Characterisation Of Ugandan Selected Grasses And Tree Leaves For Pulp Extraction For Paper Industry

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Abstract: All types of plants and their differentparts contain similar chemical constituents although in dissimilar quantities. Cellulose in form of fibres is among the most abundant constituents in all parts and types of plants, grasses and tree leaves inclusive. Cellulose fibresfrom plant materials can be isolated as pulp. Due to deforestation resulting from land pressure there is a growing insufficient supply of wood for pulp and paper industry. The land pressure emanatesfrom population explosion which relies on agriculture and wood as source of energy. There is a needof widening the alternative sources for pulp byembracing a number of non-wood materials. The aim of this work was to investigate the potential of using some selected grasses and leaves from selected trees that grow in Uganda. The selected grasses were *cymbopogon nardus*, *saccharum officinarum*, *digitaria scalarum* and *pasperumssp*while the selected trees were Pinus*spp*, *mangifera indica*, *ficus branchypoda* and *artocarpus heterophyllus.* Mature grasses and shed tree leaves for study were collected, prepared and their chemical composition determined using standard Tappi's methods as well as the standard Norman and Jenkins Methods. The Hollocellulose from the selected grasses varied from 60.97%-68.51% wt./wt. on oven dry basis while those of tree leaves from the selected tree plant varied from 32.08% to 45.59%. The α-Cellulose among the selected grasses and tree leaves varied from 26.19% - 35.00% and12.25% - 27.13% respectively.The lignin content of the selected grasses varied from 20.20% - 27.38%while for tree leaves it ranged from 36.62% - 49.09%. The hollocellulose, α-cellulose and lignin contents among the four selected grasses were equal or close to those of other non-wood materials and some typical softwood materials used in production of pulp. The hollocellulose and α-cellulose of the four tree leave were very low and lignin content was higher than those of most non-wood proved to be promising sources of pulp.Cymbopogon nardus is the most promising raw materials, followed by saccharum officinarum tops, then pasperum and finally digitaria scalarum. Tree leaves constituents makes the leaves to have low for priority pulp extraction.

Key words: *α-cellulose Lignin, pulp,non-wood materials and Uganda*

1INTRODUCTION

UGANDA being in the equatorial region is blessed with wide variety of grasses and tree species although a few of the trees grow to maturity due to the high rate of deforestation. As a result, there is insufficient wood to sustain the wood paper industry.This explains the undeveloped pulp and paper industry in country. In Uganda there are just three industries for pulp and paper recycling. One of these industries which had been built to produce virgin pulp from wood was recently turned to paper recycling plant. This has prompted an attempt to explore alternative sources of pulp for paper industry in the country like many other nations that do not have sufficient forests. Among the non-wood alternative sources of pulp which pose less environmental degradation effects are grasses and shed tree leaves. These materials have proved to be menace to the local communities who have less economic benefitsfrom them.

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In urban areas the waste grass is generated from mowing compounds,which generates vast amount of biomass of grasses such as pasperumamong others while waste leaves are generated from shedding compound trees. The collection and disposal of these waste materials tend to be a major problem to residents and municipal authorities in cities. In rural areas on the other hand, waste grasses accumulate as cleared material during the preparation of garden prior to the planting seasons. This large quantity of biomass is not beneficially utilized by the farmers but just end up being burnt. The increasing cost of pulp and paper as well as uncertainty of the future supply of wood have led to the principle focus of the current efforts of increasing the range of raw materials for pulp supply[*1*]. Therefore there is a renewed interest in the non-wood fibre sources due to the number of advantages these materials offer to the pulp and paper industry. First many of these materials have annual and biannual production compared to the long growth cycles for wood production. Also most of the non-wood sources have lower lignin contents making chemical and mechanical processes for non-wood pulping easier than pulping wood sources[*2*]. Non-wood fibres from different plant materials can be used in every grade of paper, paperboards and other composite materials. Non-wood materials such as grasses are more available due to the fact that they can regenerate easily and as a result they are less expensive. However there are some challenges associated with the processing of pulp from non-wood materials. First the handling costs are high due to their low densities, leading to bulkiness of the materials. However this can be overcome by the process of densification of the raw materials that can increase density up to about 150kg/m^3 before delivery[*3*]. Also there is a threat of security of supply of the raw materials, but in Uganda this may not be the case, since it has a warm climate andthere is no long spell of drought. Most of these grasses grow even in area with the very low moisture content in soils. Farmers in Uganda are more than ready to cultivate any crop if found to be income generating. Thirdly the high ash and silica content in the raw materials which may limit their uses for paper making. This can be minimised by avoiding soil contamination and putting measures of removing silica during the processing stages. Tree leaves as sources of fibres have a disadvantage of their availability being seasonal since many trees shed off leaves during particular seasons of the year. In order to identify the more suitable non-wood materials for pulp production, there is a need of evaluating a number of plant materials by analysing their chemical composition. Plant leaves and grasses, like wood are renewable resources that mainly consist of cellulose, lignin, hemi-cellulose, some terpenes, resins, inorganic elements and fatty acids although in dissimilar amounts. Chemical constituents in raw material for pulping are fractionated as Hollocellulose, lignin, ethanol-benzene extractives, 1% NaOH extractives,cold water extractives, hot water extractives and Ash Content. Cellulose is an organic compound with the formula $(C_6H_{10}O_5)_n$, a polysaccharide consisting of a linear chain of several hundred to over ten thousand linked D-glucose units [*4*]. Cellulose is the structural component of the primary cell wall of green plants, many forms of algae and the oomycetes. Lignin is a complex chemical compound most commonly derived from wood and it is an integral part of the secondary cell walls of plants and some algae. It fills the spaces in cell wall between cellulose, hemicellulose and pectin components and thereby crosslinks different plant polysaccharides conferring mechanical strength to the cell wall and by extension of the plant as a whole. [*4*][*5*]. Thus lignin is indigestible by animal enzymes. The 1% NaOH extractives are the low molecular weight carbohydrates present in the raw material and can be extracted by the 1% sodium hydroxide solution[*6*]. Ethanol-Benzene Extractives are comprised of some terpenes, resins and fatty acids and obtained by soxhlet distillation with ethanol–benzene solvent[*7*]. Ash is the residue left after igniting the dry material to higher temperatures and it is reported in percentage of residue to dry material basis. The ash content is mostly composed of metal salts such as silicates, carbonates, oxalates and phosphate[*8*]. The water extractives contain extraneous components such as soluble inorganic compounds, tannins, gums, sugars and colouring matter present in the raw materials. Hot watter in addition to the extractives with cold water it extracts starches[*9*]. Analysis of chemical composition of plant material with the potent of pulp production is very important since it discloses the cellulose content that constitutes pulp fibres and the amount of extractives that must be eliminated from the cellulosic fibres. Therefore the method and the conditions of pulping are determined depending on the chemical compositions of the fibre sources[*10*].

2MATERIALS AND METHODS

2.1 Raw Materials

Four different grasses and leaves from four different treeswere collected from the two regions of the country, Eastern and Central Uganda from both rural and urban areas. The selected grasses were *cymbopogon nardus*, *saccharum officinarum*, *digitaria scalarum* and*pasperum spp.* While the shed leaves were from the selected trees which included Pinus*spp*, *mangifera indica*, *ficus branchypoda*and*artocarpus heterophyllus.* Grasses were collected when the straws were bearing mature seeds. The materials were collected from the areas where they grow with economic advantage i.e. where they grow either naturally or planted in big quantities. The whole stalks above the ground in case of grass or the whole leaflets from shedding trees were sampled and prepared for analysed.

Table1. The Sampling Area and Common Names ofthe Materials Sampled

Raw materials sample	Scientific Name	Common Name	District of Sampling Area	Status of the Area
Grasses	1. *Cymbopogon nardus*	Citronella (Eng.)	Busia and Tororo	Rural
	2. *Saccharum officinarum*	Sugar cane tops (Eng.)	Mukono	Rural
	3. *Digitaria scalarum*	Couch grass (Eng.)	Mukono	Rural
	4. *pasperum*	Pasperum (Eng.)	Busia Mukono	Rural Urban
Shed Tree Leaves	1. *Pinus spp*	Coniferous tree (Eng.)	Tororo	Rural
	2. *Mangifera indica*	Mango tree(Eng.)	Tororo Mukono	Rural and Urban Rural and Urban
	3. *Ficus branchypoda*	Mukokowe (Lug.)	Mukono	Rural
	4 *Artocarpus heterophyllus*	Jack fruit (Eng.)	Mukono	Rural and Urban

2.2 Preparation of Materials

The collected samples were carried to the workshop, where they were cut in sizes of about 2-3 cmwith a cutter, screened to remove the fines, cleaned with distilled water to removed adhered soils, and dried in air drier at about 60^{o}C. After that the dry plant material were ground in the grinder to fine powder.

2.3 Chemical analysis

The different constituents of the plant materials were analyzed as follows;

(a) Cellulose content.

The total cellulose in the fibrous materials was determined by using the **Norman** and **Jenkins**standard method[*11*]. In this case the dry ground materials of 40-60 mesh were prepared first and extracted with alcohol-benzene combination. Subsequently, known weights of the fibrous material were treated with the combination of hypochlorite and sulphite to remove other binding materials and then the cellulose content determined gravimetrically.

(b) Extractives (ethanol- benzene)

The ethanol-benzene extractable materials of the plant materials were removed and determined using the Tappi standard method **T 204 cm-97**[*7*]. This method involved the soxhlet extraction of the air dried plant materials with a combination of ethanol and benzene at 1:2 v/v for about 8hours.

(c) 1% NaOH Extractives

The air dried raw materials were extracted with 1% of NaOH solution to remove and determine the low molecular weight carbohydrates according to the standard method **T212 om-88**[*6*]. In this method an appropriate mass of material was treated with 1 % of hot NaOH solution for one hour, the extract was evaporated to dryness and the residues determined gravimetrically.

(d) Lignin content.

The Norman and Jenkins' method was used to determine lignin content by cold treatment of dry residues from the alcohol-benzene soxhlet extraction with concentrated sulphuric acid. And lignin was precipitated by refluxion in diluted acid and determined gravimetrically[*11*].

(e) Ash Content

The ash content of the dried plant materials was analyzed in accordance to TAPPI standard method T 211 om-93 which involved the combustion the materials at 525^{o}C in a muffle furnace and then the residue ash quantified gravimetrically[*8*].

(f) Cold Water Extractives

Cold water extractives were determined by the standard Tappi method T207 cm-99. First the prepared ground samples(10g) were placed in a beaker, slowly soaked with water (300ml) and continuously stirred for 48hrs at 23^{o}c. The materials were filtered and then washed with cold water (200ml). The residue materials were dried to constant weight at 105^{o}c and then weighed after cooling[*9*].

(g) Hot Water Extractives

Hot water extractives were also determined using the standard Tappi Methods T 207 cm-99.First the prepared ground samples (10g) were placed in a distilling flask, soaked with hot water (100ml) and refluxed for 3hours on a water bath. After filtering and washing, the residues were dried at 105^{o}c to a constant weight[*9*]. Therefore this research study is intended to explore more potential alternative sources of pulp for paper industry.

3RESULTS AND DISCUSSION

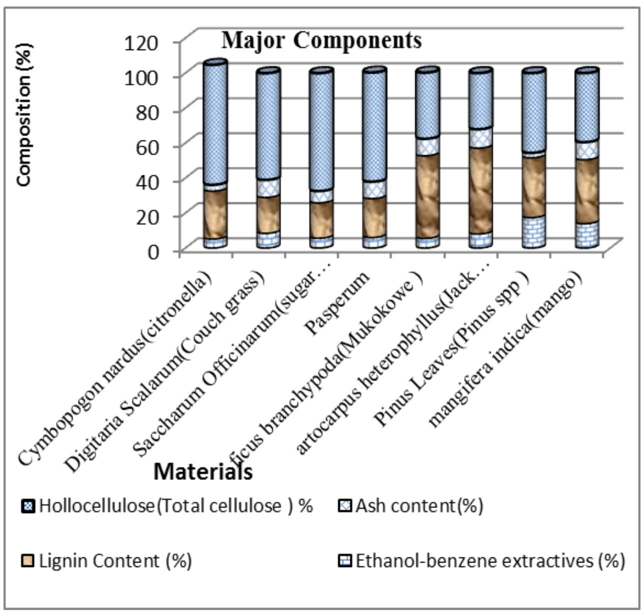
The chemical composition of the selected grasses and tree leaves are presented in Table2.Results show that the chemical constituents of grasses and tree leaves are similar to those of wood which is commonly used in production of pulp for paper industry though in dissimilar magnitude. The results indicate that all the selected plant materials contained constituents such as Hollocellulose, lignin, ethanol-benzene extractives, ash content,α-cellulose, cold water extractives and hot water extractives although in dissimilar amounts.

Table 2. Chemical Composition of the Different Grasses and Tree Leaves

Materials	**GRASSES**				**TREE LEAVES**			
	***Cymbopog on nardus* (citronella)**	*Digitaria Scalaru m* (Couch grass)	*Saccharu m Officinaru m* (sugar cane Tops)	*Pasperu mspp*	*ficus branchypod a* (Mukokowe)	*Artocarpus heterophyllu s*(Jack fruit)	Pinus Leaves (*Pinus spp*)	*mangifer a indica* (mango)
Major Components								
Hollocellulose (Total cellulose) %	68.51	60.97	67.39	62.36	37.80	32.08	45.59	39.44
Lignin Content (%)	27.38	20.49	20.20	22.27	47.25	49.09	34.19	36.62
Ethanol-benzene extractives (%)	5.14	8.42	5.60	6.00	5.50	8.00	17.36	13.86
Ash content (%)	3.66	10.06	6.77	9.69	9.73	10.82	2.84	10.07
α-Cellulose %	35.00	31.81	29.07	26.13	12.25	13.34	27.13	13.34
Other Extractives								
Cold water extractives	15.00	20.00	15.00	15.00	10.00	12.50	17.50	22.50
Hot water extractives	20.00	27.50	22.50	20.00	17.50	22.50	27.50	37.50
1% NaOH Extractives(%)	25.99	35.65	37.01	36.82	39.38	45.09	38.10	46.25

3.1 Hollocellulose

The percentage composition of Hollocellulose of all grasses are very close to other non-wood materials and wood from tree species commonly used in production of pulp for paperindustry. The Hollocellulose from the selected grasses varied from 60.97%-68.51% as compared to that of bamboo of 67.1%[*12*], Corn stalk 61.6% [*13*],Anatolian black pine 72.34% [14] and Silver Birch *(Betulaverrucosa*)73.4%[*15*]. Tree leaves samples contained very low Hollocellulose which ranged from 32.08% to 45.59%, almost a half of those of wood materials. From fig 1 it can be observed that cellulose was the most dominant fractional component among the grasses. From fig 2 it is observedthat cymbopogon nardus had the highest Hollocellulose content among the grasses with 68.51%, followed by *saccharum officinarum* with 67.39%, then*pasperumspp*with 62.36% and then digitaria scalarum being with the least of 60.97%. Among the tree leaves the Pinus spp had slightly higher Hollocellulose than others with a concentration percentage of 45.59% and *artocarpus heterophyllus* the least amount of 32.08%.



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3.2 α-Cellulose Content

From Table1 it is observed that α-Cellulose among the selected grasses varied from 26.19% - 35.00%.These α-Cellulose values were very close to some of non-wood materials that have been recommended for pulp production,for example switch grass 41.8%-43.4%[*16*][*17*],Arundo-donax reed 32.6%[*18*] wheat stalk 29%- 35%[*19*]and also very close those softwood for example hybrid poplar 29.7% [*16*] and spruce 39.5%[*15*]. α-cellulose is the fraction of the Hollocellulose which is insoluble 17.5% NaOH. Among the grasses evaluated *cymbopogon nardus* has the highest α-cellulose content with 35.0%, followed by *digitaria scalarum*31.81%, then *saccharum officinarum tops*29.07%, and least in *pasperum* at 26.13%. According to the rating system designated by Nieschlag et al 1960 described that plant materials with 34% and over of α-cellulose content were characterized as promising for pulp and paper manufacture from a chemical composition view[*20*][*18*]. According to this categorisation *cymbopogon nardus* is promising among the selected grasses. But it seem to be long since the rating system was set up, according to the increasing demand of pulp and paper as well as increasing deficiency of wood this rating may have come down to embrace plant materials with α-cellulose as low as 26% . All the selected tree leaves were identified with low α-cellulose content ranging from 12.25% - 27.13%. Therefore leaves from *ficus branchypoda*with 12.25%, *Artocarpus heterophyllus*with 13.34% and *mangifera indica* 13.34% may not be profitable for pulp production.*Pinus* needle leaves with α-cellulose composition of 27.50% may be considered for pulp production

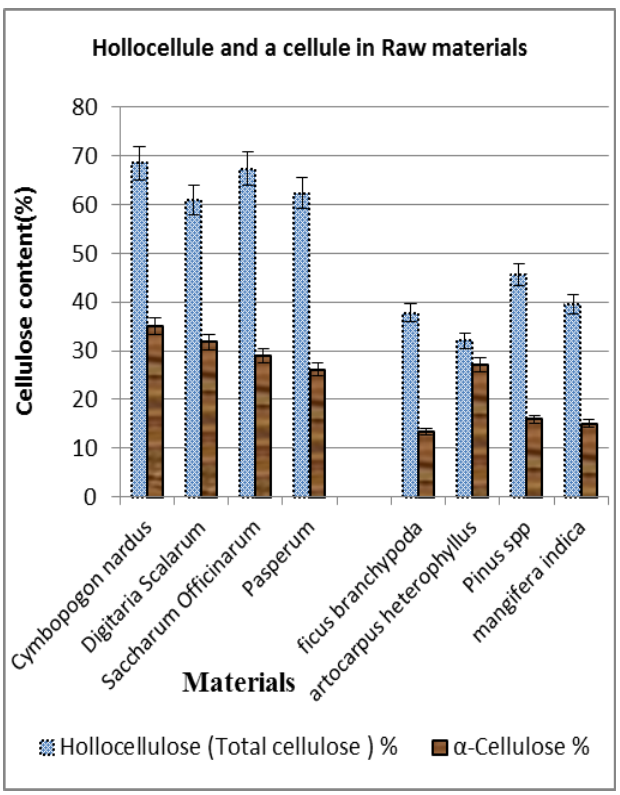

Figure 2 showing Hollocellulose and cellulose in different plant materials

3.3 Lignin Content

From Table 2 it is observedthat the lignin content of the selected grasses varied from 20.20% - 27.38% while for tree leaves, it ranged from 36.62% -49.09%. The lignin contents among the grasses were within the satisfactory level(<30%). In practice this means that these materials need in general milder conditions(i.e. lower temperatures and chemical charges) than those of softwoold and hardwood in order to reach a satisfactory kappa number[*18*].Tree leaves had higher lignin contents thus it is evedent that if they were to be pulped they are expected to require severe pulping conditions than grasses. Among the grasses *cymbpogon nardus* had the highest lignin content of 27.38%, followed by pasperum at 22.27%, then by *dagiteria scalarum* with 20.40% and the *sacharum Officinarum*had the least amount of 20.20% (fig. 3). From figure 3it is observed that among the tree leaves, *Artocarpus heterophyllus* had highest lignin content of 49.09%, followedby *ficusbranchypoda 47.25*%, then by *mangifera indica* 36.62% and Pinus Leaves with the least lignin 34.19%

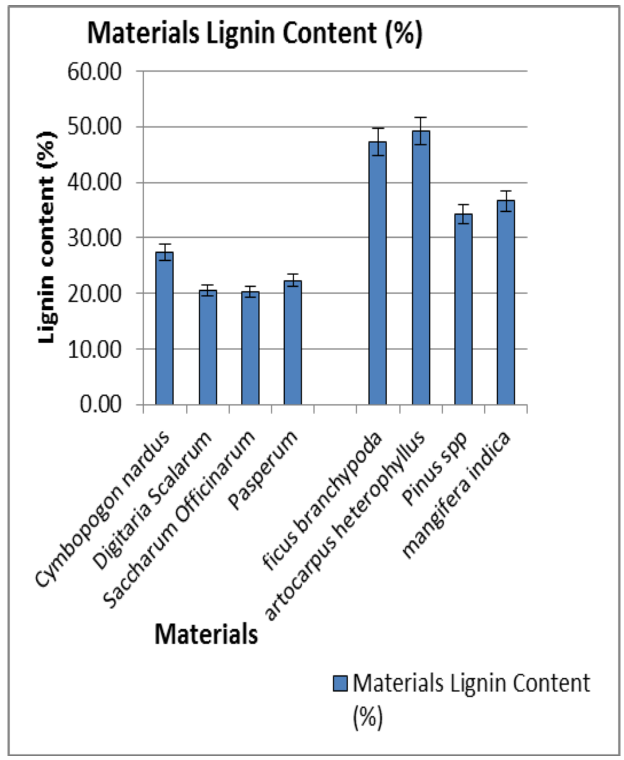

Figure 3 Lignin content for different plant materials

3.4 Ash Content

Generally the ash contents of grasses were lower than those of tree leaves. The ash content of the selected grasses ranged from 3.66% – 10.06% and those of tree leaves ranged from 2.84% - 10.82%. All these were within range values of most non-wood fiber raw materials, for example they were less than that reported for rice straw of 16.6%[*21*]. Ash high content is undesirable during refining and recovery of cooking liquor [*22*]as the trace elements interfere with H_2O_2 and O_2 during bleaching and also the alkali earth metals passed in the pulp[*23*].

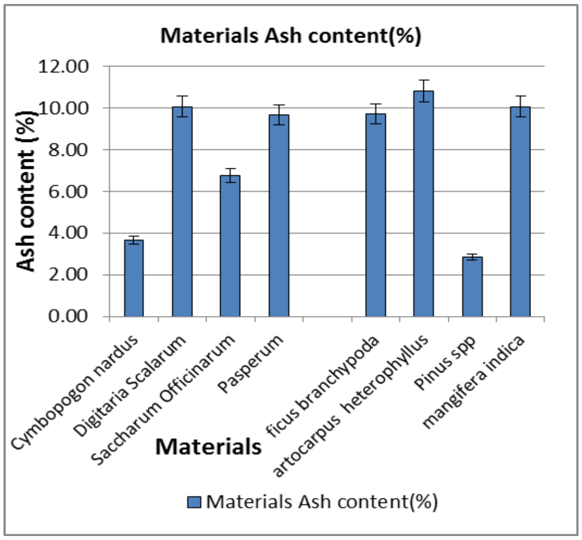

Figure 4 Ash content of the selected plant Materials

3.5 Extractive Materials Contents

Extractive materials were categorised into four depending on extraction solvent as alcohol-benzene, 1% NaOH, hot water and cold water extractives. Alcohol–benzene extractives consists of waxes, fats, resins, photosterols, non-volatile hydrocarbons, some low-molecular carbohydrates, salts and some water soluble substances. From table2, it is observed that the alcohol-benzene extractives among the selected grasses varied from 5.14% - 8.42%. These values are within limits of many non-wood materials that have been already researched upon for example sofia grass (*cymbopogon martini*) of 5.86%,*arundodonax* 7.30%[*24*], Tobacco stalks 7.10%[*25*]and corn stalk of 9.50%. Alcohol- benzene extractives of the four selected grasses were higher than those of most wood e.g. Anatolian black pine with 3.45%. The alcohol-benzene extractives among the selected tree leaves were ranging from 5.50% -17.36 % and were higher than those grasses evaluated fig 5. Among the grasses *cymbopogon nardus* had the least alcohol- benzene extractives and for leavesof *ficus branchypoda* had the least amount of 5.50% and pinus had the highest with 17.36%. The high alcohol –benzene in raw materials results in creation of pitch which is a resinous compound that adversely affects the runnability of the process equipments due to choking of fourdrinier wire and quality of paper in terms of shadow marking[*26*][*27*]. From Table2 it is revealed that the 1% NaOH extractives among the selected grasses varied from 25.99% to 37.01% and those tree leaves varied from 38.10% to 46.25%. 1% NaOH extractives indicates the amount of low-molecular–weight carbohydrates consisting mainly of hemicelloses and degraded cellulose. It indicates the degree of a fungus decay or degradations by heat, light, oxidation etc[*28*][*29*]. As more of the raw materials decay or cellulose degrades or high amount of low molecular carbohydrate, the greater the alkali soluble materials. The presence of high NaOH extractives indicates that the raw material could not be stored for a longer period after havesting. From above quoted values it shows that all the four tree leaves do not need to be stored for long[*27*]. From fig5 *cymbopogon nardus* had the lowest NaOH extractives of 25.99% among the selected grasses and *Mangifera indica* had the highest extractives of 46.25%. The NaOH extractives are with the range of values identified by most non-wood materials for example H Cannabinus (25.8%), chenopodium album (30.00%)[*27*], lemon grass (30.64%) [*24*] sunflower 50.4% [*30*]cotton stalks 39.60% [*31*]and tobacco stalk 42.00% [*25*]. But it is lower than that of wood for example *eucalyptus grandis* 17.9%[*25*] and *pinus nigra arnold ssp* 13.0% [*14*]. The water extractives contain extraneous components such as soluble inorganic compounds, tannins, gums, sugars and colouring matter present in the raw materials. Hot watter in addition to the above extracts starches[*23*]. The hot water extractives ranged from 20.00 % to 27.50% among the four grasses and from 17.50 to 37.50% among the leaves of the four selected trees. The cold water extractives also varied from 10.00% to 22.50% among all selected materials. Both cold and hot extractives did not vary much between grasses and tree leaves and were in ranges of values already identified with other non-wood materials but higher than those of wood. *Mangifera indica* had the highest water soluble extractives both for cold water (22.50%) and hot water (37.50%).

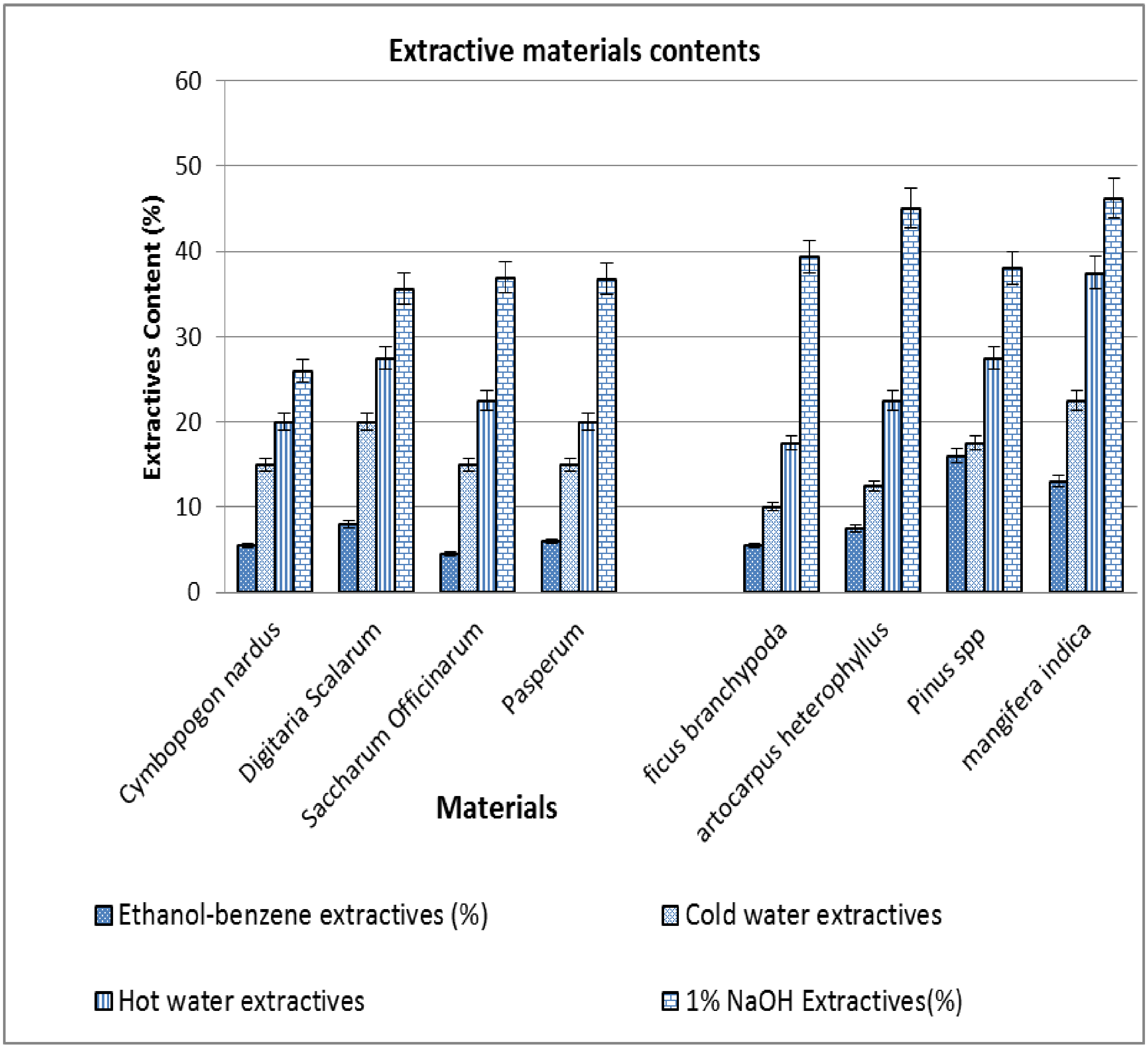

Figure 5 The Extractives of the selected materials

4 CONCLUSION
According to the chemical composition of the desirable components of the materials evaluated, all the four grasses may be exploited for pulp production. Theranking in order of priority pulp extraction isthat *cymbopogon nardus* is the most promising raw materials, followed by *saccharum officinarum* tops, then *pasperum* and finally *digitaria scalarum*. Because of the low quantity ofHollocellulose and α-cellulose; and high lignin content contained in tree leaves, their priority pulp extraction is low.

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