Water Hyacinth (Eichhornia Crassipes) for papers & Boards

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SUMMARY

Water hyacinth (*Eichhornia Crassipes*) - the most prolific aquatic weed can be utilised for making papers and paper board and greaseproof paper in particular Based on the laboratory investigations carried out at Regional Research Laboratory, Jorhat, an integrated pilot plant for making handmade papers is being set up at Regional Research Laboratory, Hyderabad, for making different varieties of papers and paperboards and collect the operational and other relevant data to evaluate the economics of utilisation of Water hyacinth for paper & board making.

The work has been carried out in India at Regional Research Laboratory, Jorhat, as a part of the project - 'Management of Water hyacinth', - launched by the Commonwealth Science Counsil (CSC) under Commonwealth Regional Rural Technology Programme and funded by the United Nations Environment Programme (UNEP).

INTRODUCTION

In recent years, Paper Industry is facing an acute shortage of fibrous raw materials. The ever increasing demand of fibrous raw materials has made it imperative to investigate alternative fibrous materials other than the conventional bamboo and wood, as these two raw materials may not be able to feed the entire demand of Paper Industry in our country. It has been said on many occasions that the agricultural residues, like bagasse, jute, grass, rice straw, wheat straw, etc. may play an important role in providing alternate raw materials for the paper industry. Water hyacinth (*Eichhornia Crassipes*) - another fibrous cellulosic raw material has not so far been tried for paper making, even on small scale. Water hyacinth is one of the most prolific weed which spreads at an alarming rate, having spikes of large blue flowers and roundish leaves with inflated bladder like petioles. The floating aquatic weed has adapted exceedingly well to almost every area into which it has been introduced and exists as a stable component of the tropical regions creating a serious environmental and hygienic problems to the inhabitants of that place in particular. Due to its vegetative propagation and extremely high growth rate, water hyacinth spreads rapidly, clogging drainage, ditches, shading out other aquatic vegetation and interfering with shipping and recreation. Regarding the availability of raw marerials it has been recorded that in Louisiana, USA, a single Water hyacinth produced the incredible number of 248,000 daughter plants in just 90 days[2]. It is reported that a one hectare pond of water hyacinth can produce 0.9 to 1.8 tonnes of dry mass of weed per day[3]. The disadvantages associated with this alarming rate of growth can be an advantage if the Water hyacinth be effectively utilised for any industrial purpose.

Scanning of literature in the field indicates insignificant amount of informations and reports relating to the pulping and paper making from Water hyacinth. The utilisation of Water hyacinth for making pulp and paper products are rather controversial, considering previous works carried out by different research groups in different parts of the world. The Phillippines research group on water hyacinth utilisation claims to have produced quality paper, while research workers of the University of California, after extensive testing, have expressed their complete disappointment as a source

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of paper pulp[2]. Exhaustive investigations have been made at the University of Florida with a view to making paper using various pulping conditions; these have reportedly been a failure[4]. The failure was ascribed to moisture clinging to the fibre with the result that the pulp cannot be drained or dewatered in modern high speed paper forming machines[5]. Azam[6] reported that the whole plant cannot be used for paper making as the dried leaves are brittle and the roots are rather dark in colour, which makes the pulp dirty and brittle, but that the pulp made from the stalk gives satisfactory results. The use of potassium hydroxide as the cooking chemical and digestion at atmospheric pressure of the stalk and leaves have been mentioned[7].

Nolan and Kirmse[4] reported that the alkaline pulps gave the highest, while the bisulfite pulp had the lowest strength properties in blends with pine kraft pulp. The tear factor decreased and the breaking length inereased as the proportion of the water hyacinth pulp in the blend was increased. The burst factor increased with increasing percentage of water hyacinth pulp in the blends. Kraft pulp and bisulfite pulps gave the highest and lowest burst respectively. The use of petioles along instead of the whole plants improved the breaking length and tear factor slightly but decreased both the freeness and the burst factor. The breaking length and the burst factor were higher than those of the pine kraft pulp, but the tear factor was much lower. It is reported that the papers lacked the strength properties needed for packaging purposes[14].

PROXIMATE ANALYSIS

Watar hyacinth plants are collected from a pond situated at Alengmara about 10 km from RRL, Jorhat. The weights and the proportions of water hyacinth plants vary considerably in different samples. collected in different seasons from different places. A typical whole green plant contains 24.8% root, 41.9% stalk and 33.3% leaf. Only the stalk is used in our present investigations.

The proximate analysis of water hyacinth is carried on by adopting standard procedures of the Technical Association of Pulp and Paper Industry, USA. For this pupose, water hyacinth stalk is first washed with water and then dried in the oven. The dried material is powdered and sieved. The fraction which passes through 60 BSS mesh and retained on 80 BSS mesh (i.e.–60+80) is used for proximate analysis. The average moisture content of the material as harvested is 95%. The proximate analysis is given in Table-1

For the determination of fibre length. the stalk is chopped and digested, bleached and washed until it is reduced to a white pulp, composed of cellulose fibres free from other matters such as lignin and non-cellulosic constituents. The fibres are then examined under the microscope, and the length and diameter are measured and the average maximum and minimum results are reported. The fibre length and diameter are given in Table-II. The composition and fibre dimensions of water hyacinth and some typical cellulosic raw materials are given in Table-III.

TABLE—I PROXIMATE ANALYSIS

Sl. No.	Tests	% on oven dry basis
1.	Cold water solubility	15.7
2.	Hot water solubility	17.0
3.	1% Caustic soda solubility	46.8
4.	Alcohol : Benzene (1 : 2) solubility	10.6
5.	Lignin content	6.7
6.	Pentosan content	14.2
7.	Cellulose (Cross & Bevan)	29.0
8.	Ash content	18.4
9.	Moisture content of the sample	13.8

TABLE—II FIBRE LENGTH AND DIAMETER OF WATER HYACINTH PULP

Sl. No.	Characteristics	Minimum	Maximum	Average
1.	Fibre length (mm)	0.66	2.53	1.604
2.	Fibre diameter (micron)	1	20	5.5

PULPING

Water hyacinth stalks are collected and then crushed and squeezed in crushing machine fabricated in the laboratory. The initial moisture content of the stalks is about 95-96%. After crushing, the moisture content comes down to about 50–60%. This crushed material is used in all the investigations in the laboratory. Experiments are carried out for the optimisation of different parameters for digestion of the crushed water hyacinth for making the pulp by pre-hydrolysis-soda, soda, sulphate and alkaline-anthraquinone processes. The digestion is carried out in a 5-Litre stainless steel autoclave with indirect heating. The quantity of chemicals and the temperature are varied whereas in all the experiments the material to liquor ratio used is 1:6. The temperature in the digester is raised to maximum at a steady rate and allowed to remain at the maximum temperature for the desired cooking time. The cooked material is discharged from the autoclave to a vessel with perforated bottom and washed thoroughly with water to get the unbleached pulp free from alkali. The yields of the pulp at different cooking conditions and the respective permanganate numbers are determined. The results are tabulated in Table–IV.

BLEACHING

The unbleached pulp is bleached by two stage hypochlorite bleaching sequence with an intermediate alkali extraction.

In the first stage, 'hypochlorite, 60% of total chlorine requirement is added according to the demand, at a consistency of 10% for about 120 minutes at 30°C with occasional slow agitation. The pulp is washed thoroughly with water and then extracted with 1% sodium hydroxide at a consistency of 10% for 60 minutes at 60°C. This is washed thoroughly before the second stage hypochlorite treatment. In the second or final stage of bleaching, hypochlorite, 40% of total chlorine demand is added to the pulp at a consistency of about 10% and kept at 30°C for 120 minutes with occasional agitation. After the retention time the pulp is washed thoroughly with water. The yields of bleached pulp are determined; the test results are given in Table–V. Bleached and unbleached pulp yields from water hyacinth along with some other raw materials are recorded in Table–VI.

SHEET MAKING

Bleached and unbleached pulps are beaten in a standard laboratory valley beater at 5% consistency to a freeness of 350 c.c. CSF and handsheets are made in a standard laboratory sheet forming machine (20 cm dia). The strength properties of unbleached and bleached paper are determined according to TAPPI standard procedures. Results are given in Table–VII and VIII respectively, The strength properties of papers made from water hyacinth and other raw materials, as well as blended with other pulps are given in Table–IX and X.

TABLE—III COMPOSITIONS AND FIBRE DIMENSIONS OF SOME TYPICAL VEGETABLB RAW MATERIALS

Raw materials or type of fibres	Proximate analysis			Average dimensions	
	Ash %	Lignin %	Cellulose %	Length (mm)	Diameter (micron)
Water hyacinth	12-18.4	6-10	28-35	1.6	5.5
Straw	15-18	12	32	1.1	16
Bagasse	2-6	18-21	32-41	1.4	18
Bamboo	2-4	20-32	30-40	1.4-3.8	9-22
Cotton	—	—	92-97	18	20
Jute	—	12	57	2	22
Softwood Temperate coniferous woods	1.0	26-30	40-45	—	—
Indian softwoods	1.0	28-30	39-46	2.7-3.6	27-52
Hardwood Temperate coniferous woods	1.0	18-25	38-49	—	—
Indian Hardwoods	0 4-1.8	21-28	35-45	0.7-1.8	9-44

TABLE—IV COOKING COMPOSITIONS & YIELD OF WATER HYACINTH PULP

Sl. No.	Cook	Type of cooking	Total chemical NaOH	Total chemical Na_2S	Total chemical H_2SO_4	Total chemical Anthra-quinone	Cooking temperature	Cooking Pressure	Cooking period at top temperature	Permanganate No. ($KMnO_4$ No.)	Unbleached pulp yield (on O.D. basis)
			%	%	%	%	°C	kg/cm^2	(Mints.)		%
		Soda									
1.	A		5.0	—	—	—	130	3.0	120	17.0	35
2.	B		7.5	—	—	—	130	3.0	120	15.6	30
3.	C		10.0	—	—	—	130	3.0	120	14.4	28
		Sulphate									
4.	D		3.75	1.25	—	—	130	3.0	120	18.2	34
5.	E		5 625	1.875	—	—	130	3.0	120	15.0	29
6.	F		7.5	2.5	—	—	130	3.0	120	15.0	25.5
		Water Pre-hydrolysis									
7.	G	Ist stage	—	—	—	—	130	3.0	120	19.2	44.5
		IInd stage	2.0	—	—	—	130	3.0	120		
		Acid Pre-hydrolysis									
8.	H	Ist stage	—	—	0.5	—	130	3.0	120	14.0	28
		IInd stage	2.0	—	—	—	130	3.0	120		
9.	I	Ist stage	—	—	1.0	—	130	3.0	120	8.8	18
		IInd stage	2.0	—	—	—	130	3.0	120		
		Soda-Anthraquinone									
10.	J		5.0	—	—	0.10	130	3.0	120	15.5	37.0
11.	K		5.0	—	—	0. 5	130	3.0	120	15.2	37.0
12.	L		5.0	—	—	0.50	130	3.0	120	15.0	36.0

TABLE—V BLEACHING CONDITIONS OF WATER HYACINTH PULP

Sl. No.	Cook No.	Hypo treatment: Ist stage hypo treated at 10%cy for 120 min at 30-40°C. %	Alkali Extraction: Alkali Extraction at 10% cy for 60 min. at 60°C. %	Hypo treatment: IInd stage Hypo for 120 min. at 30-40°C. %	Yield of bleached (on O.D. basis) %
1.	A	4.8	1.0	3.2	28.0
2.	B	4.7	1 0	3.1	25.0
3.	C	4.3	1.0	3.0	22.0
4.	D	4.9	1.0	3.2	27.0
5.	E	4.3	1.0	3.2	25.0
6.	F	4.2	1.0	2.8	20.0
7.	G	5.7	1.0	3.8	27.0
8.	H	2.6	1.0	1.7	15.0
9.	I	4.2	1.0	2.8	24.0
10.	J	4.7	1.0	3.0	32.0
11.	K	4.6	1.0	3.0	31.2
12.	L	4.5	1.0	3.0	31.0

TABLE—VI BLEACHED AND UNBLEACHED PULP YIELDS FROM WATER HYACINTH ALONG WITH SOME OTHER RAW MATERIALS

Sl. No.	Types of pulp	Unbleached pulp yield %	Bleached pulp yield %
1.	Water hyacinth	35	25
2.	Straw[9]	35-45	—
3.	Bagasse[10]	35	30.5
4.	Bamboo	44	36
5.	Softwood[12]	50-55	40-48
6.	Hardwood[12]	37-43	33-40

TABLE—VII TEST RESULTS OF UNBLEACHED PAPERS MADE FROM WATER HYACINTH PULP

Sl. No.	Cook No.	Basis wt. gm/m^2	Bulk density cc/gm	Breaking length metre	Burst factor	Tear factor	Folding endurance (Double fold)
1.	A_1	60.2	1.55	3770	23	30	5
2.	B_1	60.0	1.50	3700	22	34	8
3.	C_1	60 3	1.52	3550	19	37	12
4.	D_1	60.0	1.58	3820	26	29	22
5.	E_1	60.2	1.59	3770	22	27	26
6.	F_1	59.8	1.56	3550	23	25	22
7.	G_1	60.1	1.65	2210	13	45	15
8.	H_1	59.6	1.62	3600	22	30	3
9.	I_1	60.1	1.63	3310	20	33	2
10.	J_1	59.8	1.80	3900	25	31	25
11.	K_1	59.3	1.80	3880	24	30	22
12.	L_1	60.2	1.81	3910	22	32	23

TABLE—VIII TEST RESULTS OF BLEACHED PAPERS MADE FROM WATER HYACINTH

Sl. No.	Cook No./Type	Basis wt. gm/m^2	Bulk density cc/gm	Breaking length metre	Burst factor	Tear factor	Folding endurance (Double fold)
1.	A_2	59.5	1.30	3710	22	33	3
2.	B_2	59.2	1.25	3660	20	36	7
3.	C_2	60.1	1.27	3500	17	39	10
4.	D_2	60.1	1.33	3790	24	31	18
5.	E_2	60.5	1.34	3600	21	30	25
6.	F_2	59.9	1.34	3500	20	28	18
7.	G_2	60.2	1.40	2100	11	43	12
8.	H_2	60.0	1.38	3550	21	32	5
9.	I_2	60.2	1 37	3220	19	30	1
10.	J_2	60 2	1.55	3875	24	32	23
11.	K_2	60.1	1.55	3865	23	32	22
12.	L_2	60.2	1.55	3870	23	33	22

TABLE—IX TEST RESULTS OF THE PAPER MADE FROM WATER HYACINTH PULP AND PAPER FROM OTHER RAW MATERIALS

Sl. No.	Stock composition	Basis weight gm/m²	Bulk density cc/gm	Breaking length metre	Burst factor	Tear factor	Folding endurance double folds
1.	Bleached water hyacinth pulp sheet	60.1	1.30	3710	20	33	3
2.	Bleached rice straw Pulp sheet[13]	60.0	1.32	2110	10	30	2
3.	Bleached bagasse pulp sheet	60.2	1.45	4250	29	57	12
4.	Bleached bamboo pulp sheet	60.0	1.33	4115	36	90	85
5.	Unbleached water hyacinth pulp sheet	59.8	1.55	3778	21	30	16
6.	Unbleached rice straw pulp sheet[12]	60.0	1.52	2360	11	32	3
7.	Unbleached bagasse pulp sheet	60.1	1 48	5585	40	47	36
8.	Unbleached bamboo pulp sheet	60.0	1.35	6220	40	84	125

TABLE—X TEST RESULTS OF PAPERS MADE FROM WATER HYACINTH PULP BLENDED WITH OTHER PULPS

Sl. No.	Stock composition	Blending propor-tions	Basis weight gms/m²	Bulk density cc/gm	Breaking length metre	Burst factor	Tear factor	Folding endurance double fold
1.	Bleached water hyacinth pulp +bleached bamboo pulp	100 0	60.1	1 30	3710	20	33	3
2.	—do—	90 10	60.0	1.30	3750	22.5	46.3	10
3.	—do—	75 25	60.0	1.32	3800	24 2	56.3	15
4.	—do—	50 50	60.1	1.35	3880	26.0	72.0	36
5.	—do—	25 75	60.5	1.33	4000	34.2	82.8	75
6.	—do—	0 100	60 0	1 33	4115	36	90.0	85
7.	Bleached water hyacinth pulp +Rag pulp	90 10	60.3	1.35	3550	21.2	45	8
8.	—do—	75 25	60.6	1 40	3600	22.0	51	16
9.	—do—	50 50	60.3	1.45	3750	22.7	55	25
10.	—do—	25 75	62 2	1.55	3895	23.8	62	32
11.	—do—	0 100	60 1	1.60	4050	24.9	70	40

TABLE—XI TEST RESULTS OF GREASEPROOF PAPER MADE FROM WATER HYACINTH

1.	Basis weight, g s.m.	—	45.0
2.	Bulk density, cc/gm	—	0 75
3.	Breaking length, m	—	5080
4.	Burst factor	—	49
5.	Tear factor	—	26
6.	Folding endurance, double folds	—	12
7.	Blister test	—	very good
8.	Transudation period, secs	—	1800

DISCUSSION

Investigations are first made in the laboratory using the pulp from the whole plant, consisting of root, stalk end leaves, but this affects the quality of the paper to a great extent, because the dried leaves are comparatively brittle and the roots are rather dark and stiff. Hence, the paper made from such pulp becomes dirty, brittle and gritty, because of the unequal tension of the fibres and also the interference of silicious particles. It has been observed during our investigations that the paper made from only stalk pulp gives the most satisfactory results. The use of the leaves is optional but the roots are discarded. However. there is no difficulty in using the green leaves along with stalk.

In the alkaline pulping process, the yield decreases with an increase in the concentration of alkali, keeping all other parameters constant. The permanganate number of the pulps ranges from 17.0 to 14 4 for the minimum to maximum chemicals used.

In the sulphate process, the yield appears to be lower than the soda. process, and the bleach requirement is also slightly higher. The original freeness of the pulp is also much lower in this process.

In prehydrolysis soda process the yield is considerably lower in comparison to soda and sulphate process but the yield shows higher in water hydrolysis. The bleach requirement is higher in case of water hydrolysis but lower in acid hydrolysis.

The alkaline process with the addition of a small quantity of anthraquinone is the best, so far as the test results are concerned. In this case the yield is slightly higher, the strength properties are slightly better than all other processes as described above.

Two stage hypochlorite with an intermediate alkali extraction is found to be satisfactory for bleaching water hyacinth pulp.

Water hyacinth pulp can be beaten in a very short time in order to get the desired degree of freeness and hence the energy requirement is much less. However, the pulp becomes too hydrated with a higher beater load and thus the drainage rate becomes very low and under such circumstances it may be difficult to use it in modern high speed paper machines. The pulp thus requires very careful beating or refining.

The shrinkage property of unbleached pulp is rather high. However, this can be minimised by careful bleaching, stock preparation and by adding about 10% of waste papers or any other fibre such as bamboo, jute, rag etc.

The fibre length and the strength characteristics indicate that good quality papers can be made from water hyacinth. Although the tear factor and folding endurance are lower, the tensile and the bursting strengths are comparable with those prepared from some conventional raw materials.

It has been observed that water hyacinth requires much less chemicals for cooking and can be cooked at a lower temperature and pressure. The bleach consumption is low. The pulp yield is however low and in the range of 30-35%. Due to the soft and weak fibre characteristics of water hyacinth pulp, the beating time to get the desired degree of freeness is exceptionally low resulting in a very low power consumption for stock preparation. But with higher beater load the pulp becomes too hydrated and thus the drainage rate becomes very low and under such circumstances it may be difficult to use it in modern high speed paper machines. The pulp thus requires very careful beating or refining.

A major drawback of water hyacinth pulp is its easy hydration and slow drainage properties making it difficult to use in high speed machines. To overcome this problem, investigations have been carried out for making greaseproof paper, a speciality paper which is made at a higher freeness from a very hydrated stock. This highly hydrated stock imparts, certain desirable properties which include high sheet density, high transparency and resistance to the passage of oil or grease. Grease proof paper finds extensive applications in packaging industries—for packaging different types of products like—dairy products, dehydrated foods, pharmaceuticals, surgical instruments, sophisticated machines and machine parts.

For making greaseproof paper, the pulp is prepared in the usual manner as described above. The stock is beaten in a standard laboratory valley beater to a freeness of 150 cc CSF and standard sheets are made in the standard laboratory sheet forming machine. The strength characteristics of the hand sheets are determined and the resulsts are given in Table-XI.

It is significant to note that water hyacinth pulp can be beaten to a freeness of 150 cc CSF in a standard beater in 10 15 minutes time to get properties required for making greaseproof paper. Table-XI above indicates that the Blister test and the Turpentine transudation test are very good, the bursting strength and the breaking length are comparable whereas tear factor and folding endurance are poor. It may therefore be concluded that water hyacinth may be an excellent raw material for making greaseproof papers for some of its uses particularly in the countries where suitable raw materials for making greaseproof paper are not available. The laboratory results will be confirmed shortly in pilot paper making machines.

Based on the investigations carried out at Regional Research Laboratory, Jorhat, an integrated pilot plant for making handmade paper and paperboards is being set up at RRL, Hyderabad for making different varieties of papers and boards to collect all the operational and other relevent data to find out the economics of the process. The plant will also provide samples of different grades and qualities for market survey.

The present scheme is of course intended to :

1) help the development of small scale handmade paper industries particularly in rural areas where water hyacinth is in abundance,

2) convert water hyacinth into higher value products other than common writing and printing papers,

3) use the cellulosic fraction in the case of integrated programme of utilisation of water hyacinth, and

4) produce a commercial commodity on a cottage scale in the rural areas without involving any major financial outlay and promote development and training of technical manpower at the grassroot level.

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