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Development of High Strength Towel Paper

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Abstract: ***High competitive market of tissue paper complied industries to manufacture cost effective and sustainable products. Towel grade tissue paper is generally meant for its high dry and wet strength to serve the purpose in household as well as away from home. The choice of fibers (especially long soft wood fibers) and their refining which require high energy is directly linked to cost and consumption of energy. Tissue paper is categorized by keeping in a view of end use and its product accordingly we define its characteristic and modified the manufacturing process accordingly. There is always an opportunity to cater the market with the new requirement at the same time there is a challenges to meet out its characteristics with lower cost of production. A Systematic study with scientific approach was conducted aimed at quality improvement by optimizing the fiber furnish and wet end chemistry which helped to maintain the machine parameter while manufacturing the high strength towel grade paper. After optimizing the imported softwood pulp a combination of 20% softwood pulp along with 80% mill pulp was selected for the research work. Using this selected combination of raw material furnish along with application of commercial cellulose refining enzyme, tensile strength increased by 15.0% and wet strength also increased by12.8%as compared to competitors samples.***

Keywords: High strength towel grade, Wet strength additives, Bulk, Cellulase refining enzyme, Gram force (gmf)

1. Introduction

In today's life tissue paper plays a vital role and contributes to improve hygiene, comfort and convenience of our society. Tissue sector has boomed over the last few years. Paper towels can be defined as tissue paper products used for drying and cleaning (Council of Europe 2004). To fulfill its purpose, toweling products should have high water absorbency. Since, paper towels are mainly used under wet conditions, they need to have high wet strength to maintain the integrity of paper structure while using. Consequently, absorbency and wet strength are among the essential properties that define the performance of paper towels (Kim et al. 1994; Gigac and Fišerová 2008; Kullander et al. 2012). Other properties, such as softness, brightness, and appearance (e.g., embossing design, graphic printing), are not much essential as they do not directly contribute to the main purpose (performance) of toweling products (drying and cleaning surfaces).The properties developed in tissue paper products, including kitchen towels, are typically a function of manufacturing technology, raw material (Gigac and Fišerová 2008), and the chemistry used (de Assis et al. 2018). Paper machine configuration (e.g., wet pressing, creping, structured fabrics) have an important influence on tissue paper properties. Conventional machine technologies (e.g., dry crepe), where wet-pressing is used to partially dewater the tissue paper web, produce denser and stronger tissue paper products with lower bulk, softness, and absorbency. However, advanced technologies (e.g., through air drying – TAD), where minimum pressing is applied on the wet tissue paper web, enable the production of higher quality tissue paper products with enhanced properties (high bulk, absorbency, and softness). The Advanced Tissue Molding System (ATMOS) uses mechanical ways to dewater a structured tissue paper web to about 40% before the final drying at the Yankee dryer (Voith 2018). Wet end chemistry also plays an important role in tissue paper properties. Various chemicals (e.g., wet strength, dry strength, surfactants, and softeners) are used to improve tissue paper performance (Forbess 1997). It is desirable to manufacture tissue paper with the required strength, bulk and softness, utilizing a furnish that requires as little energy as possible for dewatering and drying on the paper machine. Wet strength additives are used in paper towels to promote resistance to wet conditions. Wet strength performance depends on having a coherent network of fibers reinforced with a cross-linked network of wet strength additives. Additionally, tissue paper products with higher stretch abilities tend to have higher wet tensile energy absorptions. (Kan et al. 2016)

Wet strength and absorbency are considered to be the most important functional properties of kitchen towel products (de Assis et al. 2018). The main objective of application of enzymatic preparations for pulps treatment is to reduce refining energy and make the process not only less expensive but also more environmentally friendly (Torres. et .al 2012). Lecourt et al. (2010) observed that cellulases damaged the fibers, which caused deterioration of paper strength properties, particularly the tear resistance. The effect of higher blending of eucalyptus pulp with pine pulp on tensile strength, hand-felt softness, bulk and water absorbency (capillary rise of water) using an on-site paper machine was studied by Chang et al. (2018).

In the present study 20% soft wood pulp and 80% hard wood pulp were used to obtain the high strength in towel grade of tissue paper. Competitor samples issued from market for benchmarking the strength properties and accordingly optimize the fiber furnish ratio and chemical dosage.

2. Materials and Methodology

2.1 Materials

Experiments were carried out in a commercial industry R&D lab using bleached hard wood pulp, bamboo mixed pulp and bleached soft wood pulp.

2.2 Methodology

Pulp beating and preparation of hand sheets

The pulp hand sheets were prepared of 40gsm and at freeness of 30°SR after applying the refining enzyme by TAPPI 205method. As per end use requirement of High strength towel we need to add some quantity of high strength softwood pulp which has good flexibility, high folding strength, good tensile strength in mixed hard wood pulp. Various studies with different proportion of hard wood and soft wood pulp were carried in a lab to get optimum test results similar to benchmarked sample. Both the above mentioned pulp was separately refined (Mixed hard wood at 28-30°SR and Soft Wood at 40°SR) in PFI mill according to ISO 5264-2.The pulp freeness of mixed hard wood and soft wood were kept between 32-34°SR.Low drainage resistance was chosen for all tested pulps as pulp beating markedly reduces the water absorption, bulk softness and brightness (Fišerová et al. 2019). Refining enzymes were used during pulp refining to reduce specific energy consumption and improve paper strength properties. Softwood pulp have many long and stiff fibers that do not bond extensively to each other, Thus increase in bonding is attained by refining these pulps to low drainage levels. Wet strength additives with high solid content 30 % were used to improve the tensile strength of tissue paper by cross linking the cellulase fiber with covalent bond that does not break upon wetting.

Cellulose Fiber

Cellulose fibers are fibers made with ethers or esters of cellulose, which can be obtained from the bark, wood or leaves of plants, or from other plant-based material. In addition to cellulose, the fibers may also contain hemicellulose and lignin, with different percentages of these components altering the mechanical properties of the fibers. The main applications of cellulose fibers are in the textile industry, as chemical filters, and as fiber-reinforcement composites, [Monica et.al. 2015] due to their similar properties to engineered fibers, being another option for biocomposites and polymer composites

Cellulase Enzyme

Cellulases are a complex group of enzymes which are secreted by a broad range of microorganisms including fungi, bacteria, and actinomycetes. Cellulase is not a single enzyme. It is a group of enzymes which is mainly composed of endoglucanases and exoglucanases including cellobiohydrolases and β-glucosidase. Cellulase is potential tool for modification of pulp properties to save energy requirement during refining process.

The hardwood pulp fiber was also refined according to ISO 5264-2. The hand sheets of 40 g/m^2 were prepared and tested according to ISO-1:2005.Before the evaluation of physical properties, towel samples were properly conditioned in a room maintained at 50% relative humidity and temperature of 23 °C for 24 h (TAPPI T 402 sp-08 2013).

Table 1: Comparative test results of Competitor samples from two different locations

S. No.	Particulars		UOM	Towel samples from Location A	Towel sample from Location B
1	Actual GSM-Average		g / m^2	40	40
2	Thickness		micron	134	136
3	Bulk		cc / gm	3.3	3.4
4	Brightness		%ISO	81.6	83.4
5	Tensile strength	MD	gmf/cm^2	1488	1386
		CD		1188	1119
6	Wet strength 10 ply	MD	gmf/ 15mm	3158	3010
		CD		2605	2438
7	Stretch	MD	%	43.2	40.3
		CD		17.1	15.2

As shown in above table, towel paper samples were collected from two different locations i.e. location A and location B for physical properties reference. Towel paper sample collected from location A, having tensile strength 1488 gmf/cm^2 and wet strength 3158 gmf/15 mm and towel paper sample collected from location B contain tensile strength 1386gmf/cm^{2}and wet strength 3010 gmf/15.

Mixed pulp preparation

Bleached mixed wood pulp (Hard wood and Bamboo) was mixed with bleached soft wood pulp in the following ratio as given in table no.2.

Table 2: Different Ratio of Harwood and Softwood Pulp

Mixed wood pulp (%)	Soft wood pulp (%)
90	10
80	20
70	30
60	40

Analysis:

Commercial cellulase refining enzyme used in this study with consistent dosing of 30 g/t at 4% pulp consistency. Refining of the pulps was carried out in the PFI mill. Hand sheets of refined pulp were prepared and tested for different physical strength and surface properties. Bulk of sheet was determined according to ISO 534:2011(en) and Brightness, Tensile strength was determined following ISO 2470-1:2016 (en) and ISO 1924-2:2008(en) test methods. Wet tensile

strength of hand sheet was carried out as per test method ISO 12625:2016.

3. Results and Discussions

Hand sheet properties of mixed pulp

The properties of hand sheets prepared using different ratio of mixed pulp and soft wood pulp were compared. Pulp refining is important parameter of pulp so both above used pulp were refined by PFI Mill. Refining affects dewatering performance of the pulp and its properties. Mixed bleached pulp requires less revolution as compared to bleached soft wood pulp to get desired drainage. Enzymatically refined pulp improves fiber flexibility and sheet forming properties without loss of strength properties. Tensile strength is an important characteristic of high strength towel grade paper, which represents the maximum tensile force developed in a test specimen before rupturing during the tensile test under prescribed condition. Tensile strength depends upon fiber length, fiber strength and their bonding ability during manufacturing of tissue paper. Dry strength is a physical property determined by a paper's ability to maintain the paper web structure and integrity while being used. Dry strength is result of fiber-to fiber bonding and typically attributed to hydrogen bonding. The dry sheet strength is crucial for towel grade of tissue papers to ensure they can withstand a certain load capacity and meet the consumer's expectations. Additionally, dry strength is particularly important to monitor within tissue paper as increased strength can lead to decreased softness and lower the bulkiness. Dry strength is generally modified in a sheet through the introduction of additives. These additives help increase the relative amount of bonded area and strength of the paper. It is important to recognize the extent to which pulp is subjected to mechanical action. The amount of refining and addition of dry strength additives work in parallel therefore it may not be advantageous to utilize large amounts of both. Bulk of hand sheets is an important property for tissue paper because the thickness and volume of the paper correlate well with the absorbency as well as bulk softness.

Table 3: Comparative chart of treated softwood and mixed pulp with refining enzyme

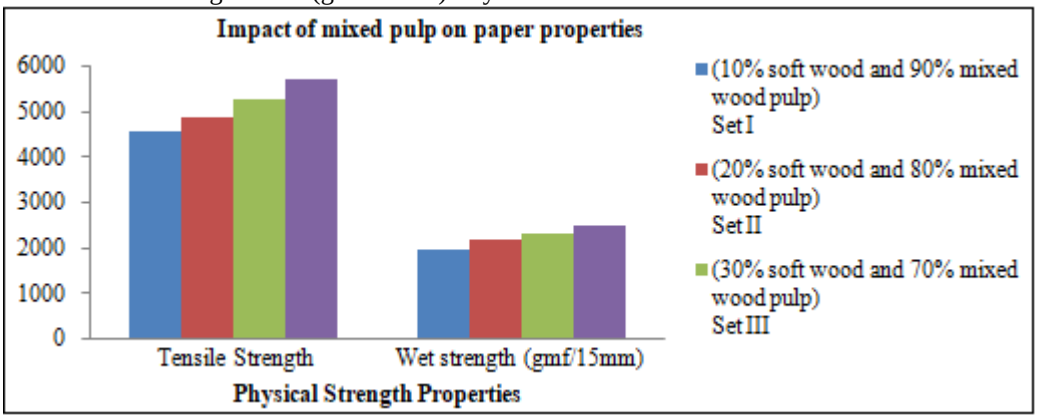
Parameters	Soft wood pulp		Mixed Pulp (Hard wood and Bamboo)	
	Blank	Enzymatic treatment	Blank	Enzymatic treatment
Initial °SR	12	13	16	17
Final °SR	40	40	30	30
Revolution	13700	10960	3000	2490
pH	6.8	6.4	6.0	6.5
Temperature	Ambient	52	Ambient	54

The comparative chart demonstrated in Table No.03 indicates that application of commercial cellulase refining enzyme, decreased the number of revolutions of both the pulp were by 20 % and 17 % in softwood pulp and mixed hard wood pulp respectively. This further reduced the specific energy consumption of refiner.

Table 4: Comparative physical strength properties of hand sheet (mixed wood pulp and soft wood pulp in various ratios)

S. No	Parameters	UOM	(10% soft wood and 90% mixed wood pulp)	(20% soft wood and 80% mixed wood pulp)	(30% soft wood and 70% mixed wood pulp)	(40% soft wood and 60% mixed wood pulp)
			Set I	Set II	Set III	Set IV
1	Refine Enzyme Dose	g/ton	30	30	30	30
2	PFI revolution	No's	3337	4184	5031	5878
3	GSM	g/m2	40	40	40	40
4	Bulk	cc/gm	1.60	1.62	1.65	1.77
5	Brightness	%ISO	88.0	88.5	88.2	88.3
6	Tensile strength	gmf/cm^2	2046	2184	2369	2561
7	Wet strength	gmf /15mm (10ply)	1971	2185	2341	2501

It can be concluded from Table No. 04 that wet strength of hand sheet and tensile strength have increased by addition of 40% soft wood in mixed wood pulp. By addition of 20% soft wood and 80% mixed wood pulp we observed Tensile strength 4854 meter and wet strength 2185 (gmf/15mm).Dry strength as well as wet strength of hand sheet were observed in increasing order after addition of long wood fiber in mixed hard wood fiber at lower revolution by using refining enzyme.



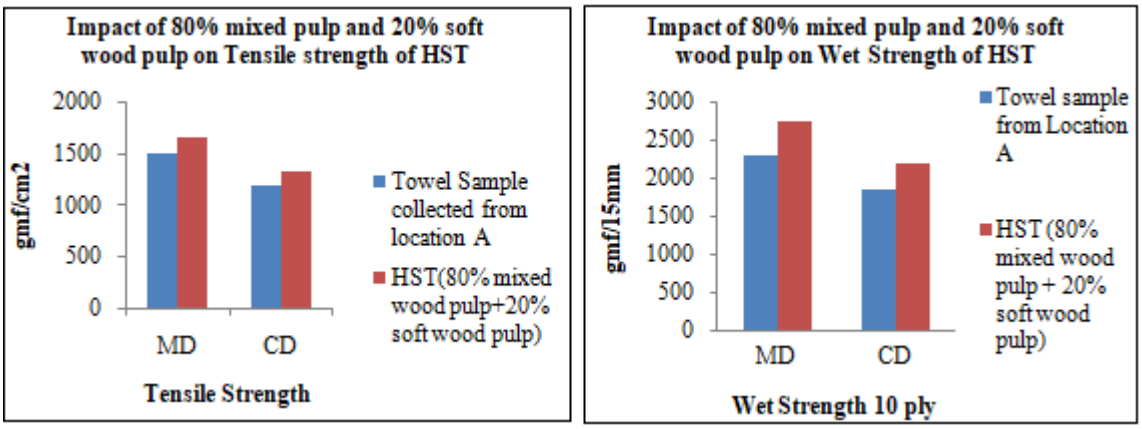
Graph 1: Impact of mixed pulp on paper properties

Above graph (Graph No. 01) shows that the tensile strength of the pulp sheet is directly proportional to the fraction of softwood utilized while manufacturing HRT. As the percentage of softwood pulp increased in raw material furnish, the tensile strength was also observed to elevate.

Table 5: Comparative test results of Competitor samples from two different locations along with manufactured HST paper in plant

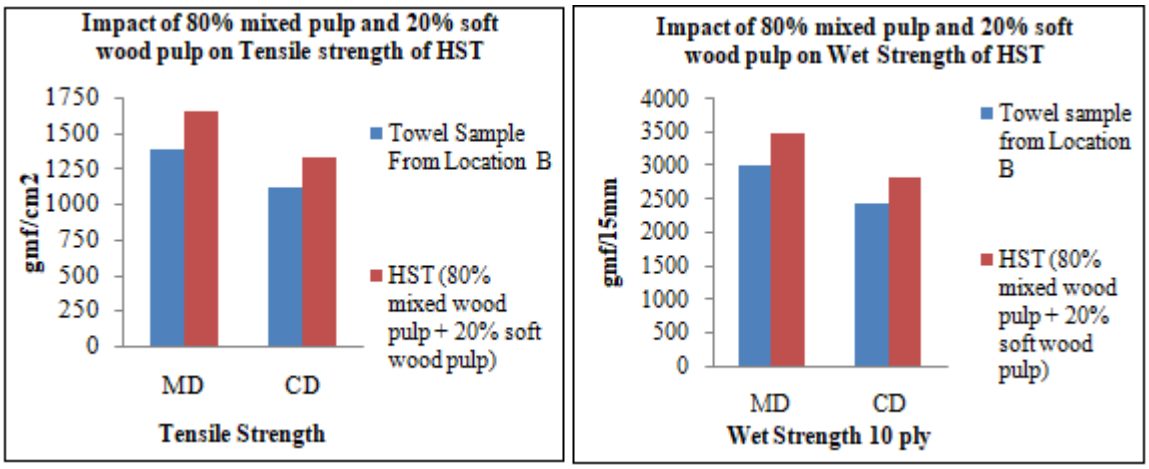
S.No.	Particulars		UOM	Towel samples from Location A	Towel sample from Location B	High strength towel mfd. at commercial industry with 80% mixed and 20% Soft wood pulp combination
1	Actual GSM-Average		g / m^2	40	40	40
2	Thickness		micron	134	136	136
3	Bulk		cc / gm	3.3	3.4	3.4
4	Brightness		%ISO	81.6	83.4	84.2
5	Tensile strength	MD	gmf/cm^2	1488	1286	1652
		CD		1188	1119	1321
6	Wet strength 10 ply	MD	gmf/ 15mm	3158	3010	3478
		CD		2605	2438	2836
7	Stretch	MD	%	43.2	40.3	45.2
		CD		17.1	15.2	19.2

A property of competitor samples collected from two different locations along with manufactured HST paper in plant was compared. Thetensile strength and wet strength parameters of manufactured HST were found to be superior with respect to sample received from location A and location B. The results are clearly depicted in table no. 05.



Graph 2: Impact of 80% mixed pulp and 20% soft wood on paper properties

Above graph no.02 clearly indicates the increment in Tensile strength and wet strength in MD as well as CD as compared to the sample of Location A.



Graph 3: Impact of 80% mixed pulp and 20% soft wood on paper properties

Above graph no.3 clearly indicates the increment in Tensile strength and wet strength in MD as well as in CD while compared to Location B sample.

Wet tensile strength is an important characteristic for towel grade of tissue paper. Fiber of tissue paper is mainly hold together by hydrogen bonds. These are dependent on

physical contact among fibers and can be broken by wetting of fiber due to water fiber bonding. Wet strength additives with high solid content 30 % were used instead of conventional WSR with 10-15% solid content to improve the wet tensile strength of tissue paper by cross linking the cellulose fiber with covalent bond that does not break upon wetting.

4. Conclusion

Sheet strength is a crucial target in tissue paper production, which can be pursuit through the selection of fibers, the refining level and the use of dry and wet strength additives. Fiber is the main constituent to overall cost of tissue paper manufacturing process. 50% of the total cost of finished product is guided by the fiber only. By increasing the soft wood pulp fraction in the raw material furnish mix, would definitely increase the wet and dry strength of paper but cost of paper would increase as soft wood pulp are costlier than the hard wood pulp and chemical additive.

As observed physical strength properties mainly tensile strength and wet strength in the competitor's sample (table no.1) of 40 gsm is comparable with the strength properties of high strength towel manufacture at commercial production by using 20% soft wood and 80% mixed pulp of bamboo and hard wood. Tensile strength increased by 11.0 % in MD and Wet strength increased by 10.13 %in MD as compared to sample from location A and tensile strength increase by 19.22% in MD and wet strength increased by 15.5 % as compared to sample from location B. Fiber quality is key contributor in tissue product quality such as bulk, softness, stretch, water absorption, wet strength and dry strength. Superior quality of tissue paper in terms of higher strength is achieved by incorporation of softwood pulp in virgin mixed hard wood pulp. Pulp varieties, refining condition, chemical formulation and fiber furnish composition influence tissue products characteristic and make it possible to fulfill various end use requirements of the tissue products. Refining enzyme not only reduces the energy consumption but also improves fibre fibrillation. Enzymes improve the refining of pulp at same refining degree (°SR) and desired paper properties can be achieved at decreased refining time. Soft wood pulp always enhanced the strength properties of tissue product.

From the above study it can be concluded that, by optimizing the raw material furnish mix, application of refining enzyme and formulation of better recipe at wet end, strength properties of towel grade tissue paper was enhanced to a great extent, thus, yielding improved quality of the towel grade tissue paper.

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