Optimizing Rice Straw for Sustainable Packaging Materials Viz.Molded Products, Paper and Board Production

Presenting By –
Dr Priti Shivhare Lal
Scientist

Central Pulp and Paper Research Institute, Saharanpur

Global Demand for Paper and Packaging

- **Global CAGR of 12-15% in paper/packaging material demand.**
- **The price of raw material like hardwood is increasing**
- **The strong need of alternate pulp making raw material**
- **Rice straw pulp and board utilization is potential alternate**

Rice Straw

- Rice is one of the most widely consumed foods globally. Rice Straw is an abundant crop residue left in fields .
- 510 million metric tons of milled rice was produced worldwide (2022-2023).
- Per unit rice cultivation generates 1.5 times of rice straw.

Rice Straw Production in India

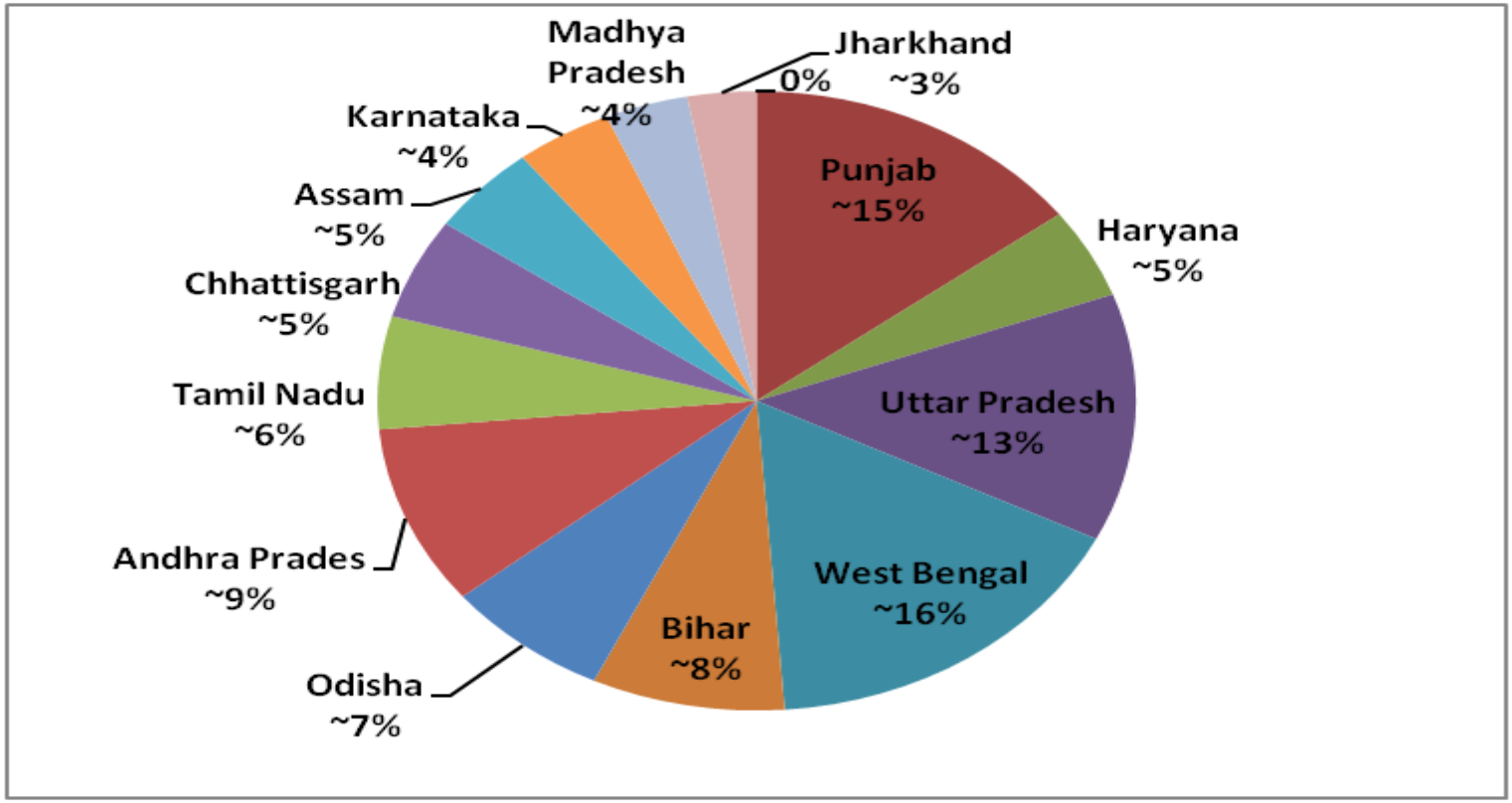


Fig 1: State wise percentage share of rice straw production in India

Sustainability Challenges in Rice Cultivation

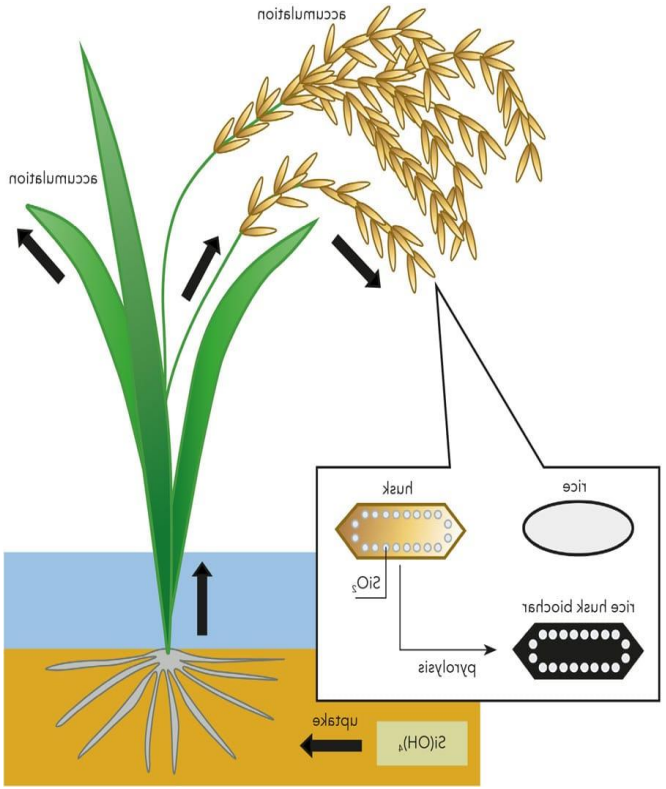
- Among the various crops cultivated, the main contributors of crop residual are rice (50%)
- Burning of agroresidue causes air pollution severe air pollution problem.
- Burning leads to health issues and greenhouse gas emissions.
- The burning of parali in northwest India significantly contributes to Delhi's air pollution.
- This process releases greenhouse gases such as CO_2, CH_4, CO, and N_2O, impacting human health.

Advantages of using Rice Straw for Pulp Production

- They are renewable annually.
- They require fewer chemicals for pulping.
- Expensive chemical recovery systems are unnecessary.
- Cheap chemicals like lime can be used for straw and similar materials to produce semi-chemical pulp.
- Small mills can be established with less capital investment.
- The process and equipment are simpler.
- Energy consumption is low.

Challenges with Rice Straw Pulping

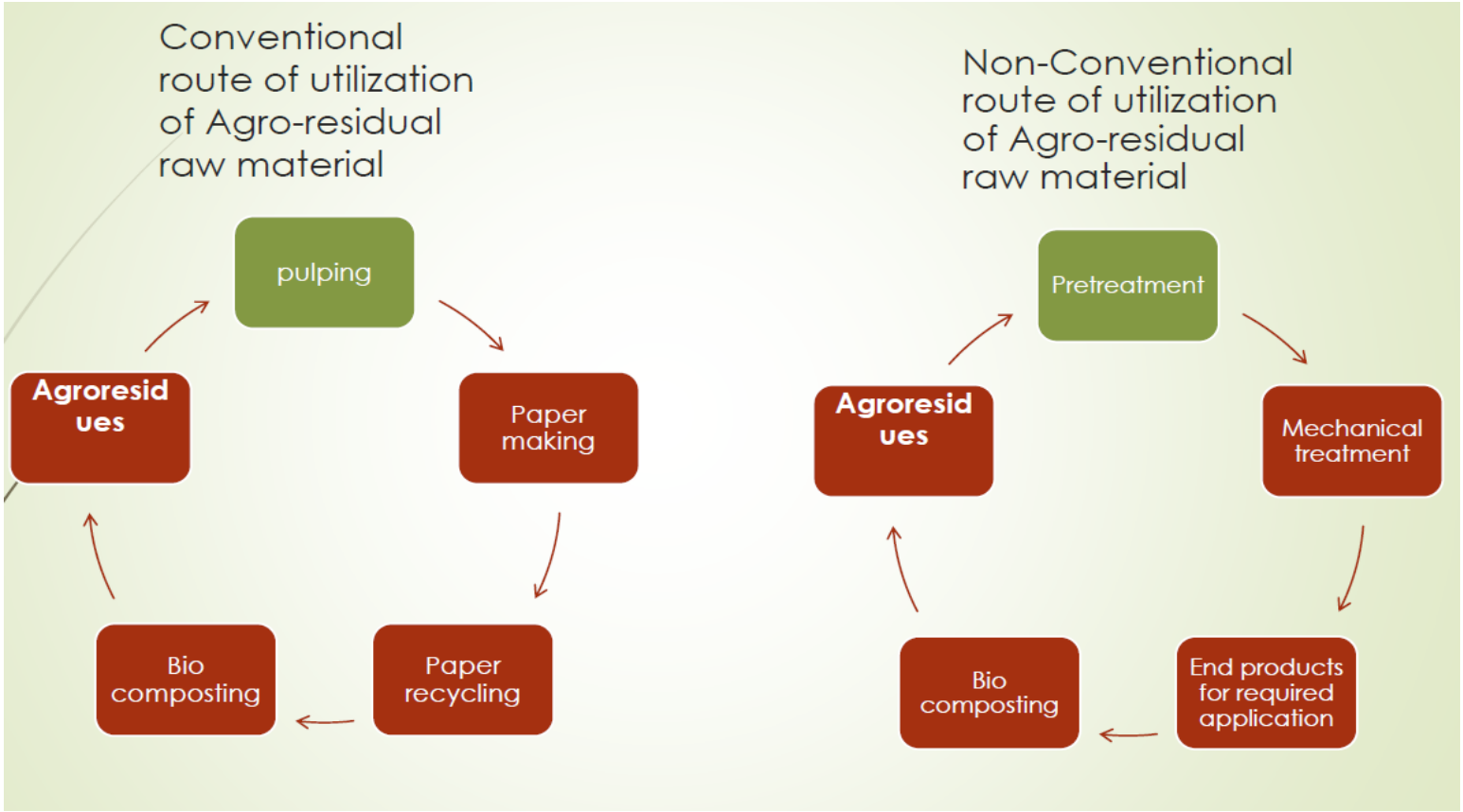
- Rice straw has a higher parenchyma cell content than wheat straw, leading to issues with drainage during processing.
- Rice straw pulps contain a large amount of fines, which results in low freeness before refining and impairs paper machine runnability.
- The chemical pulp from rice straw requires fewer chemicals compared to wheat straw or bagasse, but its yield is lower.
- The high silica content (over 5%) in rice straw complicates chemical recovery and makes it unsuitable for **conventional pulp production.**



Potential Solutions for Rice Straw Pulping Challenges

- **Fiber Fractionation:** Separating fines from fibers improves pulp strength, making it suitable for high-strength packaging.
- **Semi-Chemical/CTMP Pulping:** These methods reduce silica issues and fiber fragility, requiring less bleaching and producing stronger packaging paper.
- **Mild Refining:** Mild refining after semi-chemical or CTMP pulping reduces effluent load and preserves fiber quality.
- **Value-Added Packaging:** Alternate techniques enable the use of rice straw for various sustainable packaging products.
- Reinforcement of rice straw pulp with long fiber pulp for strength.

Different route of Utilizing Agroresidual Raw Materials



Proximate chemical analysis of rice straw from different regions

S. No.	Parameters,%	Chhattisgarh	Punjab	West Bengal	Uttar Pradesh
1.	Ash	17.28	14.17	16.47	14.20
2.	Silica	10.29	7.0	9.5	6.95
3.	Acid insoluble lignin	16.51	15.02	13.96	13.55
4.	Holocellulose	53.11	56.42	58.62	55.96
5.	Pentosan	18.51	20.14	22.31	18.2
6.	Hot water solubility	19.29	21.53	16.78	19.58
7.	Cold water solubility	11.84	12.91	8.58	10.33
8.	1/10 NaOH solubility	45.07	44.08	45.06	45.46
9.	Extractives	5.39	7.23	4.13	4.25
10.	α-Cellulose	36.92	37.65	38.57	36.58
11.	β-Cellulose	11.53	10.34	14.92	14.33
12.	γ-Cellulose	4.65	8.43	5.13	5.04

Semichemical Pulping of Rice straw

Cooking chemical NaOH%	2.5
Solid liquid ratio	1:5
Cooking temperature ^{o}C	130
Time at maximum temperature hours	3.8
Pulp yield %	63.0
Pulp freeness ml, csf	250

Baur Mc Nett Classification of Rice Straw

S.No	No of cells per gm/10^6	Cell coarseness	No of fines (<0.2mm)	Weight of fines(gm)	No of Average fibre length	Length of fibre length (mm)
Whole pulp	42.10	0.061	62.24	17.57	0.30	0.64
+50 fraction	23.61	0.089	29.86	4.31	0.48	0.78

Effect of Fractionation on Strength Properties of Rice Straw Pulp

S.No	Parameters	Rice Straw whole pulp		+50 fraction of Rice Straw pulp			
1	PFI, rev	0	500	0	500	1000	2000
2	Freeness ml,csf	425	200	580	482	310	200
3	Apparent density g/cm3	0.92	0.98	0.79	0.84	0.91	0.96
4	Burst index, kPam2/g	1.82	2.96	1.70	2.10	3.11	3.46
5	Tear index MNm2/g	5.14	4.87	6.01	7.98	7.90	6.89
6	Tensile Nm/g	25.1	40.6	26.3	42.1	48.1	50.4
7	Stretch , %	3.0	3.86	2.8	3.9	4.2	4.6
8	Fold KM log	0.78	1.2	0.61	1.27	1.40	1.68

Comparison of Soda pulping with Urea Pulping

S. No	Particulars	Pulping Processs	
		NaOH	NH_2CONH_2
1	Cooking Chemical, on raw material, %	4.0	8.0
2	Pulp Yield, %	67.9	68.2
3	K-Number	29.8	35.6
4	Spent liquor analysis	8.6	8.2
	a. pH	8.6	8.2
	a. Lignin removed, % on total lignin present in raw material	71.7	55.4
5	Strength Properties at freeness 200 ml C.S.F.		
	a. Tensile Nm/g	44.5	35.6
	a. Tear. mNm^2/g	3.80	4.9
	a. Burst, KPm^2/g	2.30	2.16
6	Effluent analysis:		
	a. COD, Kg/ton pulp	453	417.5

Result of Strength Properties Of Urea Pulping And Blending With Gunny Pulp

	PFI (rev)	Freeness CSF	Drainage Time	Apparent Density Gm/cm^3	Burst Index KPm^3/g	Tensile Index Nm/g	Stretch %	Fold kohler molin log	Tear Index mNm^2/g
Used Gunny pulp	0 500 1000 2000	400 255 210 165	5.27 8.16 9.66 13.32	0.56 0.57 0.58 0.61	2.80 3.90 4.10 4.80	50.0 64.0 66.5 76.0	2.1 2.4 2.4 2.6	1.87 1.92 1.98 2.10	12.0 9.3 8.65 8.30
Pulp blend of: 10% used gunny+ 90% urea pulp		330	20.3	0.56	1.30	28.0	1.5	0.84	5.50
20% used gunny + 80% urea pulp		320	19.7	0.57	1.65	31.0	2.0	1.04	5.85
30% used gunny + 70% urea pulp		295	22.4	0.57	1.97	33.0	2.2	1.23	6.90

*Pulp blends produced from it Urea pulp (300 ml C.S.F.) and used gunny pulp (255 ml C.S.F)

Properties of Rice straw Pretreated and Refined pulp

S. No.	Parameters	Exp.1	Exp.2
1	Raw Materials		
2	Alkali charge (NaOH)	2 %	3 %
4	Bath Ratio	1:6	1:6
5	Temperature ^{0}C	95	
6	Time (minute)	30, 90	
	After steaming in bombs at 95^{0}C take these materials for refining in disc refiner at 20 and 10 tou.		
7	Unscreened yield %	80.0	82.5
8	Screening yield %	74.2	76.0
9	Brightness ISO %	25	26
10	CSF	340	322

The Physical Strength Properties of Rice straw CTMP pulp

200 GSM hand sheets of CTMP unbleached pulp samples were prepared through laboratory sheet former for physical strength properties					
Physical strength properties	**GSM**	**Burst Index (k. Pa. M2/g)**	**Tensile index (N. m/g)**	**Bulk, cc/gm**	**Tear index (mN.m2/g)**
Unbleached Pulp Sheet (NaOH 2%	200	0.9	11.8	2.19	2.78
Unbleached Pulp Sheet NaOH 3%	200	1.0	15.0	1.96	2.90

Some common application of Rice Straw CTMP Pulp

Inherently flexible molded fiber offers substantial benefits to manufacturers of Food related, Horticultural, Industrial and Medical products:

- Clam shell and carryout food containers
- Cups, bowls, plates and serving trays
- Planter pots and seedling trays
- Egg, fruit, berry and mushroom containers and trays
- Vehicle Parts; gears, panels, headlights, wheels, etc.
- Household items; toasters, coffee makers, furniture, etc.
- Electronics, cell phones, TV, modems, DVD, etc.
- Single use medical bowls, kidney dishes, bedpans, etc.

Properties of straw boards

Basis weight gsm	870
Breaking length m.	2840
Density yield %	0.43
Bulk cm^3/g	2.32

Properties of the fiberboards

Thickness of the board mm	3.2	-	-
Density g/cm^3	1.0	-	-
MOR kg/cm^2	370	523	584
Tensile strength kg/cm^2	270	315	371
Water absorption 24h %	150	49	430
Thickness swelling 24h %	130	60	310

CONCLUSIONS

- Utilization of rice straw as raw material for production of pulp, by chemically, mechanically, or chemi mechanically separating cellulose fibers from the straw is value addition to rice straw.
- Materials derived from rice straw such as cellulose, hemi cellulose, chitin, starch and protein have the potential to be turned into different types of packaging including food packaging.
- As compared to other raw materials cost of rice straw is less then ¼ of wood and half of agroresidual raw material.
- Rice straw pulp may fulfil the requirement of food packaging industry where only virgin pulp is required.
- If use wisely, Rice straw pulp of different grade, is potential alternate to packaging paper board and moulded products.


THANKYOU