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The Use of Alternate Ligno-cellulosic Raw Materials Banana *(Musa sapientum)* Ankara *(Calotropis procera)* and Pineapple *(Ananas comosus)* in Handmade Paper & their Blending with Waste Paper.

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Abstract: - The studies were made to established suitability of lingo-cellulosic raw materials namely leaf fibre **Banana (Musa Sapientum),** bast fibre **Ankara (Calotropis Procera), &** leaf fibre **Pineapple (Ananas Comosus)** for making pulps for handmade paper industry. This should help in providing a cost effective, good quality cellulosic raw material as an alternate to cost prohibitive traditionally used cotton hosiery waste traditionally used for manufacturing good quality handmade paper & it's products. This will help in improving the cost economics & competitiveness of the Indian paper industry in the global market besides addressing the problems of environment & global warming. The aim of the research was to study the extraction, morphology, chemical composition and pulping of these fibres and relate these properties to the composite properties obtained with these fibres as reinforcement with short fibres viz. waste paper. For the pulp production to be feasible it is essential to use suitable pulping methods, which maximize the yield of pulp and introduce as low damage as possible to the fibres. The different pulping methods were applied to these fibre to get optimized strength properties papers. The Studies thus carried out provide useful information about the nature of these raw materials, suitable pulping & bleaching process to produce an eco-friendly handmade paper and converted products. The research work provides a good quality cost effective lingo-cellulosic raw material for handmade paper industries with a possibility of replacement of the expensive and traditionally used cotton hosiery waste. The paper thus produced using environmental friendly pulping and bleaching process is characterized for its strength properties like tensile, tear, bursting, folding endurance and other parameters. The effluents generated from pulping and bleaching of above ligno-cellulosic waste materials were characterized for various pollution parameters like Residual Alkali, BOD, COD etc. The research work thus carried out in the present research has of great importance for handmade paper industry not in India but also in developing and developed countries in other parts of the world. Further the study will be useful in providing opportunities for employment generation and income enhancement among the rural masses.

Keywords: - *Alkaline Peroxide Pulping (APP), Alkaline Sulphite Pulping (ASP), Bast fibres, BOD, COD, Leaf fibre, RCF, TAPPI*

I. INTRODUCTION

Handmade paper making is one of the traditional industries of India, though it's invention is claimed by Chinese dated back to 105 A.D. by T'sai Luin, but recent researches showed that the papers were used in India dated back 325 BC when Budhism took place here [1]. However, prior to this period, the palm leaves were the medium of writing in India. 'Papyrus' from which the world 'Paper' has been derived, on the bank of Nile river in Egypt, has been the medium of communication in Egypt[2].

1.1 Scenario in India:

As per estimates, there are nearly more than 500 handmade paper units scattered all over India producing nearly 50,000 tonnes of handmade paper and board. The Indian handmade paper industry had grown remarkably in the recent past wherein the production of handmade paper industry has reached to a turnover of Rs 250,000 million. Due to increased literacy, industrialization and modernization, the per capita consumption of the paper and paper board has increased remarkably from 4.5 kg in the year 2000 to nearly 9.0 Kg in the recent past. This industry provides employment to about 15,000 people and most of them are situated in the rural areas[3].

With the growing trend of environmental friendliness, demand of handmade papers made out of natural fibers is rising. Moreover, the rising cost of traditionally used cellulosic raw materials like cotton rags and hosiery waste, being used in handmade papermaking is also forcing the industry to search for additional cellulosic raw materials for production of handmade paper and board which are available as waste biomass in different parts of the world. This should help in providing more opportunities for cost effective, locally available lignocellulosic raw materials / agro residues like Banana, Ankara, Pineapple, etc. there by addressing the problem of environment and the issue of global warming in a right prospective.

Handmade paper sector is considered to be eco-friendly, utilizing non woody and waste raw materials in its manufacturing process. The durability of the paper is high with exclusive look and texture. The paper is available in a saga of rich varieties, designs, shapes and colors. Most of the handmade paper units in India have been traditionally using cotton hosiery waste as the main source of raw material, which produce paper with excellent strength characteristics.

1.2 Share in Export Market:

China is holding the maximum share of 27% in the export of handmade paper and paper products while India is at Number 2 position with a share of 24% . Thailand and Philippines are the next competitors in the handmade paper and paper products export. Data is depicted in Table -1 &Fig- 1.

II. OBJECTIVE OF THE STUDY

2.1 The aim of the research: The aim of the research was to study the morphology, chemical composition and pulping of these fibres and relate these properties to the composite properties obtained with these fibres as reinforcement with short fibres viz. waste paper. For the pulp production to be feasible it is essential to use suitable pulping methods, which maximize the yield of pulp and introduce as low damage as possible to the fibres.

2.2 Different Pulping Method: The different pulping methods were applied to these fibre to get optimized strength properties papers. The Studies thus carried out provide useful information about the nature of these raw materials, suitable pulping & bleaching process to produce an eco-friendly handmade paper and converted products.

III. METHODOLOGY OF THE STUDY

3.1 Proximate / Chemical analysis and Fibre length & Dia of Banana, Ankara and Pineapple Fibres:

The trimmed sample of fibres were grilled in dust making machine and screened, since no diffusion limitations were observed for the particle size in preliminary studies. Samples were dried, homogenized in a single lot to avoid differences in composition among aliquots, and stored.

Characterization experiment involved the following parameters: 1% NaOH solubility (Tappi 212 om-98), hot water solubility (Tappi 207 cm-93), ash (Tappi-211, om-85), alcohol-benzene extractives (Tappi 204 cm-97), cellulose (Tappi 203-om-93), Klason lignin (Tappi T 222 om-98) and holocellulose (Wise et al., 1946) contents. All treatments in this study were in a completely randomized design with five replications (variation coefficient less than 5%. less than 1% for holocellulose and cellulose contents).The results are depicted in Table-2 & Graph-1.

For determination of fiber length, 100 individual fiber were measured from each variety. Statistical analyses were performed using PROJECTINA Microscope and the differences among varieties were compared. The means were separated on the basis of least significant difference at 0.05 probability level. The results are depicted in Table-3 & Graph-2.

3.2 Pulping of the Fibres:

Pulp is a fibrous material resulting from complex manufacturing processes that involve the chemical and / or mechanical treatment of various types of plant material. Pulp is one of the most abundant raw materials worldwide which is used predominantly as a major component in the manufacture of paper and paperboard, and with increasing importance also in the form of a wide variety of cellulose products in the textile, food, and pharmaceutical industries. It is self-evident that the competitiveness of pulp and its products produced thereof can only be maintained through continuous innovations at the highest possible level. In context of handmade

paper, cotton waste and hosiery waste being the basic raw materials for paper making in India, pulping of these selected raw materials were subjected to following pulping processes.
3.2.1 Atmospheric Temperature & Pressure Pulping.
3.2.2 Alkaline Pulping.
3.2.3 Alkaline Peroxide Pulping.
3.2.4 Alkaline Sulphite Pulping.

Concerned to the global environment, utilization of these lignocellulosic raw materials has become a major focus in the handmade paper / paper board production. The preparation of pulps from plant fibers normally requires the use of the digester for the fiberization and delignification processes. This research concerns the development of a pulping process, suitable which can be performed under atmospheric temperature & pressure. In this process, the only sodium hydroxide used as a pulping chemical to delignify the fibres, without the use of digester. The cooking conditions were milder than the methods used in the other said pulping processes, and subsequently resulted in pulps with higher yields and good physical properties. [4]

Alkali treatments refers to the application of alkaline solutions such as NaOH, Ca(OH) 2 or ammonia. Among these, treatment with NaOH has been used for delignification of these pseudo stem, bast and leaf fibres. The alkali treatment causes swelling, leading to an increase in internal surface area, a decrease in the degree of polymerization, a decrease in crystallinity, separation of structural linkages between lignin and carbohydrates, and disruption of the lignin structure. As a consequence, the lignin is dissolved from the raw material, being separated in the form of a liquor rich in phenolic compounds that represents the process effluent. The inconvenient of this technique is that it also degrades part of the hemicellulose. [5]

Hydrogen peroxide treatment utilizes alkaline solutions at temperatures 95º C, which promote a fast decomposition of H2O2. As a consequence, more reactive radicals such as hydroxyl radicals (HO) and superoxide anions (O2–) are produced, which are responsible for lignin degradation. This technique is used for bleaching and delignification purposes (to improve the brightness of pulp as it reacts with colored carbonyl-containing structures in the lignin). However, total chlorine free pulp may be obtained by this delignification process. [6]

Similarly to the alkaline treatment, during the lignin solubilization by hydrogen peroxide part of the hemicellulose is also removed from the material structure.

Alkaline Sulphite treatment is another way to remove the lignin content of lignocellulosic materials. Lignin attacks as a scavenger during this pre-treatment because it consumes most of sulphite during the degradation of the carbohydrate content. As a consequence, low alkali amounts are available for cellulose degradation. However, this treatment may also attacks the cellulose and hemicellulose components besides the lignin molecule. Cellulose degradation has been attributed partly to a direct reaction of with the glycosidic linkage and partly to a free radical mediated oxidation of hydroxyl groups in glucose. Some advantages of this treatment are that the effluent after concentrating can be use as adhesive chemicals for other industries. [7]

Conditions involved in the pulping processes:
3.2.1 Atmospheric Temperature and Pressure Pulping

After cutting the raw materials into suitable size, ie 1 -1.5 inches it was subjected to above said method with different % of NaOH. The raw materials were soaked at room temperature and pressure with 8%, 10% and 12% of sodium hydroxide and left for 24 hours with the bath ratio 1:8 as depicted in Table 5.

Strength Characteristics

After washing, the fibers were beaten in laboratory valley beater. The pulps were beaten up to ~300 ml CSF (Canadian Standard Freeness) and laboratory sheets of 60 GSM were formed in hand sheet former. The sheets were conditioned for 24 hours at 27 $\pm$1ºC and 65$\pm$2 % relative humidity. After conditioning, the physical strength properties were evaluated as per the Standard Test Methods viz TAPPI, BIS, IS & ISO:2471. The results are recorded in Table 6 and Graph-3.

Results and Discussion

The physical strength properties of these fibres at atmospheric temperature and pressure showed that these fibres can be used for making handmade paper by using NaOH simply without any external source of heat. The pulp thus produced can be used for making variety of handmade papers / paper boards. This method can be useful for the that type of industry people who do not have the cooking utensils like digesters or can not afford to have digesters.

3.2.2 Alkaline Pulping:

After cutting the raw materials into suitable size ie 1-1.5 inches, it was subjected to alkaline pulping method. The raw materials were cooked at 100° C temperature with 8%, 10% and 12% of sodium hydroxide and cooked for three hours with the bath ratio 1:8. The conditions are depicted in Table 7.

Strength Characteristics

After washing, the fibers were beaten in laboratory valley beater. The pulps were beaten up to ~300 ml CSF (Canadian Standard Freeness) and laboratory sheets of 60 GSM were formed in hand sheet former. The sheets were conditioned for 24 hours at 27 $\pm$1ºC and 65$\pm$2 % relative humidity. After conditioning, the physical strength properties were evaluated as per the Standard Test Methods viz TAPPI, BIS, IS & ISO:2471. The results are recorded in Table 8 & Graph-4.

Results and Discussion

The physical strength properties of these fibres at 100 degree temperature showed a remarkable changes in their strength properties that can be seen in above table. Also the effluent generated is under control. The tensile and folding strength increased remarkably, also the other strength properties like tear and burst also improved. So these fibres can be used for making handmade papers by using NaOH in digester. The pulp thus produced can be used for making variety of handmade papers / paper boards, particularly specialty papers . This method can be useful for the industry people who have the cooking utensils like digesters or even they do not have digesters simply go for open digestion.

3.2.3 Alkaline Peroxide Pulping:

After cutting the raw materials into suitable size ie 1-1.5 inches, it was subjected to alkaline peroxide pulping method. The raw materials were cooked at 95° C temperature with 8%, 10% and 12% of sodium hydroxide and 2% hydrogen peroxide for three hours with the bath ratio 1:8. The conditions are depicted in Table 9. But before pulping following pretreatment were followed to get better results.

Pretreatment with chelating agent

The plant materials like banana, ankara and pineapple contains metal ions like iron, manganese etc. which if present may decompose hydrogen peroxide and form complex with the metallic ions affecting the brightness and permanence of paper.

Therefore to avoid the interference of metallic ions pretreatment of raw material with chelating agent EDTA (Ethylene diamine tetra acetic acid disodium salt) was carried out. The following conditions were applied:

EDTA: 0.05 %, pH: 4 to 5, Time: 30 Mints, Temperature: Room temperature

After chelation, these raw materials were cleaned by de-mineralized water. After washing, the raw material were cooked with different doses of chemicals ie 8%, 10% and 12% of NaOH and 2% H2O2. The materials were pulped with APP process under the conditions recorded in Table 9.

The experiments on pulping of raw materials, carried out with Alkaline Peroxide process as per the following procedure.

Strength Characteristics

After washing, the fibers were beaten in laboratory valley beater. The pulps were beaten up to ~300 ml CSF (Canadian Standard Freeness) and laboratory sheets of 60 GSM were formed in hand sheet former. The sheets were conditioned for 24 hours at 27 $\pm$1ºC and 65$\pm$2 % relative humidity. After conditioning, the physical strength properties were evaluated as per the Standard Test Methods viz TAPPI, BIS, IS & ISO:2471. The results are recorded in Table 10 &Graph-5.

3.2.3.1 Utilization of Banana, Ankara & Pineapple pulp for manufacturing of Tissue paper and its application in Archival use

The pulp thus produced from Alkaline Peroxide pulping of Banana, Ankara & Pineapple (Exp- 8% NaOH & 2% H2O2) were further explored for making archival tissue paper (11 GSM) & other grammage paper (25, 40 GSM). The results of the strength properties and age of the Banana, Ankara & Pineapple papers are shown in Table 11 &Graph-6.

Results & Discussion:

From the result shown in table 11, it was observed that the strength properties are increased reasonably in all the parameters as the peroxide was used the better delignification occurred. In some of the properties banana fibre showed better results than the other fibres. The banana fibre has some inherent characters like lustrous, fine structure and clean texture make a super quality fibre / pulp over the others. From the results shown in Table 11, it has been observed that the tissue paper produced from banana possess reasonably higher strength properties, double fold no. (250) coupled with the high age (650 years) making it very much suitable for archival application for the preservation of old documents and manuscripts.

The other paper of higher GSM (25 & 40) produced from Banana, Ankara & Pineapple because of their specific peculiar texture coupled with the other features viz. higher age, very high strength properties made its suitable for high end application & value added hand craft products viz. lamp shades, greeting cards specially stationary items & other gift items etc.

3.2.4 Alkaline Sulphite Pulping:

After cutting the raw materials into suitable size ie 1-1.5 inches, it was subjected to alkaline sulphite pulping(ASP) method. The raw materials were cooked at 120° C temperature with 8%, 10% and 12% of total chemical out of which 70% NaOH and 30% Na2SO3 were maintained for three hours with the bath ratio 1:8. The conditions are depicted in Table 12.

Strength Characteristics:

After washing, the fibers were beaten in laboratory valley beater. The pulps were beaten up to ~300 ml CSF (Canadian Standard Freeness) and laboratory sheets of 60 GSM were formed in hand sheet former. The sheets were conditioned for 24 hours at 27 $\pm$1ºC and 65$\pm$2 % relative humidity. After conditioning, the physical strength properties were evaluated as per the Standard Test Methods viz TAPPI, BIS, IS & ISO:2471. The results are recorded in Table 13 & Graph-7.

Results & Discussion:

From the result shown in table - 13 it was observed that the strength properties are increased with all respect as compared to APP and other pulping process reasonably. Again in some of the properties banana fibre showed better results than the other fibres at low chemical dosages particularly in case of tensile and burst strength.

It was observed that the pulp produced from this process there is requirement of brightness for making high quality papers like archival tissue papers. To over come of this property a bleaching experiment was conducted with 2% of hydrogen peroxide.

The bleached pulp obtained as above and the bleach effluent was characterized for strength characteristics (Table-14) and pollution loads in respect of COD & BOD respectively. Whereas the spent pulping liquor obtained after the alkaline sulphite pulping and washing the unbleached pulp were mixed and evaporated to a solids concentration of 30% w/w for its application in various industries.

3.2.4.1 Bleaching Studies

The unbleached pulp obtained by Alkaline Sulphite pulping of these raw materials with total chemical of 8% Alkaline Sulphite Process were bleached with 2% hydrogen peroxide under following
Hydrogen Peroxide-2 %, NaOH-1 %, EDTA 0.15 %, Consistency-8-9 % Temperature 60-70° *C*,Time-1 hr

The bleached pulp obtained as above and the bleach effluent was characterized for strength characteristics (Table-14) and pollution loads in respect of COD & BOD respectively. Whereas the spent pulping liquor obtained after the alkaline sulphite pulping and washing the unbleached pulp were mixed and evaporated to a solids concentration of 30% w/w for its application in various industries. The Physical strength & optical properties of the bleached pulp from Alkaline Sulphite Pulping (Total 8% chemicals) followed by peroxide bleaching process (~300 ml freeness) were recorded in Table-15.

Results & Discussion:

The bleached pulp of 8% treated pulp shows little bit of increase in strength properties. Of course the brightness of the pulp is increased remarkably. From the results shown in Tables. 10, 11, 13 & 15, it is observed that the strength & optical properties of the pulp produced from alkaline peroxide pulping and alkaline sulphite pulping process followed by peroxide bleaching were superior in respect of Tensile, Tear, Burst & Double fold with a reasonable brightness value wherein it was possible to achieve a brightness 48.60% ISO, 44.11% ISO & 43.41% ISO in case of Banana, Ankara & Pineapple pulp produced from alkaline sulphite pulping followed by peroxide bleaching which was higher compared to other pulping processes.

3.3 Blending Studies

3.3.1 Fibre strength in RCF Pulp blended with these fibre at different pulping condition:

In this section of study, the pulp which were cooked with 8% of chemical in Pulping at atmospheric temperature and pressure process, Alkaline Pulping, Alkaline Peroxide Pulping and Alkaline Sulphite Pulping process were taken for the blending with the RCF pulp. The results of these pulp sheets at this condition have remarkable strength properties which is suitable for making any kind of handmade paper and paper products. These result are once again depicted in table-16,17,18 and 19, respectively & RCF in table-20 to understand the result in better way.

3.3.1.1. Physical and optical strength properties of the pulps from Pulping at atmospheric temperature and pressure process- Blended with Recycled fibre (RCF).

The recycled fibre beaten up to the level of ~300 CSF and it was blended with the pulps of Banana, Anakra and Pinapple which were cooked with 8% of NaOH for 24 Hrs at Room Temp. The result are depicted in table-21.

Strength Characteristics:

After blending, the fibres were run in laboratory valley beater without any load, and laboratory sheets of 60 GSM were formed in hand sheet former. The sheets were conditioned for 24 hours at 27 ±1ºC and 65±2 % relative humidity. After conditioning, the physical strength properties were evaluated as per the Standard Test Methods viz TAPPI, BIS, IS & ISO:2471. The results are recorded in Table 21 & Graph-8.

Results and Discussion:

The physical strength properties of these blended fibres sheet showed a remarkable changes ie increase in their strength properties that can be seen in above table. The tensile and folding strength increase, also the other strength properties like tear and burst also improved. So RCF can be used for making handmade papers by using these lignocellulosic raw material pulp. The paper sheets thus produced can be used for making variety of handmade papers / paper boards. This is useful method to industry who do not have Digester.

3.3.1.2. Physical and optical strength properties of the pulps from Alkaline Pulping Process Blended with Recycled fibre (RCF).

The recycled fibre beaten up to the level of ~300 CSF and it was blended with the pulps of Banana, Anakra and Pinapple which were cooked with 8% of NaOH for 3 Hrs at 100° C. The result are depicted in table-22.

Strength Characteristics:

After blending, the fibres were run in laboratory valley beater without any load, and laboratory sheets of 60 GSM were formed in hand sheet former. The sheets were conditioned for 24 hours at 27 ±1ºC and 65±2 % relative humidity. After conditioning, the physical strength properties were evaluated as per the Standard Test Methods viz TAPPI, BIS, IS & ISO:2471. The results are recorded in Table 22 &Graph-8.

Results and Discussion:

The physical strength properties of these blended fibres sheet showed a remarkable changes ie increase in their strength properties that can be seen in above table. The tensile and folding strength increased remarkably, also the other strength properties like tear and burst also improved. So RCF can be used for making handmade papers by using these lignocellulosic raw material pulp. The paper sheets thus produced can be used for making variety of handmade papers / paper boards. This can be useful for the industry people who are using RCF as a raw material.

3.3.1.3. Physical strength and optical properties of the pulp from Alkaline Peroxide Pulping Process Blended with Recycled Fibre (RCF).

The recycled fibre beaten up to the level of ~300 CSF and it was blended with the pulps of Banana, Anakra and Pinapple which were cooked with 8% of NaOH and 2% H2O2% (Hydrogen Peroxide) for 3 Hrs at 95° C. The results are depicted in table-23.

Strength Characteristics:

After blending, the fibres were run in laboratory valley beater without any load, and laboratory sheets of 60 GSM were formed in hand sheet former. The sheets were conditioned for 24 hours at 27 ±1ºC and 65±2 % relative humidity. After conditioning, the physical strength properties were evaluated as per the Standard Test Methods viz TAPPI, BIS, IS & ISO:2471. The results are recorded in Table 23 &Graph-10.

Results and Discussion:

The physical strength properties of these blended fibres sheet showed a remarkable changes ie increase in their strength properties that can be seen in above table. The tensile and folding strength increased remarkably, also the other strength properties like tear and burst also improved. So RCF can be used for making handmade papers by using these lignocellulosic raw material pulp. The paper sheets thus produced can be used for making variety of handmade papers / paper boards, particularly specialty papers . This can be useful for the industry people who are using RCF as a raw material.

3.3.1.4. Physical strength and optical properties of the pulp from Alkaline Suiphite Pulping (ASP) Process Blended with Recycled Fibre(RCF).

The recycled fibre beaten up to the level of ~300 CSF and it was blended with the pulps of Banana, Anakra and Pineapple which were cooked with 8% of Total chemical (Out of which NaOH-70% and Na2SO3 (Sodium Sulphite) for 3 Hrs at 120° C. The results are depicted in table-24.

Strength Characteristics:

After blending, the fibres were run in laboratory valley beater without any load, and laboratory sheets of 60 GSM were formed in hand sheet former. The sheets were conditioned for 24 hours at 27 $\pm$1ºC and 65$\pm$2 % relative humidity. After conditioning, the physical strength properties were evaluated as per the Standard Test Methods viz TAPPI, BIS, IS & ISO:2471. The results are recorded in Table 24 & Graph-11.

Results and Discussion:

The physical strength properties of these blended fibres sheet showed a remarkable changes ie increase in their strength properties that can be seen in above table. The tensile and folding strength increased remarkably, also the other strength properties like tear and burst also improved remarkably. So RCF can be used for making handmade papers by using these lignocellulosic raw material pulp depends upon their availability in that particular region. The paper sheets thus produced can be used for making variety of handmade papers / paper boards, particularly specialty papers . This can be useful for the industry people who are using RCF as a raw material.

IV. FIGURES AND TABLES

Table 1. Export Scenario of Handmade Paper in World

COUNTRY	EXPORT IN RS CRORES	% AGE SHARE
INDIA	366	24
PHILIPPINES	127	8
NEPAL	15	1
CHINA	411	27
OTHERS	435	28
TOTAL	1546	
	341.07 MILLION US $	

Source: Report on "Market research in Indian Handmade Paper Industry" by M/S Sycom Projects Consultants Pvt. Ltd. New Delhi.

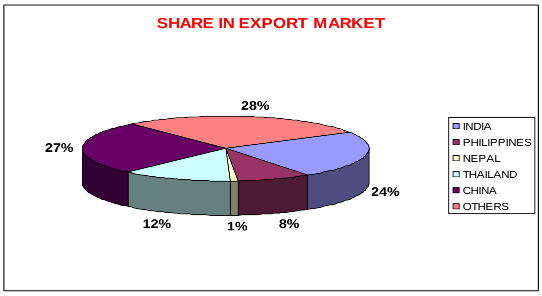
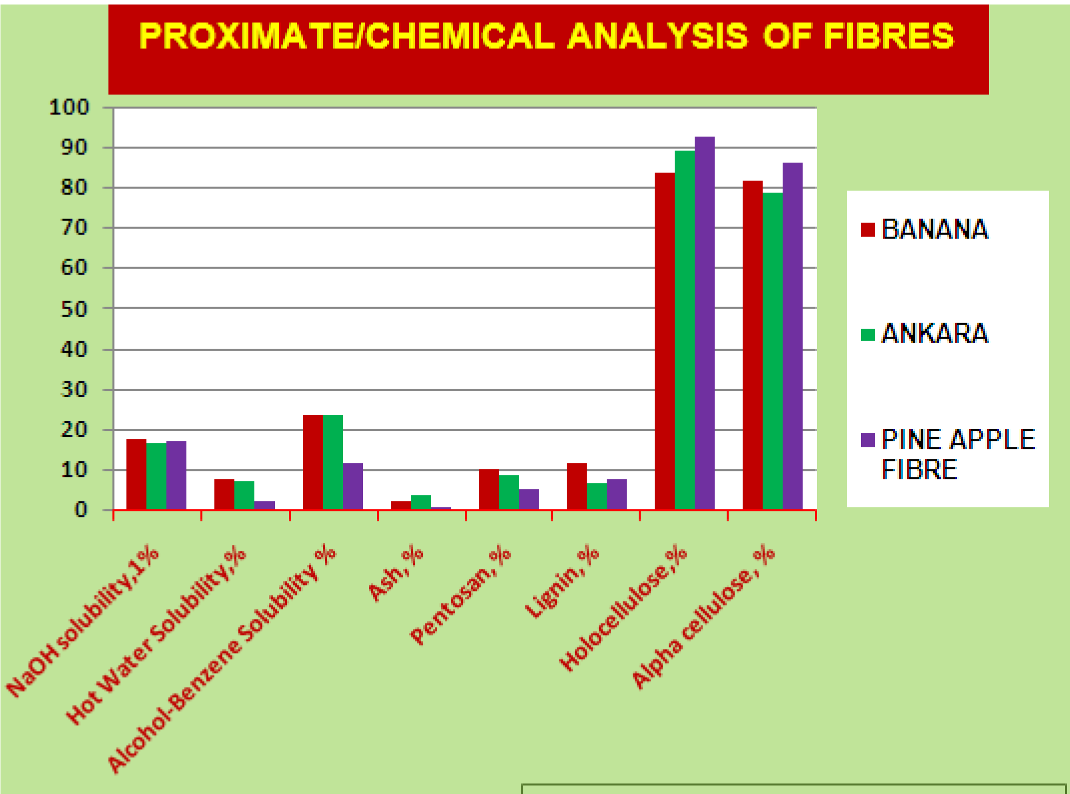


Figure 1. Percentage share of countries in export

Table-2 Proximate / Chemical analysis of Banana, Ankara and Pineapple Fibres:

Particulars	Banana fibre	Ankara fibre	Pineapple fibre
NaOH solubility,1%	18.01	16.90	17.33
Hot Water Solubility,%	7.91	7.30	2.56

Alcohol-Benzene Solubility %	24.04	23.90	12.10
Ash, %	2.45	4.10	1.00
Pentosan, %	10.32	8.90	5.50
Lignin, %	11.90	7.10	7.85
Holocellulose,%	84.11	89.50	92.81
Alpha cellulose, %	82.00	79.00	86.41



GRAPH-1

Table-3 Length and Dia of Banana, Ankara and Pineapple Fibres:

Common name (Scientific name)	Fibre Length (mm)		Fibre Dia (μm)	
	Avg	Range	Avg	Range
Banana (*Musa sapientum*)	3.00	1.8~15	24.00	16~32
Ankara (*Calotropis procera*)	3.56	2~20	25.00	15~40
Pineapple (*Ananas comosus*)	9.11	6~25	28.00	25~40

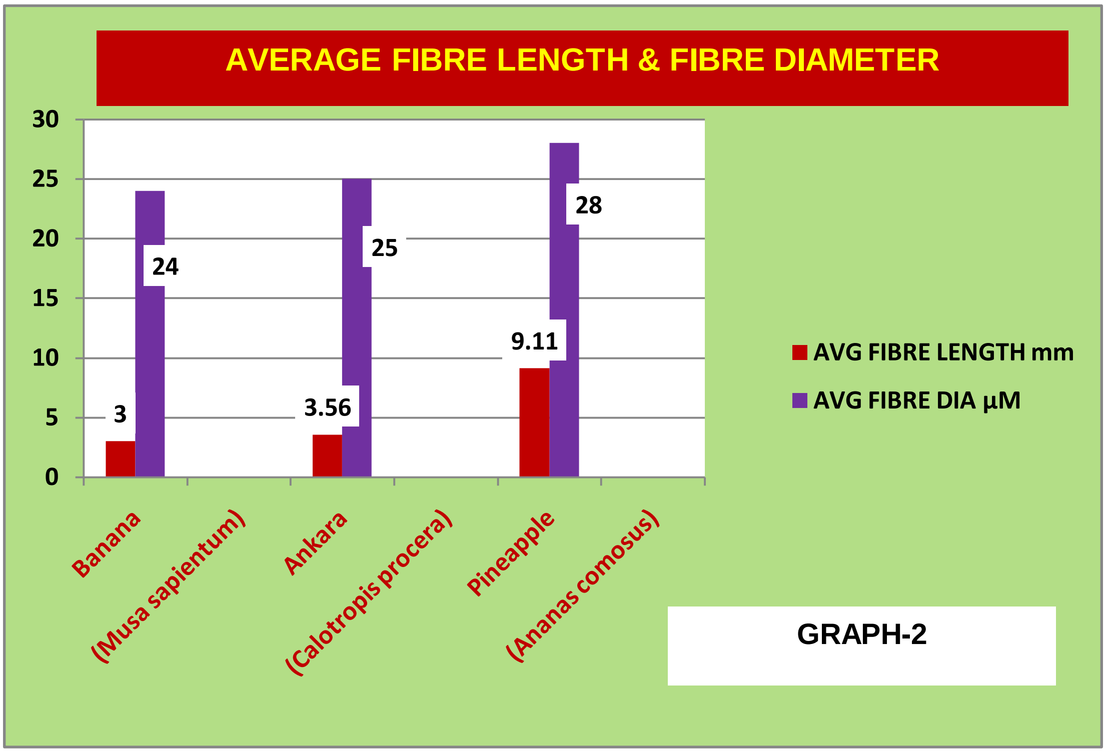


Table 5 Pulping condition of fibres at atmospheric temperature and pressure:

S. No.	Characteristics	Banana			Ankara			Pineapple		
1.	**Cooking conditions**									
	Soaking Time, Hrs.	24			24			24		
	NaOH %	8	10	12	8	10	12	8	10	12
	Temperature ° C	RT	RT	RT	RT	RT	RT	RT	RT	RT
	Pressure	Atm	Atm	Atm	Atm	Atm	Atm	Atm	Atm	Atm
	Bath ratio	1:8	1:8	1:8	1:8	1:8	1:8	1:8	1:8	1:8
2.	**Black liquor analysis**									
	Residual active alkali after digestion, gpl	Nil	Nil	0.10	Nil	Nil	0.12	Nil	Nil	0.15
3.	**Pulp Yield%**	86.91	85.11	84.90	84.89	83.23	82.78	89.90	86.19	85.12

RT-Room Temperature
Atm-Atmospheric Pressure

Table 6 Physical and optical strength properties of the pulp from Pulping at atmospheric temperature and pressure process (At ~ 300 ml freeness)

S.No.	Characteristics	Banana			Ankara			Pineapple		
	CSF, ml	**~300**			**~300**			**~300**		
	NaOH %	8	10	12	8	10	12	8	10	12
1.	Tensile Index, (Nm/g)	29.23	32.61	35.21	28.20	30.91	34.30	35.20	38.81	41.20
2.	Tear Index ,(mN.m^2/g)	1.96	2.01	2.15	1.78	1.94	2.02	2.10	3.71	3.44
3.	Burst Index, (Kpa.m^2/g)	1.90	2.10	2.40	1.81	2.00	2.21	2.51	3.00	3.51
4.	Double Fold, No.	1270	1450	1700	1200	1420	1630	1700	1810	2100
5.	Brightness (%) ISO	41.50	40.10	38.00	36.50	35.95	35.00	35.90	34.40	33.31

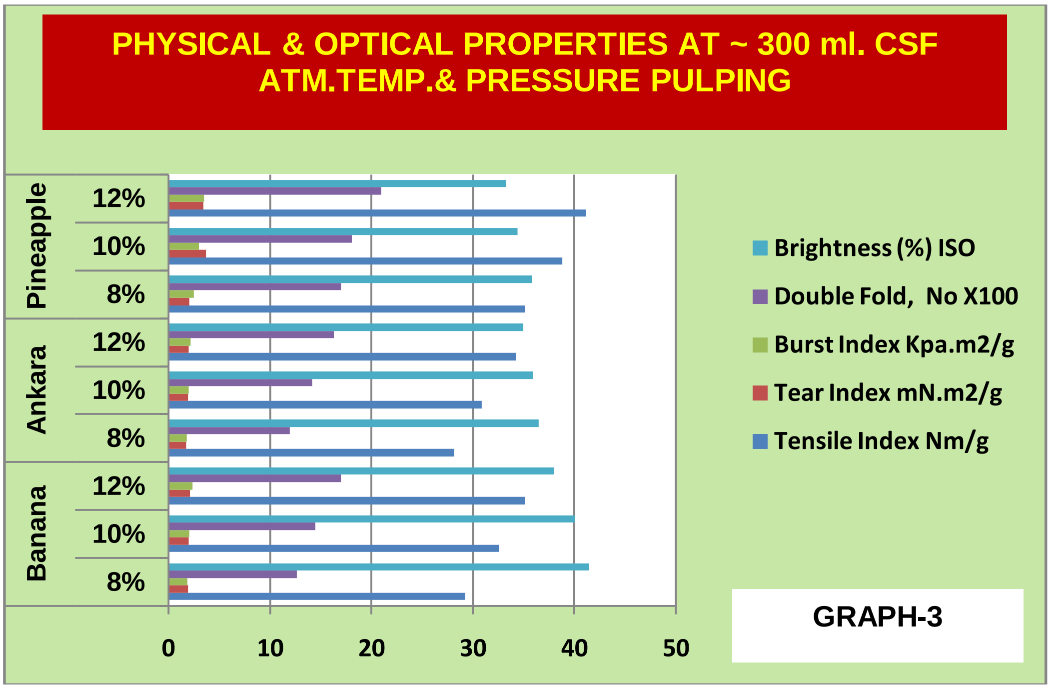


Table 7 Pulping conditions of Banana, Ankara and Pineapple fibers (Alkaline Pulping)

S.No.	Characteristics	Banana			Ankara			Pineapple		
1.	**Cooking conditions**									
	NaOH, %	8	10	12	8	10	12	8	10	12
	Time, Hrs	3	3	3	3	3	3	3	3	3
	Temperature °C	100	100	100	100	100	100	100	100	100
	Bath Ratio	1:8	1:8	1:8	1:8	1:8	1:8	1:8	1:8	1:8
2.	**Effluent Characteristics**									
	Residual active alkali after digestion, gpl	1.00	1.15	1.50	1.12	1.30	1.72	1.25	1.55	1.94
	BOD (Biological Oxygen Demand) **ppm**	1220	1380	1500	1300	1450	1730	1300	1450	1730
	COD (Chemical Oxygen Demand) **ppm**	6000	7700	8100	7000	8100	8700	7100	8200	8800
3.	Pulp Yield ,%	86.66	85.21	84.42	86.65	85.11	84.12	89.60	87.40	86.31

Table 8 Physical and optical strength properties of the pulps from Alkaline Pulping Process (At~ 300 ml freeness).

S.No.	Characteristics	Banana			Ankara			Pineapple		
	CSF,ml	**300**			**300**			**300**		
1.	Tensile Index, (Nm/g)	72.03	75.65	77.71	71.00	71.89	72.80	72.10	73.20	74.15
2.	Tear Index (mN. m^2/g)	4.86	4.91	5.14	4.80	4.82	4.98	4.90	5.10	5.66
3.	Burst Index, (Kpa.m^2/g)	4.10	4.98	5.12	3.80	4.01	4.51	3.97	4.81	4.97
4.	Double Fold , No.	8500	8600	8650	8400	8450	8500	9500	9700	9800
5.	Brightness ,(%) ISO	41.00	40.00	40.00	36.00	35.00	35.00	41.60	41.10	40.00

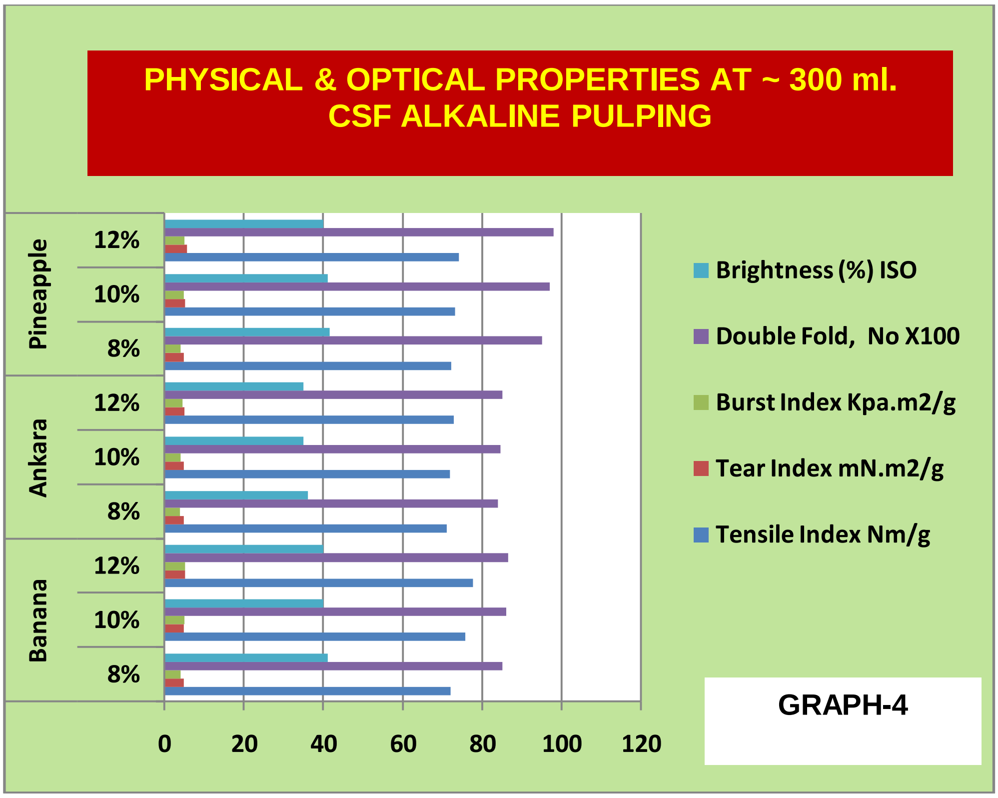
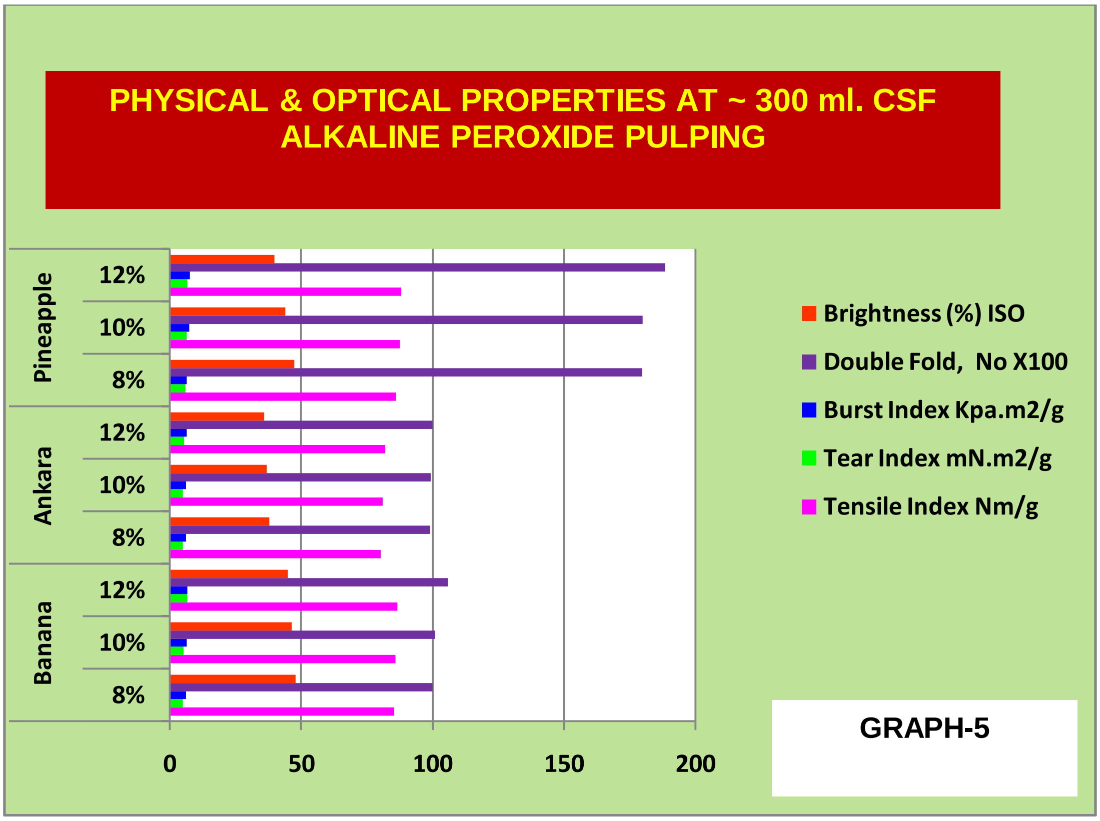


Table 9 Pulping conditions of Banana, Ankara and Pineapple fibers (Alkaline Peroxide Pulping)

S. No.	Characteristics	Banana			Ankara			Pineapple		
1.	**Cooking conditions**									
	NaOH %	8	10	8	8	8	12	8	8	12
	H2O2%	2	2	2	2	2	2	2	2	2
	Time, Hrs	3	3	3	3	3	3	3	3	3
	Temperature ° C	95	95	95	95	95	95	95	95	95
	Bath ratio	1:8	1:8	1:8	1:8	1:8	1:8	1:8	1:8	1:8
2.	**Effluent Characteristics**									
	Residual active alkali after digestion, gpl	1.12	1.25	1.59	1.20	1.39	1.81	1.32	1.65	2.00
	BOD(Biological Oxygen Demand), **ppm**	1800	2000	2300	2300	2300	2600	2320	2350	2630
	COD (Chemical Oxygen Demand), **ppm**	7000	8000	8000	8000	8000	9000	8050	8070	9050
3.	**Pulp Yield%**	80.20	78.89	75.00	75.00	74.50	73.11	84.10	83.00	82.21

Table 10 Physical strength and optical properties of the pulp from Alkaline Peroxide Pulping Process (At ~ 300 ml freeness).

S. No.	Characteristics	Banana			Ankara			Pineapple		
	CSF, ml	~300			~300			~300		
1.	Tensile Index (Nm/g)	85.50	86.10	86.65	80.31	81.11	82.10	86.20	87.70	88.11
2.	Tear Index (mN. m^2/g)	5.05	5.45	6.71	5.00	5.10	5.59	6.00	6.60	6.90
3.	Burst Index (Kpa.m^2/g)	6.31	6.51	6.80	6.26	6.31	6.53	6.50	7.50	7.88
4.	Double Fold , No.	10000	10110	10600	9910	9950	10000	17970	18000	18850
5.	Brightness (%) ISO	48.00	46.50	45.00	38.00	37.00	36.00	47.50	44.00	39.90



GRAPH-5

Table 11 Physical and optical strength properties of different GSM Tissue Papers developed from these fibres at ~300 ml freeness

S. N.	Characteristics	Banana			Ankara			Pineapple		
		8% NaOH+2% H2O2			8% NaOH+2% H2O2			8% NaOH+2% H2O2		
	GSM	~11	~25	~40	~11	~25	~40	~11	~25	~40
1.	Tensile Index (Nm/g)	52.76	60.00	65.12	32.50	35.97	40.12	60.30	63.21	69.16
2.	Tear Index (mN.m^2/g)	4.64	6.10	7.71	2.72	6.00	6.70	5.00	6.70	7.75
3.	Burst Index, (Kpa.m^2/g)	2.46	3.87	4.00	2.25	3.95	3.90	3.00	4.30	4.50
4.	Double Fold ,No.	250	600	1000	17	451	800	250	655	1000
5.	Brightness (%) ISO	48.00	48.50	48.50	46.00	47.60	48.00	47.00	46.50	46.00
6.	Age, Years (Average)	-	650	-	-	452	-	-	650	-

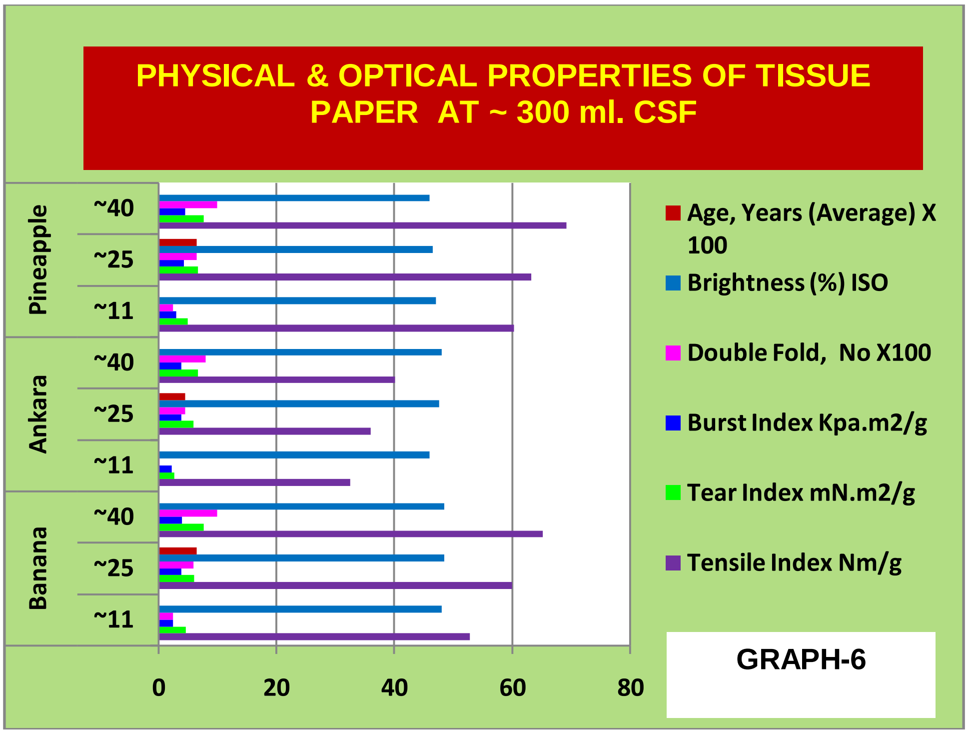


Table 12 Pulping conditions of Banana, Ankara and Pineapple fibers (Alkaline Sulphite Pulping).

S. N.	Characteristics	Banana			Ankara			Pineapple		
1.	**Cooking condition**									
	Total Chemical	8%	10%	12%	8%	10%	12%	8%	10%	12%
	NaOH	70%	70%	70%	70%	70%	70%	70%	70%	70%
	Na2SO3	30%	30%	30%	30%	30%	30%	30%	30%	30%
	Time Hrs	3	3	3	3	3	3	3	3	3
	Temperature ° C	120	120	120	120	120	120	120	120	120
	Bath ratio	1:8	1:8	1:8	1:8	1:8	1:8	1:8	1:8	1:8
2.	**Black liquor analysis**									
	Residual active alkali after digestion, **gpl**	0.72	1.29	1.73	1.02	1.47	1.98	1.07	1.56	2.00
	BOD (Biological Oxygen Demand), **ppm**	2300	2350	2500	2400	2500	2700	2450	2530	2710
	COD (Chemical Oxygen Demand), **ppm**	8000	8500	9100	8700	8900	9100	8750	8920	9160
3.	Yield,%	79.50	78.51	74.80	74.10	73.00	71.51	83.00	82.00	80.30

Table 13 Physical strength and optical properties of the pulp from Alkaline Suiphite Pulping (ASP) Process (At ~ 300 ml freeness).

S.No.	Characteristics	Banana			Ankara			Pineapple		
	CSF	**300**			**300**			**300**		
1.	Tensile Index, (Nm/g)	84.91	85.30	85.90	79.01	80.51	81.30	86.33	86.45	87.28
2.	Tear Index ($mN.\ m^2/g$)	5.35	5.95	6.90	5.00	6.51	6.78	6.00	6.76	7.00
3.	Burst Index, ($Kpa.m^2/g$)	6.10	6.50	6.70	5.70	6.00	6.10	6.20	6.81	7.15
4.	Double Fold, No.	9100	10100	10700	9000	9210	9800	16200	18430	19000
5.	Brightness (%) ,ISO	39.00	38.49	38.00	38.12	38.00	37.77	39.41	38.90	36.44

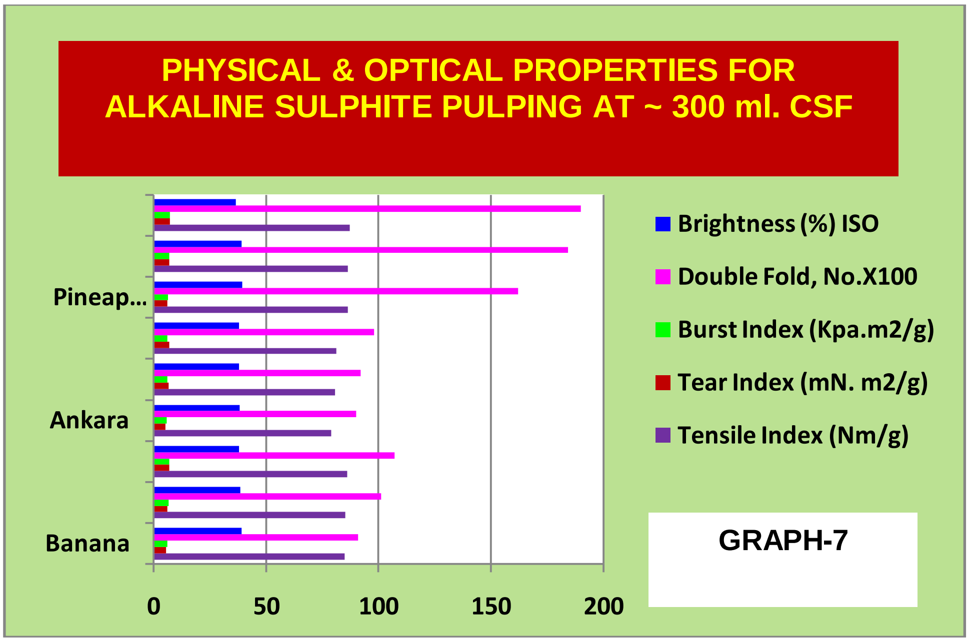


Table 14 Effluent Characteristics of Banana, Ankara and Pineapple fibers (8% Alkaline Sulphite Pulping) after the bleaching.

Characteristics	**Banana**	**Ankara**	**Pineapple**
Effluent Characteristics			
BOD (Biological Oxygen Demand), **ppm**	60	80	82
COD (Chemical Oxygen Demand), **ppm**	640	800	810
Pulp Yield,%	79.00	73.50	82.52

Table 15 Physical strength & optical properties of the bleached pulp from Alkaline Sulphite Pulping (Total 8% chemicals) followed by peroxide bleaching process (~300 ml freeness)

S.No.	Characteristics	Banana	Ankara	Pineapple
1.	Tensile Index (Nm/g)	84.98	79.50	86.73
2.	Tear Index (mN. m^2/g)	5.45	5.17	6.10
3.	Burst Index (Kpa.m^2/g)	6.18	5.90	6.22
4.	Double Fold ,No.	9,120	9040	16210
5.	Brightness (%) ISO	48.60	44.11	43.41

Table-16: Physical and optical strength properties of the pulp from Pulping at atmospheric temperature and pressure process (At ~ 300 ml freeness):

S.No.	**Characteristics**	**Banana**	**Ankara**	**Pineapple**
	CSF, ml	**~300**	**~300**	**~300**
	NaOH %	8	8	8
1.	Tensile Index (Nm/g)	29.23	28.20	35.20
2.	Tear Index(mN.m^2/g)	1.96	1.78	2.10
3.	Burst Index (Kpa.m^2/g)	1.90	1.81	2.51
4.	Double Fold,No.	1270	1200	1700
5.	Brightness (%) ISO	41.50	36.50	35.90

Table 17. Physical and optical strength properties of the pulps from Alkaline Pulping Process (At ~ 300 ml freeness).

S.No.	Characteristics	Banana	Ankara	Pineapple
	CSF,ml	**300**	**300**	**300**
1.	Tensile Index (Nm/g)	72.03	71.00	72.10
2.	Tear Index (mN.m^2/g)	4.86	4.80	4.90
3.	Burst Index (Kpa.m^2/g)	4.10	3.80	4.17
4.	Double Fold ,No.	8500	8400	9500
5.	Brightness (%) ISO	41.00	36.00	41.60

Table 18. Physical strength and optical properties of the pulp from Alkaline Peroxide Pulping Process (At ~ 300 ml freeness).

S. No.	Characteristics	Banana	Ankara	Pineapple
	CSF, ml	**~300**	**~300**	**~300**
		100%B	100%A	100%P
1.	Tensile Index (Nm/g)	85.50	80.31	86.20
2.	Tear Index (mN. m^2/g)	5.05	5.00	6.00
3.	Burst Index (Kpa.m^2/g)	6.31	6.26	6.50
4.	Double Fold , No.	10000	9910	17970
5.	Brightness (%) ISO	48.00	38.00	47.50

Table 19. Physical strength and optical properties of the pulp from Alkaline Suiphite Pulping (ASP) Process (At ~ 300 ml freeness) .

S.No.	Characteristics	Banana	Ankara	Pineapple
	CSF	**300**	**300**	**300**
		100%B	100%A	100%P
1.	Tensile Index (Nm/g)	84.91	79.01	86.33
2.	Tear Index (mN. m^2/g)	5.35	5.00	6.00
3.	Burst Index (Kpa.m^2/g)	6.10	5.70	6.20
4.	Double Fold, No.	9100	9000	16200
5.	Brightness (%) ISO	39.00	38.12	39.41

Table 20. Physical strength and optical properties of the pulp of RCF(At ~ 300 ml freeness).

S.No.	Characteristics	RCF
	CSF	**300**
		100%
1.	Tensile Index (Nm/g)	21.4
2.	Tear Index (mN. m^2/g)	3.61
3.	Burst Index (Kpa.m^2/g)	2.20
4.	Double Fold, No.	15.00
5.	Brightness (%) ISO	45.00

Table 21. Physical and optical strength properties of the pulps from Pulping at atmospheric temperature and pressure process (At ~ 300 ml freeness) Blended with Recycled fibre (RCF).

S.N.	Characteristics	Banana(B)			Ankara(A)			Pineapple(P)		
	CSF, ml	300			300			300		
		100% B	100% RCF	80% RCF +20%B	100% A	100% RCF	80% RCF +20%A	100%P	100% RCF	80% RCF +20%P
1.	Tensile Index (Nm/g)	29.23	21.4	24.91	28.20	21.4	23.62	35.20	21.4	25.00
2.	Tear Index (mN. m^2/g)	1.96	3.61	2.10	1.78	3.61	1.91	2.10	3.61	2.89
3.	Burst Index (Kpa.m^2/g)	1.90	2.20	2.11	1.81	2.20	2.00	2.51	2.20	2.53
4.	Double Fold, No.	1270	15.00	200	1200	15.00	180	1700	15.00	300
5.	Brightness (%) ISO	41.50	45.00	43.00	36.50	45.00	40.00	35.90	45.00	41.00

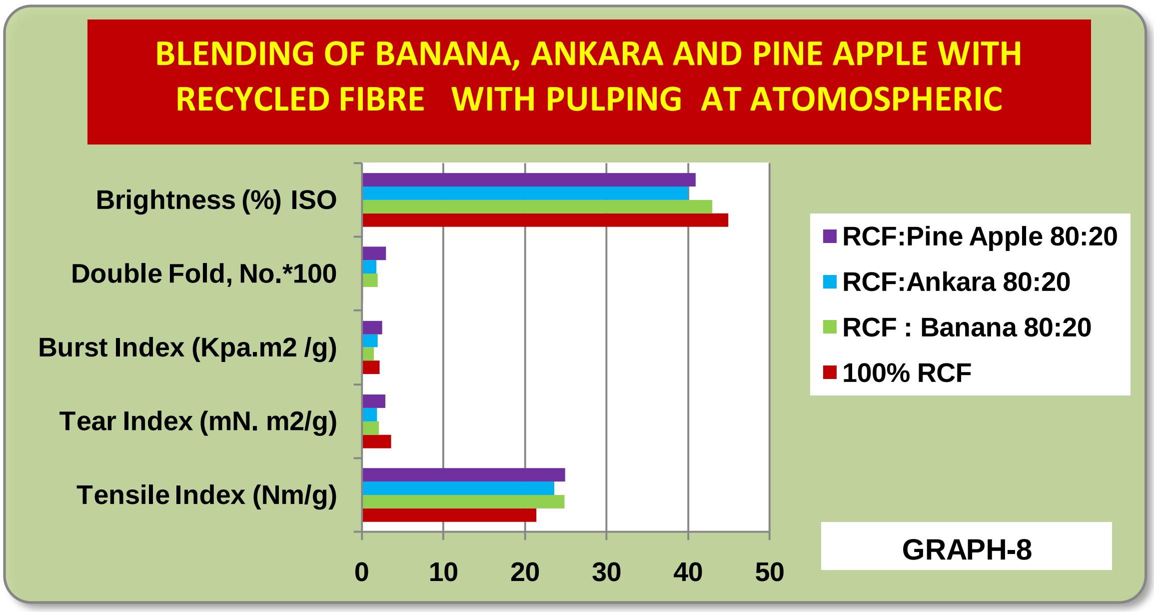


Table 22. Physical and optical strength properties of the pulps from Alkaline Pulping Process (At ~ 300 ml freeness) Blended with Recycled fibre (RCF).

S. N.	Characteristics	Banana(B)			Ankara(A)			Pineapple(P)		
	CSF, ml	300			300			300		
		100% B	100% RCF	80% RCF +20%B	100% A	100% RCF	80% RCF +20%A	100%P	100% RCF	80% RCF +20%P
1.	Tensile Index (Nm/g)	72.03	21.4	35.16	71.00	21.4	34.60	72.10	21.4	42.33
2.	Tear Index (mN. m^2/g)	4.86	3.61	4.51	4.80	3.61	4.42	4.90	3.61	4.80
3.	Burst Index (Kpa.m^2/g)	4.10	2.20	3.14	3.80	2.20	3.00	4.17	2.20	3.96
4.	Double Fold, No.	8500	15.00	451	8400	15.00	408	9600	15.00	500
5.	Brightness (%) ISO	41.00	45.00	42.00	36.00	45.00	44.00	41.60	45.00	43.00

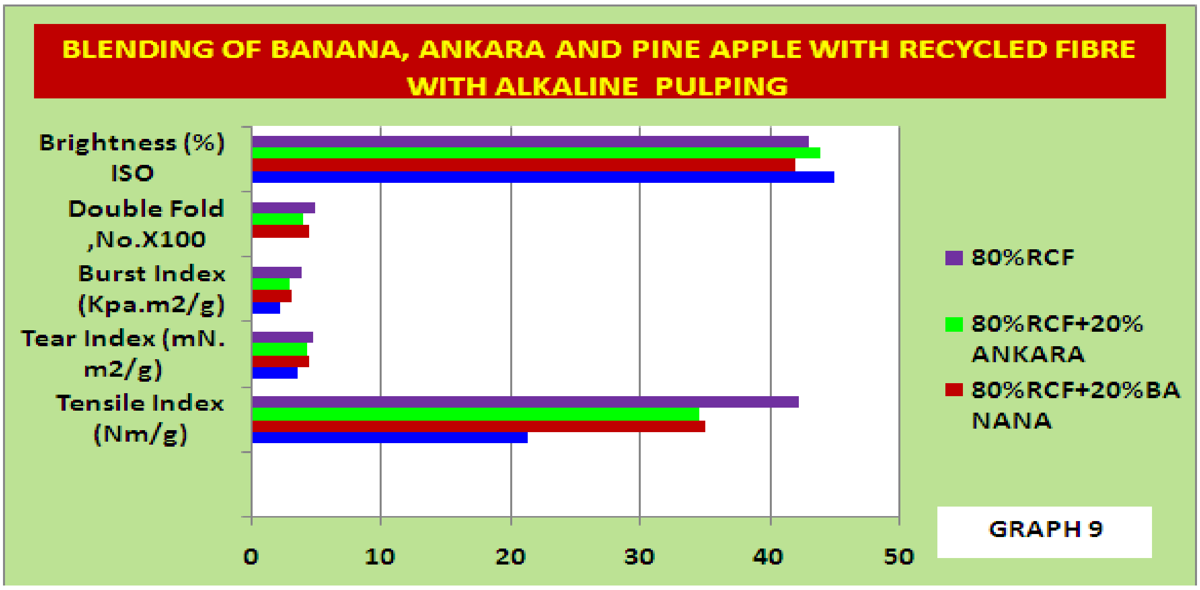


Table 23. - Physical strength and optical properties of the pulp from Alkaline Peroxide Pulping Process (At ~ 300 ml freeness) Blended with Recycled Fibre (RCF).

S. No.	Characteristics	Banana(B)			Ankara(A)			Pineapple(P)		
	CSF, ml	~300			~300			~300		
		100%B	100% RCF	80% RCF +20%B	100%A	100% RCF	80% RCF +20%A	100%P	100% RCF	80% RCF +20%P
1.	Tensile Index (Nm/g)	85.50	21.4	39.61	80.31	21.4	41.03	86.20	21.4	42.21
2.	Tear Index (mN. m^2/g)	5.05	3.61	4.81	6.20	3.61	4.71	6.00	3.61	4.91
3.	Burst Index (Kpa.m^2/g)	6.31	2.20	5.00	6.26	2.20	4.12	6.50	2.20	5.51
4.	Double Fold , No.	10000	15.00	760	17900	15.00	700	17970	15.00	790
5.	Brightness (%) ISO	48.00	45.00	46.00	38.00	45.00	40.00	47.50	45.00	46.00

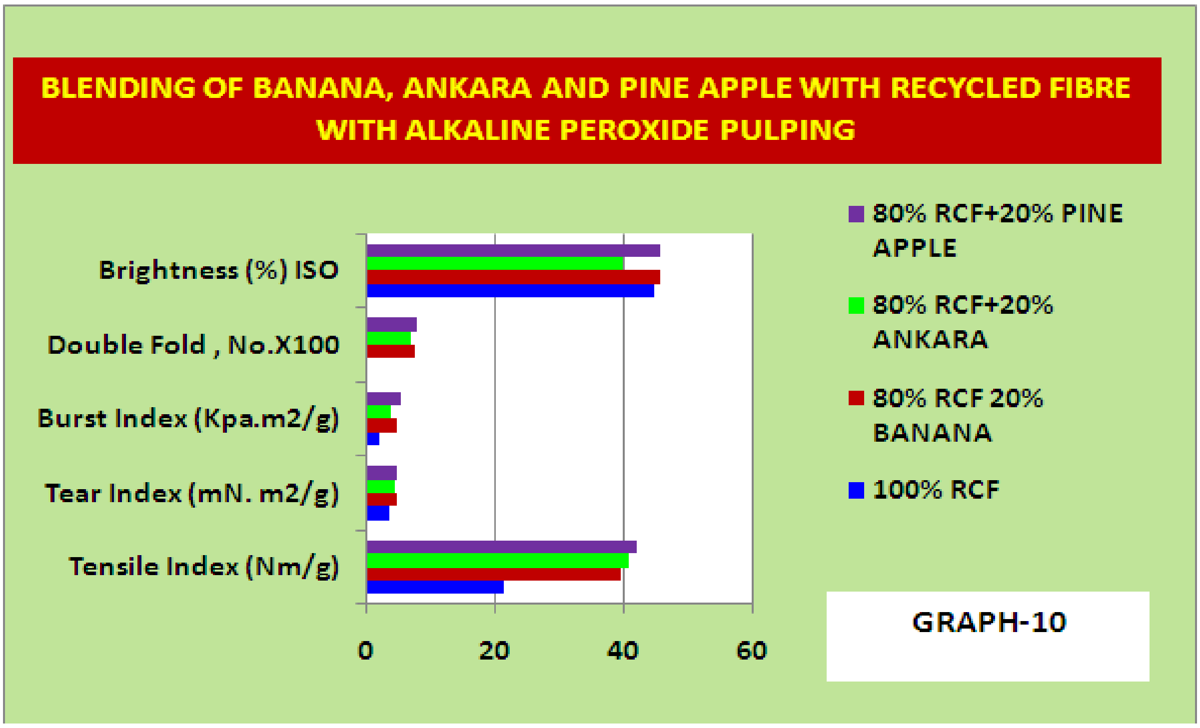
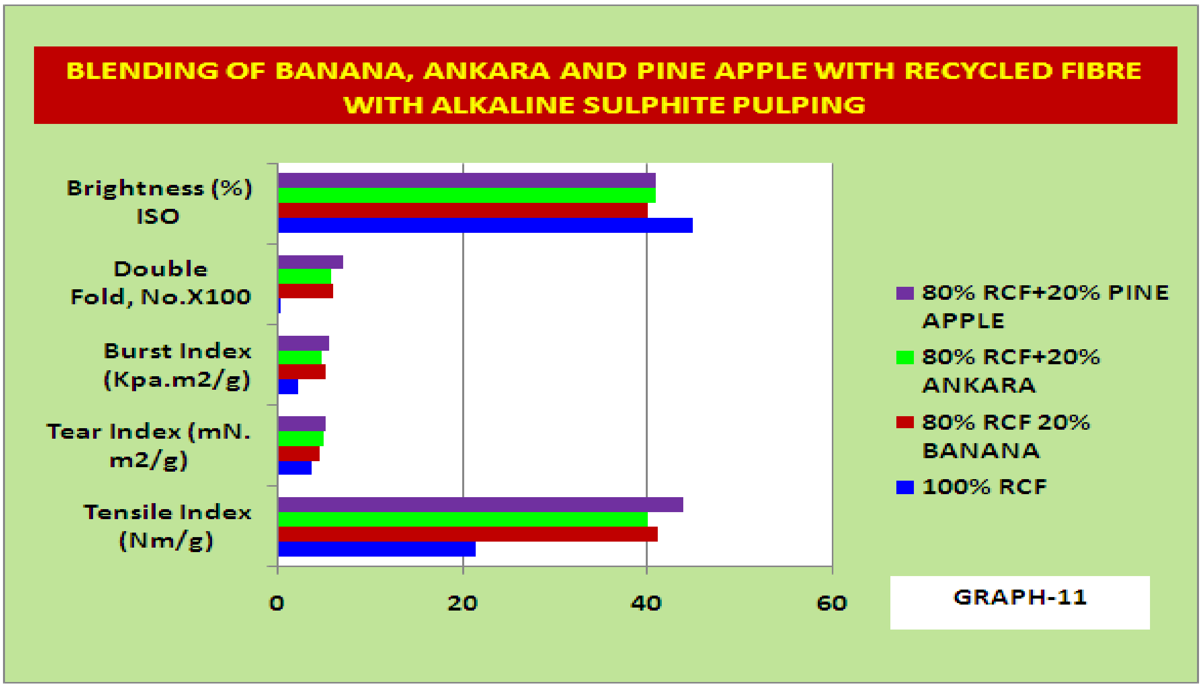


Table 24. - Physical strength and optical properties of the pulp from Alkaline Suiphite Pulping (ASP) Process (At ~ 300 ml freeness) Blended with Recycled Fibre (RCF).

S.N.	Characteristics	Banana(B)			Ankara(A)			Pineapple(P)		
	CSF	300			300			300		
		100% B	100% RCF	80% RCF +20%B	100%A	100% RCF	80% RCF +20%A	100%P	100% RCF	80% RCF +20%P
1.	Tensile Index (Nm/g)	84.91	21.4	41.11	79.01	21.4	40.00	82.33	21.4	43.81
2.	Tear Index (mN. m^2/g)	5.35	3.61	4.53	5.00	3.61	4.91	6.00	3.61	5.10
3.	Burst Index (Kpa.m^2/g)	6.10	2.20	5.01	5.70	2.20	4.71	6.20	2.20	5.41
4.	Double Fold, No.	9100	15.00	600	9000	15.00	570	16200	15.00	700
5.	Brightness (%) ISO	39.00	45.00	40.00	38.12	45.00	41.00	39.41	45.00	41.00



V. CONCLUSION

- These non-wood fibers have tremendous variations in chemical and physical properties. Of particular importance for pulping are fibre length, lignin content and cellulose content. Fiber length-Nonwood fibers average 3 mm (banana) and can be as long as 9 mm (pine apple). Lignin content-Lignin content of fibers is lower than that of any woody pulp. The low lignin content indicates that these fibres will require very mild pulping conditions. Cellulose content-Cellulose content of these fibers is 80% and higher.
- The raw materials used most commonly in handmade industry are the off cut of the textile industry ie hosiery waste in white colour as well as in mixed colours, cotton rags, off cut from HMPI, and recycled secondary fibres. Global trends towards sustainable development have brought to the light that natural, renewable, biodegradable raw materials, among them bast fibres, leaf fibres continue in extending their use in handmade paper industries.
- Recent new trend of applications of green fibres and related products permit to draw the following conclusions: Fast growing population as well as eco and health awareness create large space for future expansion of other than rag fibres. The change of consumer's taste also attract the handmade paper makers for the production and processing of these fibres in handmade paper industry.
- Due to fast progress in research and development, leaf and bast fibres are used for the production of non-wood pulps. This can help to stop forest depletion, flood of non biodegradable waste, environmental degradation. This can also rise living standard of rural areas in many part of globe.
- **Recycling** of natural fibre-reinforced composites is relatively easy and convenient. This fact makes one of the most important factors in forecasting the future **growth of production and consumption** of these materials.
- When preparation of natural fibers from the point of view of their homogeneity and quality would be improved, a new **big potential market** for natural fibers can emerge.
- Beating / Pulping of these raw materials is based on the use of non-polluting chemicals such as NaOH, peroxides, sulphite. It has been avoided to use harmful chemicals like sulphate, chlorine and chlorine compounds for the delignification processes. There is no any major pollution or negative impact on environment.
- The another very good use of these pulps are as to blend it with RCF(Recycled Fibre Pulp). As evident from the results depicted in tables 22, 23 and 24 that the strength properties increased remarkably in many parameters. Here, it may also recommended that these fibre can replace imported long fibre wood pulp sheets which are being imported by big paper mills.

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