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# Effect of Process Variables on Pulp Yield of Indigenous Raw Materials

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***Abstract:*** ***The biggest issue before pulp and paper producers is availability of quality raw material. India is fiber deficit country, this message has become more intense after covid when price of different raw materials are increased by 20-25%, . Chemical pulp is produced by chemical delignification of wood and non-wood plants. After kraft pulping the remaining lignin is removed by oxygen delignification and bleaching to produce higher purity cellulosic pulp.***

***The goal of delignification processes is to remove lignin from the raw material without a negative effect on the cellulose and strength of pulp.***

***The economics of pulp and paper production is more related to the yield of unbleached and bleached pulp production. Marginal increment in pulp yield reflects into savings of crore of rupees on yearly basis. An overall vigilant concern on process conditions and variables is required during production of pulp. BAT technology for pulping along with utilization of various additives and pretreatment methods allow to fine tune these process to obtain pulp with desired yield and quality. The primary aim of this paper is to review different process variables in respect to the yield of the pulp.***

## Introduction :

The Indian paper industry uses a diverse mix of fibrous raw material primarily forest based , agro residues including bagasse, straw and waste paper. Though agroresidues are available in plenty, however associated problems like complexity during processing of these fibres, quality of the end product and environmental issues are the major concern to encourage use of this potentially available renewable raw material. The operations of the paper industry depend on the sustained availability of quality fibrous raw material-a fact that goes in stark contrast with ecological conservation.(1)

Out of 419 million tons of paper consumed globally, India consumes 22.83 million tons of paper and paper board annually, putting the national paper demand at 5.45% of the global demand (2019-20 figures). With steady growth in the country's economy since the early 1990s, India has witnessed a steady rise in the consumption of paper. (2)

The consumption of paper in India increased from 16.91 million Tons in 2016-17 to 22.83 million tons in 2019-20. During this period India's paper consumption registered CAGR of 6% compared to the global growth of 3% making India one of the largest growing paper markets in the world.

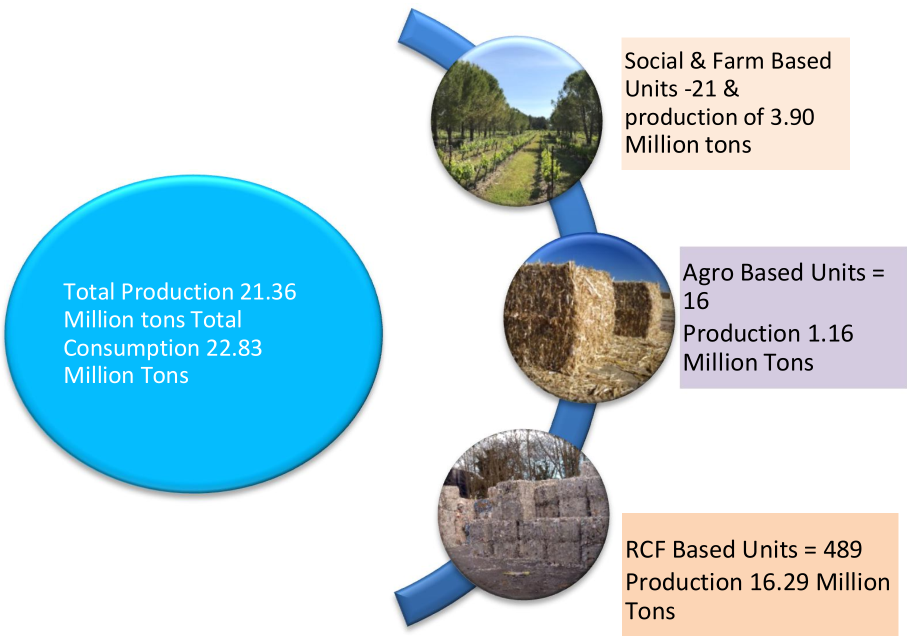


*Fig-1 The scenario of Indian Pulp and Paper Industry in respect of raw material utilized and production of pulp*

## 2. Factors affecting the Raw Material Quality and yield of unbleached pulp:

### 2.1 Type of Raw Material:

with vernacular fibre supply scenario, the production of virgin pulp in India mainly depends on mixed hardwood like eucalyptus, casuarinas, subabul, acacia and agroresudues like wheat straw, bagasse and some other locally available and pulpable raw materials.the very first criteria of selection of raw material is its availability, growth, species or clonal genetic linage for better put through. Hardwoods are grown through farmers under farm forestry or social forestry plans. The selection of right clones is the basic requirement which results into availability of quality wood supply to the mill.

The wood with bark creates lots of problem and should be removed before the pulping . The acidic natured extractives not only consume chemical both pulping as well as bleaching and also results into poor yield as compared to the debarked raw material.

**Table 1; Effect of debarking of wood on pulp yield(3)**

| Sl. No. | Cook No. | Alkali taken on B.D. Chips as NaOH % | Alkali Consumed % | Screened Pulp Yield % | Reject % | Permangnate No. of pulp |
|---|---|---|---|---|---|---|
| 1. | 1A Debarked wood | 22 | 20.26 | 42.7 | 0.2 | 17.0 |
| 2. | 2A ,, | 18 | 17.65 | 44.9 | 3.6 | 19.8 |
| 3. | 3A ,, | 14 | 13.93 | 55.7* | — | 35.0 |
| 4. | 4A Wood along with bark | 22 | 20.67 | 41.8 | 0.2 | 18.3 |
| 5. | 5A ,, | 18 | 17.65 | 43.0 | 3.5 | 20.3 |
| 6. | 6A ,, | 14 | 13.95 | 52.0* | — | 36.0 |
| 7. | 7A Bark only | 22 | 21.2 | 38.8 | 2.8 | — |
| 8. | 8A ,, | 18 | 17.7 | 36.0 | 6.8 | — |

**2.2 Cleanliness of Agroresidual raw materials**

It is very clear that raw material quality and cooking of raw material are very important part in case of agriculture residue paper manufacturing process. We have to recover the fibers being lost along with the sewer to improve the profitability of the Pulp and Paper Industry and also to take care of the environmental problem (1)

Efficient wet washing is an essential requirement of open structured agroresidual raw material. Efficient wet washing not only remove adhered silica but also helps in removal of non process elements, which overall affects on efficiency of recovery plant.The state of art mills which are using agroresidual raw materials are very focus on cleaniliness of agroresidual raw material and wet washing system of their plant.

**2.3 Effect of chip quality.**

The pulping reaction proceeds in five steps.

i) Transportation of the pulping chemical into chip by bulk flow and diffusion. (ii) Adsorption of the chemical. (iii) Chemical reaction. (iv) Desorption of reaction products. (v) Transportation of reaction products from the reaction site

There is heterogeneity among the various parts of wood like heart wood and sap wood, which is unavoidable. The optimization of cooking conditions are carried out for cooking chemical dose, temperature as well as time. keeping in mind the required kappa number well impregnated chips give its best put through without loss in yield by fines formation. The transportation of the pulping liquor into the wood structure and of the lignin reaction products out of the wood chip depends on the permeability behaviour of the wood species. The key factor for ideal pulping being uniform penetration of the pulping liquor, the problem becomes more important when mixed hardwoods of different permeability and densities are cooked together. An alternate approach has been to investigate the chip dimensions suitable for pulping in different wood species. Lower chip dimensions give a higher surface to volume ratio and provide better prospects for uniform penetration.(4)

**Table 2**

Pulp yield and pulp properties from different chip thicknesses in different locations.

| LOCATION | Chip thickness mm | Unbleached yield % | Kappa number | Lignin content | Alkali consumed g/l |
|---|---|---|---|---|---|
| SAPWOOD | 1 | 30.05 | 21.68 | 2.39 | 32 26 |
| | 2 | 36.00 | 22 04 | 2.24 | 31.98 |
| | 3 | 41.35 | 23.19 | 2.68 | 29.30 |
| | 4 | 44.96 | 23 38 | 2.98 | 27.68 |
| OUTER HEARTWOOD | 1 | 35 05 | 24.00 | 2.95 | 32.75 |
| | 2 | 39.69 | 24.20 | 3.05 | 31.74 |
| | 3 | 42 36 | 24.91 | 3.06 | 30.50 |
| | 4 | 38.63 (1.0 SR)* | 26.10 | 3.68 | 28.90 |
| MIDDLE HEARTWOOD | 1 | 37.20 | 27.29 | 3.55 | 33.86 |
| | 2 | 41.30 | 29.18 | 3.79 | 33.42 |
| | 3 | 42.50 | 30.00 | 3.45 | 32.60 |
| | 4 | 39.04 (–2.5 SR)* | 31.39 | 4.12 | 31.30 |
| INNER HEARTWOOD | 1 | 35.80 | 29.50 | 3.37 | 33.54 |
| | 2 | 42 44 | 30.90 | 4.02 | 32.97 |
| | 3 | 42.90 | 32.00 | 4.30 | 32.03 |
| | 4 | 40 07 (–2.7 SR)* | 32.68 | 4.70 | 30.90 |

### 2.4 Effect of Kappa number on Pulp yield

## Table 3 Effect of Kappa number on Pulp yield

| Dosage as NaOH | Unbleached Pulp | | | | | CEH Bleaching | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yield, | Screen rejects | Kappa no | Pento san | viscosity (unbld.) pulp | $Cl_2$ dosage | Res. $Cl_2$ | Alkali Extr, | Hypo as $Cl_2$ | Res. $Cl_2$ | Bld Yield | Pentos ans | Viscosi ty (Bld) | Bright -ness | P.C. | Visco sity drop |
| % | % | % | | % | $cm^3/g$ | % | ppm | % | % | ppm | % | % | $cm^3/gm$ | % | No. | % |
| **Soda Pulp** | | | | | | | | | | | | | | | | |
| 12 | 48.2 | 0.5 | 34.8 | 22.1 | 907 | 6.95 | 2900 | 3.0 | 3.0 | 240 | 43.5 | 19.5 | 430 | 85.4 | 1.55 | 52.6 |
| 14 | 45.9 | 0.4 | 28.4 | 22.0 | 886 | 5.67 | 2840 | 2.5 | 2.5 | 160 | 41.9 | 18.1 | 426 | 85.1 | 1.45 | 51.9 |
| 16 | 43.2 | 0.3 | 19.3 | 20.7 | 863 | 3.85 | 2560 | 2.0 | 2.0 | 140 | 39.8 | 20.3 | 430 | 87.7 | 1.37 | 50.2 |
| 18 | 42.1 | 0.2 | 15.5 | 19.4 | 857 | 3.10 | 2500 | 1.5 | 1.5 | 80 | 39.5 | 18.8 | 453 | 84.9 | 1.34 | 47.1 |
| 20 | 41.7 | - | 13.7 | 18.1 | 849 | 2.74 | 900 | 1.5 | 1.5 | - | 39.3 | 15.3 | 488 | 85.0 | 1.37 | 42.5 |
| 22 | 40.4 | - | 12.4 | 17.6 | 795 | 2.47 | 640 | 1.5 | 1.5 | - | 38.2 | 16.6 | 392 | 84.1 | 1.56 | 50.7 |
| **Kraft Pulp** | | | | | | | | | | | | | | | | |
| 8 | 54.3 | 0.6 | 49.1 | 24.5 | 1073 | 9.82 | 380 | 3.5 | 3.5 | 40 | 48.5 | 18.7 | 591 | 86.5 | 0.85 | 44.9 |
| 9 | 52.4 | 0.4 | 33.4 | 22.3 | 1023 | 6.68 | 360 | 3.0 | 3.0 | 30 | 47.7 | 17.6 | 576 | 87.4 | 0.92 | 43.7 |
| 10 | 49.9 | 0.2 | 25.1 | 21.5 | 945 | 5.02 | 300 | 2.5 | 2.5 | 40 | 45.9 | 17.4 | 556 | 87.2 | 0,65 | 41.2 |
| 12 | 48.0 | 0.1 | 15.0 | 21.3 | 890 | 3.00 | 85 | 1.5 | 1.5 | 30 | 45.1 | 17.4 | 551 | 87.3 | 0.67 | 38.1 |
| 14 | 44.0 | 0.0 | 11.0 | 21.1 | 756 | 2.20 | 90 | 1.5 | 1.5 | 20 | 41.5 | 18.7 | 504 | 86.0 | 1.56 | 33.3 |
| 16 | 40.6 | 0.0 | 10.3 | 19.8 | 741 | 2.07 | 50 | 1.5 | 1.5 | 10 | 38.5 | 17.8 | 481 | 85.4 | 1.17 | 35.1 |

The kappa number greatly affect on unbleached pulp yield followed by yield after bleaching. It was time when unbleached pulp with high kappa number was produced during 1980 and early 1990. With growing awareness towards environment the bleach plant entering kappa number reduced to 20-25. By end of 1990 decade most of the large wood based pulp and paper mills installed ODL technology and the kappa number reduced to 10-12 before bleaching. Table 3 is depicted the data of CPPRI study on effect of targeted kappa number on both unbleached and bleached yield.(5)

## Table 4 Effect of kappa number on yield viz a viz Raw material requirement

| Sl. No. | Chemica l dose | Screen Yield | Kappa No. | Chlorine dose | | Shrinkage | Bleached yield | Raw material/ BD Ton Pulp |
|---|---|---|---|---|---|---|---|---|
| | % | % | | Ele. $Cl_2$ | Hypo (Cl) | % | % | Ton |
| Soda as NaOH | | | | | | | | |
| 1 | 12 | 48.2 | 34.8 | 6.95 | 3.0 | 9.8 | 43.5 | 2.30 |
| 2 | 14 | 45.9 | 28.4 | 5.67 | 2.5 | 8.7 | 41.9 | 2.39 |
| 3 | 16 | 43.2 | 19.3 | 3.85 | 2.0 | 7.9 | 39.8 | 2.51 |
| 4 | 18 | 42.1 | 15.5 | 3.10 | 1.5 | 6.2 | 39.5 | 2.53 |
| 5 | 20 | 41.7 | 13.7 | 2.74 | 1.5 | 5.7 | 39.3 | 2.54 |
| 6 | 22 | 40.4 | 12.4 | 2.74 | 1.5 | 5.5 | 38.2 | 2.62 |
| Kraft as $Na_2O$ | | | | | | | | |
| 7 | 8 | 54.3 | 49.1 | 9.82 | 3.5 | 10.6 | 48.5 | 2.06 |
| 8 | 9 | 52.4 | 33.4 | 6.68 | 3.0 | 8.9 | 47.7 | 2.10 |
| 9 | 10 | 49.9 | 25.1 | 5.02 | 2.5 | 8.1 | 45.9 | 2.18 |
| 10 | 12 | 48.0 | 15.0 | 3.0 | 1.5 | 6.0 | 45.1 | 2.22 |
| 11 | 14 | 44.0 | 11.0 | 2.2 | 1.5 | 5.6 | 41.5 | 2.41 |
| 12 | 16 | 40.6 | 10.3 | 2.07 | 1.5 | 5.1 | 38.5 | 2.50 |

**2.5 Preservation of yield during Oxygen delignification and Bleaching:**

Oxygen delignification technology (ODL) of unbleached pulp is an environment friendly technology. A stage which help in kappa number reduction by oxidation of lignin in alkaline medium. The benefits of ODL are multiple , On one hand it saves bleach chemical, on other hand it reduces load of effluent of bleach plant.

After ODL if kappa number reduction is 10 point, which means that pulp shrinkage or yield loss is 1.5%. Normally typical yield loss during ODL amounts 2.5 to 3%. It also depends on kappa number, type of raw material, its quality etc. Additional yield loss may be due to dissolution of low molecular weight hemicelluloses and fines formation. In order to enhance the selectivity during ODL and for preservation of yield and strength, $MgSO_4$ or Magnesium hydroxide is added during ODL.Role of Magnesium sulphate/ Magnesium hydroxide as yield preservative is reported at many places.In a study sponsored by Research Steering committee(RSC)DCPPAI of DPIIT, Government of India under the project on “Improvement of Selectivity of Oxygen Bleaching”it was observed that addition of 0.3% $Mg(OH)_2$, there was a gain of 1.3% during oxygen pretreatment overall yield of pulp after DEopD sequence was 0.8%.(6)

Bleaching of pulp is the process stage where there is great scope of preservation of pulp yield. The selection of the bleach chemical is the main task which decides the response of bleaching while having good bleach yield as well as optical properties. The selectivity of bleach chemicals is that which make it possible to react with lignin and be unreactive or less reactive towards other . Chlorine dioxide removes selectively lignin and preserve cellulose. Introduction of DEpD bleaching sequence is resulted into better bleach plant yield as compared to CEpH bleaching. The kappa number after ODL is kept ~8-11, which after several studies considered to be ideal for indigenous raw materials.

**3.0 CONCLUSIONS**

1. A good quality check on fibre line results into maximum benefit in terms of yield gain.

2. The raw material type and quality, way its stored and preparation are the variables which impacts substantially on preservation of pulp yield.

3. Pulp yield showed an increasing trend with increasing permeability when standard sized chips were used. Composite permeability to pulp liquor decreased significantly with increase in chip thickness.

4. Kappa number increased as the chip thickness increased showing a low degree of de lignification with decrease in permeability . Lignin free yield was found to be related to composite permeability. At higher permeability, a lower chip thickness resulted in lower yeild indicating an over reaction.

5. Kraft pulps respond with better brightness and low reversion level compared to soda pulps at any given kappa number and bleach chemical consumption.

6. Loss in yield of Kraft pulps during bleaching is low compared to those of soda pulps.

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