

Potential Use of *Arundo donax* as an Alternate Raw Material in Mix Agro Furnish for Making Chemical Pulp

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ABSTRACT

Scarcity of raw material continue to be a paramount problem and associated with an unbearable cost burden as well Afforestation programmes, which are vital, are still very meagre and industry is required to look for agro residue and locally available grasses which have good fibre potential. Contrary to this the search for new and prospective sources of fibrous raw materials for making pulp, suitable for printing and writing grade paper is never ending. *Arundo donax* commonly known in India as Nara or Nada is spread over lower shivalik foothills across Punjab & Himachal border. This raw-material is evaluated for its pulp and paper-making potential to produce chemical pulp. Data on chemical constituents, fibre dimensions, bleached yield and physical strength properties of pulp sheets were obtained. The unbleached pulp yields under soda pulping process were 41 to 42.2% with 21 to 25 Kappa No. Laboratory handmade pulp sheets with adequate strength properties were obtained from soda pulp prepared from this raw material.

Key words: *Arundo donax*, Kappa number, pulping, bleaching.

Introduction

Pulp and paper industry is on the threshold of material resource crunch. The conventional raw materials like softwood, hardwood and bamboo used for pulp, paper and cellulose based industries are depleting day by day and it is predicted that by the turn of 2020, there will be a global shortage of these raw materials. During the last three decades, though many of the forest based fast growing annual and perennial plants have been identified, cultivated and their suitability for pulp and paper making have been studied⁽¹⁻¹³⁾, Search for new fiber crops is continuing. There is a necessity to evaluate new fiber crops that can be available on sustainable basis. *Arundo donax* is one such raw material which is spread over lower shivalik foot hills across Punjab & Himachal border and widely distributed in waste lands, along water canal and road sides.

Arundo donax. (Giant Reed) is a tall perennial reed, growing in fresh and moderately saline waters. Other common names include Carrizo, Spanish cane, wild cane, giant cane and arundo. Its native range may have extended from the Mediterranean region through the Middle East to India, but it is now widely planted and naturalised in the temperate and subtropical regions of both hemispheres. It forms dense stands on disturbed sites, sand dunes, in wetlands and riparian habitats.

It's Scientific classification are Kingdom: Plantae, Division: Magnoliophyta, Class: Liliopsida, Order: Poales, Family: Poaceae, Subfamily: Arundinoideae, Tribe: Arundineae, Genus: *Arundo*, Species: *A. donax*

Generally growing to 4 m, in ideal conditions it can exceed 6 m, with

hollow stems of 2-3 cm diameter. The leaves are alternate, 30-60 cm long and 2-6 cm broad with a tapered tip, grey-green, and have a hairy tuft at the base. Overall, it resembles an outsize common reed (*Phragmites australis*) or a bamboo.

Arundo donax flowers in late summer, bearing upright, feathery plumes 40-60 cm long, but the seeds are rarely fertile. Instead, it mostly reproduces vegetatively, by underground rhizomes. The rhizomes are tough and fibrous and form knotty, spreading mats that penetrate deep into the soil up to one metre deep⁽¹⁴⁾. Stem and rhizome pieces less than 5 cm long and containing a single node readily sprouted under a variety of conditions⁽¹⁵⁾. This vegetative growth appears to be well adapted to floods, which may break up individual *A. donax* clumps, spreading the pieces, which may sprout and colonise further downstream⁽¹⁶⁾.

It uses large amounts of water from its wet habitat to supply the rapid rate of growth, up to 5 cm per day in spring⁽¹⁷⁾. It is capable of growing in dense stands, which may crowd out other plants and prevent their recruitment.

Other uses of *Arundo donax* are Basketry, Biomass, Broom, Paper, Pipes, Plant support, Shelterbelt, Soil stabilization, Thatching, Weaving.

Considering the importance if its vast availability, systematic studies were carried out to optimize process parameters for producing pulp for writing and printing grade of paper. This paper deals the laboratory scale



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studies on the pulp and paper making characteristics of *Arundo donax* at ABC Paper Ltd. (Punjab)

Experimental

Raw Material: *Arundo donax* were collected from the field. Whole *Arundo donax* plant were cut into 2-2.5cm length. The chips as prepared were dried to a moisture level 12-13% and then used for experimental work on oven dry (O.D) basis, after determining the bulk density.

Proximate Chemical Analysis:

The chips powdered in a Willey mill and portion passed through 40 mesh and retained on 60 mesh was taken for the study. The proximate chemical analysis was carried out as per Tappi Standard (14) Method. The results obtained are given in Table -1.

Pulping: Soda pulping of *Arundo donax* was carried out in an electrically heated stainless steel autoclave digester with polyethylene glycol bath, thermostatically controlled system, keeping bath ratio 1:4. The digestions were carried at varying chemical concentration for 4 hrs including time to raise the temperature to $165^{\circ} \pm 2^{\circ}C$.

The pulp after digestion was thoroughly washed with water. The unbleached pulp yield, kappa numbers, rejects etc were determined. The black liquor after each digestion was collected for determination of total solids and residual active alkali. The results are given in Table- 2 (a). The strength properties of *Arundo donax* unbleached pulp were evaluated and compared with sarkanda & wheat straw pulp and the results are recorded in Table- 2(b).

Bleaching: The unbleached pulps of *Arundo donax* was bleached by C-E_p-H-H sequence. The strength & optical properties of bleached pulp were evaluated and compared with sarkanda & wheat straw bleached pulp with same chlorine charge. The results are recorded in Table-3 & Table -4.

Paper sheet formation and testing:

The unbleached & bleached pulps were beaten in a laboratory valley beater to 27 & 30 °SR. Sheets of 60± 1gm² were prepared from the pulps in a British standard laboratory hand sheet making machine followed by pressing and drying.

The pulp sheets were conditioned at 65 % relative humidity at 27°C for 2 hrs and then tested for various physical properties by Tappi method: T-220 om-88.

Result and Discussion:

The result of proximate chemical analysis recorded in Table-1 indicate the suitability of *Arundo donax* for paper making. From the results it is evident that plant material contains 63.0% holocellulose and 24.3% lignin. The pentosan is 30.9% and solubility in cold water, hot water & alcohol benzene was 12.0%,13.0% and 4.8%. Ash content is 5.6. % NaOH solubility is of important

Table-1. Proximate Analysis of *Arundo donax*

| S.No | Parameters | Unit | Results (on raw material basis) |
|------|-----------------------------|------|---------------------------------|
| 1 | Cold water Solubility | (%) | 12.0 |
| 2 | Hot water Solubility | (%) | 13.0 |
| 3 | 1% NaOH Solubility | (%) | 35.9 |
| 4 | Alcohol -Benzene Solubility | (%) | 4.8 |
| 5 | Holocellulose content** | (%) | 63.0 |
| 6 | Ash content | (%) | 5.6 |
| 7 | Pentosan | (%) | 30.9 |
| 8 | Total Lignin content* | (%) | 24.3 |

*Total lignin corrected for ash content.

**Holocellulose corrected for ash & lignin content

Table-2(a). Pulping conditions, Pulp yield and Kappa No. *Arundo donax* pulps.

| | | | |
|------------------------|-------|-------|-------|
| O.D. Raw Material (gm) | 500 | 500 | 500 |
| Alkali Charge % | 15 | 16 | 17 |
| Pulp Aid % | 0.05 | 0.05 | 0.05 |
| Bath Ratio | 1:4 | 1:4 | 1:4 |
| Cooking Time (Hrs) | 4 | 4 | 4 |
| Temperature (°C) | 165 | 165 | 165 |
| Unbleached Yield % | 42.2 | 41.7 | 41.0 |
| Kappa No. | 25.0 | 23.5 | 21.0 |
| pH | 12.27 | 12.40 | 12.51 |
| RAA (Gpl) | 1.0 | 1.2 | 1.4 |
| Total Solid % | 9.5 | 9.8 | 10.0 |

Table-2(b). Physical strength properties of unbleached Soda pulps of *Arundo donax* with compare to Sarkanda & Wheat Straw

| Particulars | <i>Arundo donax</i> | | | Wheat Straw | | | Sarkanda | | |
|---------------------------|---------------------|------|------|-------------|------|------|----------|------|------|
| | 15% | 16% | 17% | 14% | 16% | 18% | 14% | 16% | 18% |
| °SR | 27 | 27 | 27 | 28 | 28 | 28 | 27 | 27 | 27 |
| B.Wt (g/m ²) | 60.2 | 60.0 | 60.3 | 60.0 | 60.2 | 60.6 | 60.6 | 60.2 | 61.0 |
| Breaking Length (m) | 3189 | 3049 | 3027 | 3770 | 3522 | 3300 | 3470 | 3370 | 3300 |
| Tear Factor | 60.2 | 59.6 | 58.8 | 72.2 | 72.0 | 68.5 | 64.8 | 63.8 | 60.2 |
| Burst Factor | 15.3 | 15.1 | 14.9 | 18.5 | 18.4 | 18.2 | 17.0 | 16.2 | 15.2 |
| Bulk (cm ³ /g) | 1.60 | 1.58 | 1.58 | 1.62 | 1.58 | 1.58 | 1.60 | 1.60 | 1.58 |
| Ash% | 2.4 | 2.4 | 2.2 | 2.5 | 2.4 | 2.6 | 2.8 | 2.6 | 2.4 |

**Table-3. Condition & Bleaching sequence (C-Ep-H-H)
of *Arundo donax* pulp**

| Chlorination | | | | |
|-------------------------------------|----------|--------------|--------------|--------------|
| | | 15% | 16% | 17% |
| OD pulp | Gm | 100 | 100 | 100 |
| Cl ₂ Added | % | 6.0 | 6.0 | 6.0 |
| pH (initial) | - | 2.46 | 2.48 | 2.38 |
| Retention Time | Min | 45 | 45 | 45 |
| pH (final) | - | 2.28 | 2.26 | 2.24 |
| R-Cl ₂ | Gpl | Nil | Nil | Nil |
| Cl ₂ Consumed | % | 6.0 | 6.0 | 6.0 |
| Alkali Extraction | | | | |
| Temp | °C | 60 | 60 | 60 |
| Alkali Added | % | 2.5 | 2.5 | 2.5 |
| H ₂ O ₂ | Kg/T | 8 | 8 | 8 |
| pH (initial) | - | 11.00 | 10.98 | 10.96 |
| Retention Time | Hrs | 2 | 2 | 2 |
| pH (final) | - | 9.98 | 9.86 | 9.80 |
| Kappa No | - | 3.4 | 3.3 | 3.2 |
| H-I Stage | | | | |
| Temperature | °C | 40 | 40 | 40 |
| Hypo Added | % | 2.5 | 2.5 | 2.5 |
| pH (initial) | - | 8.22 | 8.16 | 8.18 |
| Retention Time | Hrs | 2 | 2 | 2 |
| pH (final) | - | 7.84 | 7.80 | 7.86 |
| R-Cl ₂ | Gpl | Nil | Nil | Nil |
| Cl ₂ Consumed | % | 2.5 | 2.5 | 2.5 |
| H-II Stage | | | | |
| Temperature | °C | 40 | 40 | 40 |
| Hypo Added | % | 1.5 | 1.5 | 1.5 |
| pH (initial) | - | 7.96 | 7.94 | 7.92 |
| Retention Time | Hrs | 2 | 2 | 2 |
| pH (final) | - | 7.58 | 7.53 | 7.51 |
| R-Cl ₂ | Gpl | Nil | 0.00142 | 0.00248 |
| Cl ₂ Consumed | % | 1.5 | 1.49 | 1.49 |
| Total Cl₂ Charged | % | 10 | 10 | 10 |
| Cl₂ Consumed | % | 10.0 | 9.99 | 9.99 |
| Shrinkage | % | 8.4 | 8.2 | 8.2 |
| Bleached Yield | % | 38.6 | 38.2 | 37.6 |
| Brightness | % | 77.6 | 78.2 | 79.8 |
| Whitness | % | 60.78 | 61.48 | 63.97 |
| L[±] | | 93.12 | 93.51 | 93.65 |
| a[±] | | -0.31 | -0.25 | -0.30 |
| b[±] | | 4.86 | 4.93 | 4.45 |
| Tint | | -1.33 | -1.44 | -1.19 |

in assessing the soundness of wood in respect its decay. The value ranging from 10-35% are normally considered adequate for further investigation. The 1% NaOH solubility is 35.9% which exhibits it's suitability as raw material for pulp & paper.

Table-2(a). shows pulping condition and properties of unbleached pulp of *Arundo donax* soda pulping. The unbleached pulp yield was 41.0% to 42.2% with varying alkali charge from 15-17% in soda cook, Kappa No. was 21.0 to 25.0. It was observed that under the identical conditions of pulping, pulp yield and kappa number decreased with increase in alkali charge.

The physical strength properties of unbleached pulps of *Arundo donax* are recorded in Table-2 (b). It may be seen that the pulp produced using 15% alkali charge with better strength properties as compare to pulp produced using 16% and 17% alkali charge. But as compare to sarkanda and wheat straw unbleached pulp strength properties were low.

Table-3 Shows the condition and sequence of bleaching of *Arundo donax* pulp. Pulp yield recorded 38.6%, 38.2% and 37.6% for the pulp produced using 15%,16%,17% alkali charge at 10% chlorine demand. Pulp have 77.6%, 78.2% and 79.8% brightness and 60.78, 61.48, & 63.97 whitness with L[±] 93.12, 93.51, 93.65 a[±] is -0.31, -0.25, -0.30 b[±] 4.86, 4.93, 4.45 and Tint -1.33, -1.44, -1.19. However a drop in pulp yield was observed in the case of pulp produced using 16%, 17% alkali charge when compared to 15%.

The physical strength properties of bleached pulps are recorded in Table-4. It is observed that breaking length is more in pulp produced with 15% alkali

**Table-4. Strength properties of Bleached pulp of *Arundo donax* with compare to
Sarkanda & Wheat Straw**

| Particulars | <i>Arundo donax</i> | | | Wheat Straw | | | Sarkanda | | |
|---------------------------|----------------------------|------------|------------|--------------------|------------|------------|-----------------|------------|------------|
| | 15% | 16% | 17% | 14% | 16% | 18% | 14% | 16% | 18% |
| °SR | 29 | 29 | 29 | 30 | 30 | 30 | 30 | 30 | 30 |
| B.Wt (g/m ²) | 60.2 | 60.0 | 60.4 | 61.0 | 60.0 | 60.2 | 60.2 | 61.0 | 60.6 |
| Breaking Length (m) | 2770 | 2710 | 2650 | 3170 | 3111 | 3100 | 3200 | 3170 | 3110 |
| Tear Factor | 42.7 | 41.8 | 41.7 | 49.2 | 46.6 | 45.2 | 49.8 | 49.2 | 48.6 |
| Burst Factor | 14.8 | 14.8 | 14.6 | 17.0 | 16.4 | 16.2 | 16.6 | 16.2 | 16.0 |
| Bulk (cm ³ /g) | 1.48 | 1.46 | 1.45 | 1.50 | 1.48 | 1.46 | 1.52 | 1.50 | 1.48 |
| Ash% | 1.5 | 1.4 | 1.4 | 1.5 | 1.6 | 1.6 | 1.5 | 1.6 | 1.5 |

charge as compared to 16% & 17%, but Tear factor and Burst factor is almost same in 15%, 16 & 17% alkali charge pulp. Bulk and ash content almost same in 15%, 16% and 17% alkali charge. But as compared with sarkanda and wheat straw strength properties of bleached pulp is low. All the pulp possess adequate strength properties and can be used for production of paper. This pulp can be used with other pulp mix in various proportional.

Conclusion: On the basis of experiment carried out on *Arundo donax* for pulp and paper making in industrial application, it seems to be a viable alternate source of raw material. This would also convey socio-economic and environmental benefits to the country, besides to meet the ever growing raw material demand in pulp and paper industry. We find that it can be easily used for producing chemical pulp in certain proportion along with other pulp. Further experiments are being conducted.

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