Production of Unbleached and Bleached Pulps from Arundo donax (Giant Reed Grass)

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Arundo donax from different places in Italy was tested in the laboratory for its suitability as a fibrous raw material in papermarking. Upon vapour-phase NSSC-Cooking at 175°C/60 min. unbleached pulp was produced with sufficient strength properties and CMT-values for corrugated medium and certain wrapping qualities.

Bleachable pulp was produced by liquor-phase cooking with $Na_2SO^{3+}NaOH$-cooking liquors (so called monosulphite process). On conventional 3-stage bleaching good bleachability could be observed.

Bleachable and unbleachable grades of Arundo donax pulps developed greaseproof properties on continued beating.

As a whole, the characteristics of technically produced read pulps were reached or surpassed by Arundo donax pulps. According to the results obtained their suitability as a fibrous source for papermaking is being judged positively.

INTRODUCTION

Arundo donax material from Italy was provided to our research laboratory by dipl.-agr. F. Metzger. This material was investigated for its suitability as a fibrous raw material for unbleached and bleached paper grades. Since test results on pulps from different cooks were quite promising additional literature studies were made also including the economy of Arundo donax plantations. 1) 2) The conclusion was that the annual pulp yield per unit area can be expected to be fairly high.

For confirmation of the paper technological properties observed some more cooking series were performed with material from Southern Italy as well as from the plains of the River Po. Both, Arundo donax stalks without leaves and such with 10% leaf content were used. A certain leaf content was added on purpose to similate the effect of improper cleaning in the preparation step.

A survey of our trials is given below.

EXPERIMENTAL SECTION

1. Analysis and preparation of the raw material

Analytical data and description of raw material preparation are compiled in **Table 1.**

Ash content in the leaves was noticeably higher than in the stalk material. For lignin and extracts no clear distinction could be observed.

In the fields actual leaf content will be higher, presumably 30—40%. The partly cleaned material delivered to us contained only approximately 10%. Because during technical cleaning always some leafy material will remain, it was decided to do also two cooks of Arundo donax stalks with a certain percentage of leaves (10% addition).

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2. Cooking

2.1 *Cooking schedule* **TABLE II**

2.2 *Cooking Trial*

Actual conditions and the yields are given in Table III.

3. Investigation of the Unbleached Pulp

3.1 *Unbeaten pulp*

After cooking the pulps were mildly disintegrated in a single-disk refiner (disk-setting 0.2 mm apart). From the defibered pulp the test data in **Table IV** were obtained.

Lowest lignin contents were found for the pulps made out of raw material from River Po. Also Arundo donax stalks originating from there were

Table 1.

Arundo donax for cook no. Origin		1/1+1/2 S. Italy	2 a+2 b S. Italy	3 a+3 b River PO
a) **Stalk material**				
lignin	%	25,8	25,0	20,7
extract	%	4,8	4,3	5,05
ash	%	1,8	1,9	2,35
dry content	%	83.4	84,8	87,1
vacuum impregnability	ml/100 g o.d.	115 (H_2O)	—	115
leaf content	%	0	9,7	10,7
b) **Leaves**				
lignin	%	—	17,2	23,5
extract	%	—	4,1	3,8
ash	%	—	4,8	6,1
dry content	%	—	84,8	87,1
c) **Preparation** order		crushing chipping	chipping only	crushing chipping

low in lignin content. Ash and extract values of the pulps were slightly higher at 10 % leaf content of the raw material.

From fiber classification it has to be noted that the percentage of fines is rather high (45—51 %) even at SR-slowness of only 16—22°SR.

3.2 *Jokro-mill beating ef tho nu-bleached puip*

Strength development was tested for all pulps. Besides, the CMT-values of the semi-chemical pulp were determined (Table V a) — V c)).

It can be seen from these tables Arundo donax from the River Po (cook No. 3 a and 3 b) developed the highest strength properties. It was also observed that material with and without leaves did not show a signicant difference in strength values.

The CMT flat crush test of the semi-chemical pulp from cook 1/1 can be considered good only on comparison to other annual plants.

Table II

Cook Pup quality		1/1 semi-chemical	1/2, 2 a + 2 b 3 a + 3 b bleachable
Application of chemicals:			
Na_2SO_3	%	15	20
Na_2CO_3	%	2	—
NaOH	%	—	2
Impregnation		vacuum	none
Liquor-ratio		vapour-phase	1 : 3,5
Temperature	°C	175	175
Heating		steam to 105 °C, afterwards electr.	electrical heating 60 min to temp.
Cooking time	min	60	120

Table III

Cook Pulp quality Leaf content	%	1/1 semi-chem. 0	1/2 bleach-able 0	2 a bleach-able 0	2 b bleach_able 9,7	3 a bleach-able 0	3 b bleach-able 10
Cooking liquor: Na_2SO_3	g/1	133,1	60,6	60,3	62.3	61,6	60,3
Na_2CO_3	g/1	17,3	—	—	—	—	—
NaOH	g/1	—	6,1	6,0	6,0	6,0	5,4
Vacuum impregnability resp. liquor-ratio	ml/100 g atro	94	1 : 3,5	1 : 3,5	1 : 3.5	1 : 3,5	1 : 3,5
Application of chemicals:							
Na_2SO_3	%	12,5	20,0	20,0	20.7	20,7	20,2
Na_2CO_3	%	1,6	—	—	—	—	—
NaOH	%	—	2,0	2.0	2.0	2,0	1,8
Na_2SO_3-Consumption	%	12.5	20,0	18,05	18,0	20,0	16,35
pH-start		9,9	12,9	11,3	11.5	ca. 12	ca. 12
pH-end		5,5	8,6	8.7	7,8	ca. 9	ca. 9
Heating	min	19+60	60+120	60+120	60+120	60+120	60+120
Temperature	°C	175	175	175	175	175	175
Blowing	min	15	20	12	15	12	10
Yield	%	59.5	63	57	58	52.5	53

Table IV

Cook Pulp quality Leaf content	%	1/1 semi-chemical 0	1/2 bleach-able 0	2 a bleach_able 0	2 b bleach-able 9,7	3 a bleach-able 0	3 b bleach-able 10
Yield	%	59,5 (?)	63	57	58	52,5	53
Lignin	%	7,2	3,85	2,6	1,4	0,75	1,0
Extract	%	0,75	0,3	0,5	0,85	0,80	1,05
Ash	%	1,5	2,3	1,35	1,7	1.1	1,75
SR-slowness	°SR	16	18	15	17	22	17
Disintegration	min	25	25	2	2	2	2
Brecht-Holl fiber classification:							
Long fibers	%	29,3	32,3	32,9	30,3	37,1	32,5
Short fibers	%	17.4	19,5	18,2	19,5	17.0	20,4
Fines	%	51.0	47,5	48,1	49,4	45,4	46,1
Shives	%	2,3	0,7	0,8	0,8	0,5	1,0
Brightness :							
With SO_3-acidification	% MgO	29,4	44,7	52,6	46.7	44,9	44,1

Table V a): Strength properties of the unbleached pulps after Jokro-mill beating

Cook		1/1			1/2				
Quality		semi-chemical			bleachable				
Leaf content	%	0			0				
SR-slowness	°SR	36	51,6	60	24,5	36	44	53,5	92
Beating time	min	10	20	25	5	10	13	16	90
Basis weight	g/m²	80	80	79,5	83	83	81,5	79,5	40,4
App. specific density	g/cm³	0,62	0,68	0,70	0,64	0,675	0,700	0,725	0,90
Tensile strength	m	4110	4890	5390	4640	5560	5970	6420	6940
Elongation	%	1,7	1,4	1,6	1,75	2,1	2,25	2,3	3,0
Rel. tear (Brecht-Imset)	cmg/cm	121	138	133	135	132	139	134	56
									abs. 22
Double folds		12	71	86	32	60	100	134	1130
Bursting strength, rel.	kg/cm²	1,59	2,2	2,45	2,05	2,60	2,70	2,95	3,25
									abs. 1,32
CMT-value	without dim.	1,93	1,97	—					
	at °SR	34	44	—					
	and g/m²	133,5	127,5	—					

Table V b) :

Origin of raw material		Southern Italy										
Cook		2 a						2 b				
Quality		bleachable						bleachable				
Leaf content	%	0						9,7				
SR-slowness	°SR	21	32	40	48,5	63	93	26.5	39.5	52	59.5	93
Beating time	min	5	10	13	15	20	90	5	10	15	20	90
Basis weight	g/m²	82	83	84,5	81	84	43	81	80	82,5	80	44
App. specific density	g/cm³	0,63	0,69	0,70	0,725	0,755	0,915	0,65	0,695	0,73	0,74	0,955
Tensile strength	m	4150	5100	5430	5570	6160	7140	4600	5420	6390	6040	7050
Elongation	%	1,9	2,1	2,4	2,3	2,5	3,1	1,9	2,1	2,5	2,3	2,75
Tear (Brecht-Imset)												
rel.	cmg/cm	131	133	137	133	143	70	130	133	134	129	48
abs.	cmg/cm	108	110	116	108	120	30	105	106	111	103	21
Double folds		22	41	74	91	192	1100	27	51	116	144	833
Bursting strength												
rel.	kg/cm²	1,79	2,39	2,65	2,70	2,95	3,35	2,10	2,50	2,70	2,85	3,20
abs.	kg/cm²	1,46	1,98	2,23	2,20	2,50	1,44	1,71	2,02	2,24	2,29	1,40

Table V c):

Origin of raw material		River Po										
Cook		3 a						3 b				
Quality		bleachable						bleachable				
Leaf content	%	0						10				
SR-slowness	°SR	22	32	43	53,5	59	92,5	17	33	42	52	61	92.5
Beating time	min	unb.	5	10	15	17	90	unb.	6	10	14	17	90
Basis weight	g/m²	80,5	78,5	80,5	80	81	39,5	79,5	80	78	79	80	39,5
App. specific density	g/cm³	0,615	0,715	0,735	0,76	0,765	0,89	0,60	0,71	0,73	0,76	0,78	0,945
Tonsile strength	m	4100	6100	6920	7050	7510	8040	3760	6790	7690	7810	7990	7600
Elongation	%	1,8	2,25	2,6	2,75	3,0	3,4	2,0	2,5	2,75	2,8	3,05	3,3
Tear (Brecht-Imset)													
rel.	cmg/cm	128	155	148	142	149	73	135	139	141	144	146	59
abs.	cmg/cm	103	122	120	113	121	29	108	111	110	113	116	23
Double folds		18	94	208	300	301	1725	18	176	254	409	324	1630
Bursting strength													
rel.	kg/cm²	1,86	3,05	3,45	3,55	3,70	4,05	1,83	3,30	3,65	3,65	3,95	3,80
abs.	kg/cm²	1.50	2.40	2.80	2.85	3.00	1.61	1,45	2,65	2,85	2,90	3,15	1,51

3.3 *Further tests on the unbleached pulps*

In addition, greaseproof properties of the pulps were studied during Jokro-mill beating **(Table VI).** Greaseproof suitability was observed at appr. 90°SR, which is similar to other NSSC-pulps from annual plants. Again a strong reduction of the long fiber content took place. However, it is known that prolonged Jokro-mill beating always gives strong reduction of fiber length. Lavstone beating as would be done in mill practice will result in a much better preservation of fibers.

4. **3-stage bleaching of Arundo donax pulps**

4,1 *Bleaching conditions and results*

TABLE VII

Table VI: Greaseproof properties and fiber classification of the beaten unbleached pulps

Cook		1/1			1/2				2 a	2 b	3 a	3 b
Quality		semi-chemical			bleachable				bleachable		bleachable	
Leaf content	%	0			0				0	9,7	0	10
Greaseproof properties:												
SR-slowness	°SR	79	86,5	89	82	87,5	88	92	93	93	92,5	92,5
Beating time	min	42	60	70	45	60	75	90	90	90	90	90
Blister test		neg.	neg.	neg.	neg.	neg.	neg.	+	+	+	+	+
Schopper-porosity	ml/min							1,7	1,0	1,0	1,0	1,0
Turpentine test	sec							1800+	1800+	1800+	600	1800+
Basis weight	g/m²								41	41	38,5	39
Fiber classification: (Brecht-Holl)												
SR-slowness	°SR				52		89	92			92,5	92,5
Beating time	min				23		70	90			90	90
Long fibers	%				31,7		20,3	1,9			14.9	1.75
Short fibers	%				21,1		25,2	20,6			28,9	—
Fines	%				46,8		54,5	79,4			56,2	—
Shives	%				0,4		—	—			—	—

Table VII

Cook		1/2	2		3	
Material		South Italy	South Italy		River Po	
			a	b	a	b
1. **Chlorination** (3 % cons., 1 h, 20°C)						
Cl_2-application	%	6	4,5	4,5	2,5	2,5
Residual Cl_2	%	traces	0	0	traces	0
2. **Alkali extraction** (5 % cons., 1 h, 40°C)						
NaOH-application	%	2	1	1	1+0,2	1
pH-start		11,50	9.9		10	10 — 11
pH-end		11,35			45′ 8,5	
3. **Sodium hypochlorite** (5 % cons., 38 — 40°C)					9 (addit. buffer)	
Duration	h	6	5	5	5	5
Application of act. Cl_2	%	2,5	2	2	1	1
Residual Cl_2	%	0,2	0	0	0	0
NaOH-buffer	%	1	0.75	0,75	0,4+0,24	0,4+0,16
pH-start		11,05	10,2	10,3	9 — 10	
pH-end		8,2	10	—	7,5 addit. buffer 2 x	8,5 addit. buffer 2 x
4. **SO_2-acidification** (0,5 % SO_2 5 % cons., 1 h, 20°C)						
Bleaching results						
Bleach yield	%	96	94	93,5	—	—
Elrepho-brightness	% ngo	79,4 (78,5 without SO_2)	72,3	71,0	76.2	69,5

At total chlorine applications between 3,5 and 8,5 % after 3-stage bleaching brightness ranged from 69,5 — 79,4 % MgO. The pulps showed good bleachability. The final brightness depends only on lignin content and chlorine addition.

4,2 *Strength properties of the bleached pulps after Jokro-mill beating*

The development of strength properties during Jokro-mill beating is demonstrated in Table VIII a) — VIII c).

4.3 *Greaseproof properties and fiber classification of the bleached pulp*

The pulp were beaten in a Jokro-mill until the blister test showed positive greaseproof properties. Corresponding greaseproof tests at the blister point are registered in **Table IX,** such as turnpentine test, Schopper-porosity and in addition fiber classification by the Brecht-Holl method.

Apparently, also the bleached pulps from Arundo donax develop greaseproof suitability. In mill practice, beating will be done with lava-stone or with bars having a large cutting angle for better preservation of fiber length.

Table VIII a): Strength properties of bleached pulp from cook 1/2

Cook		1/2			
Strength properties:					
SR-slowness	°SR	28	42	52,5	90
Beating time	min	6	10	14	70
Basis weight	g/m²	80	78,5	80,5	42,5
App. specific density	g/cm³	0,71	0,76	0,79	0,91
Tensile strength	m	4780	5120	5430	6360
Elongation	%	2,4	2,75	2,90	3,0
Tear (Brecht-Imset)	cmg/cm	122	108	115	71
					abs. 30
Double folds		19	30	44	577
Bursting strength	kg/cm²	2,1	2,45	2,65	3,0
					abs. 1,28

Table VIII b): Strength properties of bleached pulp from cooks No. 2 a and 2 b

Cook		Material from Southern Italy							
		2 a	without leaves			2 b	with leaves		
SR-slowness	°SR	29,5	39,5	50,5	92,5	28	40	48,5	92
Beating time	min	7	10	15	90	4	7	10	90
Basis weight	g/m²	79,5	82,5	79	43,5	81	32,5	80,5	43
App. specific density	g/cm³	0,69	0,71	0,75	0,965	0.67	0,705	0,725	0,955
Tensile strength	m	5020	5520	6010	7130	4640	5400	5760	7880
Elongation	%	2,45	2,6	2,7	3,45	2,05	2,5	2,5	3,1
Tear (Brecht-Imset)									
rel.	cmg/cm	134	152	139	63	138	141	137	70
abs.	cmg/cm	—	—	—	27	—	—	—	30
Double folds		46	76	165	1190	38	79	119	1250
Bursting strength									
rel.	kg/cm²	2,32	2,6	2,95	3,65	2,16	2,55	2,85	3,55
abs.	kg/cm²	—	—	—	1,59	—	—	—	1,52

Table VIII c) : Strength properties of bleached pulp from cooks no. 3 a and 3 b

Cook		Material from River Po							
		3 a	without leaves			3 b	with leaves		
SR-slowness	°SR	32	42	53	93	33	39	51	91
Beating time	min	5	9	13	90	5	8	14	90
Basis weight	g/m²	80	81,5	76,5	39	76.5	80	80,5	39
App. specific density	g/cm³	0.71	0.73	0.76	0.94	0.695	0.73	0,765	0.89
Tensile strength	m	6260	6560	7090	7810	6340	6560	7060	7970
Elongation	%	2,5	2,9	3,4	3,6	3,0	3,05	3,5	3,8
Tear (Brecht-Imset)									
rel.	cmg/cm	153	157	152	68	163	153	148	66
abs.	cmg/cm	—	—	—	27	—	—	—	26
Double folds		106	179	305	1680	113	164	284	1523
Bursting strength									
rel.	kg/cm²	2,95	3,35	3,65	3,75	3,0	3,45	3,80	4,10
abs.	kg/cm²	—	—	—	1.47	—	—	—	1,60

Table IX

Material		South Italy			River Po	
Cook		1/2	2 a	2 b	3 a	3 b
Leaf content	%	0	0	9,7	0	10
Greaseproof properties:						
SR-slowness	°SR	90	92	92	93	91
Beating time	min	70	90	90	90	90
Blister test		+++	+++	+++	+++	+++
Schopper porosity	ml/min	1,6	1.0	1,2	1.2	0,8
Turpentine test						
max.	sec.	150				
min.	sec.	90	1800+	1800+	1800+	1800+
Basis weight	g/m²	42,5	41,5	42	38,5	39
Fiber classification:						
Long fibers	%	9,5	13,6	10,8	6,0	17,2
Short fibers	%	32,7	28,8	30,2	35,7	29,0
Fines	%	57,8	57,6	59,0	58,3	53,8

DISCUSSION OF RESULTS

For unbleached pulp qualities vapour-phase NSSC-cooking was applied. Cooking conditions were 175°C/60 min and 15% Na_2SO_3 application. These conditions were chosen with concern to an intended pilot plant trial in the Escher Wyss continuous digester. The pulps from the laboratory cook showed sufficient strength properties (ordinary and flat crush) to be used for corrugated medium, duplex board and lower grade wrapping qualities.

With the same raw material bleachable NSSC-pulp was produced by liquor-phase cooking at 175°C/2 hours. Lignin content of the pulp was 3.85 %. On 3-stage bleaching with a total of 8.5 % Cl_2-application a brightness of 79.4 % could be achieved. Strength properties compared well to technical reed pulps which at 50°SR develop a tensile strength of 5000 to 6000 m.

In further pulping trials with Arundo donax material of different origin, other bleachable pulps with even lower lignin content could be obtained. After 3-stage bleaching with a total of 3.5 and 6.5 % Cl_2-application brightness was 70 and 76 % respectively. Brightness could certainly be increased by slightly higher chlorine application. With the material from the plains of the River Po. strength properties were somewhat better than with Arundo donax from Southern Italy.

Trials with material containing 10 % leaves gave neither reduced yield nor lower strength properties. Only ash content was a little higher.

CONCLUSION

1. Arundo donax pulps from NSSC-cooking can be obtained with good yield and strength properties which are equal or better than for technical reed pulps.
2. Flat crush values (CMT-values) can be considered good with respect to other annual plants. Arundo donax semi-chemical pulps can be used for corrugated medium, duplex board or lower grade wrapping paper.
3. Unbleached and bleached Arundo donax pulps develop greaseproof properties on continued beating.
4. Arundo donax pulp can be bleached conventionally in 3 stages without severe loss of strength properties.
5. Addition of 10% leaves to the stalk material did not result in a noticeable reduction of pulp quality.

RECOMMENDATIONS

1. Experimental plantations of Arundo donax should be encouraged.
2. Some more work should be devoted to the mechanical preparatiaon of the raw material.

Experimental Data:

Laboratory Trial No. 678 with supplements

Literature Survey:

Arundo donax documentation at Escher Wyss Ravensburg

1. F. Metzger
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   H. Cronert
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   W. Matzke
   "Suitability of Arundo donax for papermaking pulps" (from laboratory trial No. 678/part I)
   July 21, 1965

2. R. V. Bhat, K. C. Virmani
   "Pulps for writing and printing papers from Arundo donax"

   Indian Pulp and Paper, May 1952, pp. 459 — 464