properties of sisal hemp (*agave sisalana*) leaves fiber at different stages of fiber length and thickness, the following recommendations were made;

1. Large scale production of sisal plants should be encouraged to replace the imported fibers and save the country from foreign exchange.
2. It was recommended for lining materials in automobile parts due to its low moisture content and density.
3. The dimensional properties evaluated were fiber diameter, which was found to range between (1.933um to 2.50um). Lumen width ranged between (1.00um to 1.50um), from wall thickness of (0.50um) fall within the range requirements for constructions of insulating parts in aero planes and some automobile engines. Therefore, it is recommended for industries.

4. Further studies on thermal properties of (*agave sisalana)* leaves fiber should be carried out to suit its ability in other applications in thermoplastic in electrical and civil engineering works.

REFERENCES

Agu, C. V., Njoku, O. U, Chilaka, F.C, Okorie, S. A and Agbiogwu, D. (2012). Physico- chemical characterization of Lignocelluloses fibre from Ampelocissus cavicaulis. (Electronic Version). *International Journal of Basic and Applied Science Vol. 12(3) PP. 68-77.*

Ashish, H., Kadole, P. and Pooja, K. (2015). Agave Americana leaves fibers. Open access fiber journal, vol. 3, 64-75. ISSN 2079-6439, www.mdpi.com/journal/fiber.

Bektas, I., Tatus, A. and Eroglu H. (1999). A study of the suitability of calabrian pine (pinus bruliaten) for pulp and paper manufacturing Turkish. Journal of Agriculture Vol. 23; 589-601.

Brindha, D., Vinodhini, S. and Alarmelumangai, K. (2013), Extraction and characterization of fibre from tree plants species of the genus cleome L. (Electronic version). *Asian Journal of experimental biological science Vol.4 (1); pp. 69-73.*

Dutt, D. Upadhyaya, J. S., Sing, B. and Tyagi C. H. (2009). Studies on Hibiscus canabinus and Hibiscus sabdarifa as alternative pulp blind for soft wood; *An optimization of craft delignification process: Industrial crop produce. Vol. 29. PP.16-27.*

Hussaini M. S., Abubakar Y. and Yahaya A. (2018); Physico-Mechanical Properties of *(agave sisalana)* Leaves Fiber for Engineering Application. FANE-FANE *International Multidisciplinary Journal* Volume 6, 2018. . ISSN 2141-4483.

Istek, A. (2006), Effect of phanerochaete chrysosporium white rot fungus on the chemical composition of populous tremula. Journal of cellulose chemistry technology 40(6): 473-479.

Jorge, G. and Helena, P. (20011). *Cynara Cardunculus.* New fiber crop for pulp and paper production. *Industrial crops and Products* Vol. (13) 1-12.

Maduako, J. N., Igbanugo, A. B., Mudiare, O.J. and Asota C. N. (2001). Characterization of selected varieties of cotton plant grown in Nigeria for Utilization in paper making. Nigerian Journal of Education Technology. Vol. 2 (2) 46-52.

Maduako, J. N. (2011), Characterization of Agricultural product for mechanization of processing operation. 13th Inaugural lecture, Modibbo Adama University of Technology, Yola. PP 27-34.

Modibbo, U., Aliyu, B. A. and Nkafamiya, I. I. (2009). The effect of molarization Media on the physical properties of local plant Best fibre. (Electronic Version). *International Journal of Physical science. Vol. 4(11); pp. 698-704.*

Namessan, N. O. (2008). Use of kenaf *(hibiscus canabinus)* as base friction material in production of Automobile brake pads. Unpublished Phd. Thesis Modibbo Adama University of Technology, Yola.

Naveen, J., Sathishkumar, T. P. and Satheesh, K. S. (2014). *International Journal of Innovative research and Engineering Technology Vol. 3. PP 1091-1095.*

Ogbonnaya, C., Macauley, R. H. and Nwalozie M. C. (1997). Physical and Historical properties of kenaf, grown under water deficit on a sandy soil. *Industrial crops production* (7), 8-19.

Sahin, H. and Young R. A. (2008). Auto-catalyzed acetic acid pulping of juice. Industrial crops and products. 28, 24-28.

Saheb D. N. and J. P. Jog (1999). "Natural fibre polymer composites: a review," Advances in Polymer Technology, vol. 18, no. 4, pp. 351–363. *View at Google Scholar*

Saikia, S. N, Gosnami, T. and Ali, F. (1997). Evaluation of pulp and paper making characteristic of fast growing plant. (Electronic Version). *Journal of wood science 31; 466-478.*

Sharma, A. K, Dharm, D., Upadhyaya, J. S. and Roy, T. K. (2011). Anatomical, Morphological and Chemical Characterization of Bambusa Tulda Dendrocalamus Hamiltonii, Bambusa Balcooa, Malocana Baccifera, Bambusa Arundinacea and Eucalyptus Tereticorinis. [Electronic Version]. *Journal of Bioresources* 6 *(4); 5061-5074.*

Taiwo, K. F.,Fagbemi, O. D., Otiojun, D., Mgbachivuzor, E. and Igwe, C.(2014). Pulp and Paper Making Potential of Corn Husk. International Journal of Agricultural Science Vol. 4(4); 129-145.

Tappi, (1980). Standard and Suggested Method. Technical Association of Pulp and Paper Industries, New York, USA. 2(1) 1-19.

Ververis, C., Georhiou, K., Christodoulaku, N., Santas, P. and Santas, R. (2004). Fibre Dimension, Lignin and Celluloses Content of Various Plant Materials and their Suitability to Paper Production. [Electronic Version]. *International Journal of Crops and Products Vol. 19. PP 244-255.*

World Health Organization (WHO), (1998). Determination of Ash content; Quality control methods for medicinal plants materials. Anon Geneva. PP.61-83.

Xue L., Lope, G. and Tabil, S. P. (2007); *Journal of Polymer Environment, Volume 15, 25–33.*