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Review

Bleached and unbleached OCC soda pulp in stock preparation for sugarcane bagasse pulps

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ABSTRACT

Recycling paper (secondary fiber) for different recycled pulp grades has been seen as the solution for the lack of forest products for pulp and paper production. However on secondary fiber, both reversible and irreversible changes as hornification, loss in flexibility, swelling properties, conformability and lower strength and bonding between fibers take place in progressive and repeated recycling which results in a weaker, lower grade of paper. This study carried out a review of the state of the art of technical constraints and limiting factors of recycling and analyzes the possibility to improve the mechanical and optical properties of old corrugated container (OCC) pulps, through a stage of alkaline delignification by the soda chemical process, and subsequent elementary chlorine free bleaching (ECF). OCC soda pulp was conducted to substitute unbleached and bleached kraft pulp (UKP) for the manufacture of bagasse paper. The OCC soda pulp/bagasse pulp mixtures were evaluated according to the international TAPPI test of mechanical resistance and optical properties. Results showed that the OCC soda pulps and bagasse pulp mixtures were upgrading on tear, burst, tensile and folding minimizing the negative effects of recycling on drainability. OCC means an alternative resource of fiber to obtain unbleached pulp or bleached pulps which justify the use of the delignification stage and support this process to produce an important source of bleached fibers for the manufacturing of various types of non-wood paper and linerboard.

KEYWORDS: delignification, bleaching, OCC, bagasse pulp, physical properties

INTRODUCTION

During the past decades the restrictions in availability of forest-based raw materials along with environmental policies towards alternative sources of raw materials have forced pulp and paper industry to shift towards recycled paper and other fiber sources such as non-wood and agro-residues.

The driving forces behind this development have been the following: economic benefits; environmental issues; new technology in the areas of regeneration of papermaking potential, deinking, screening of impurities, fractionation, bleaching and web forming has promoted the use of recovered paper; the reducing volumes of solid waste for landfill.

In the late 1980’s and early 1990's, recycling issues have emerged stronger than before due to the higher cost of landfills in developed countries and an evolution in human awareness. The findings of the early 70’s on recycling effects on final paper grades have since been confirmed, although attempts to trace the cause of these effects are still not resolved [1].

The use of recycled fibers is steadily increasing in various paper products and there is a need to improve the strength properties of paper products

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made from these fibers. But the bonding ability of fibers is not always properly developed; then it is desirable to regenerate the swelling and the bonding ability of fibers. Development of papermaking properties of recycled pulps should be carried out at all stages of its processing to improve and/or modify the original waste pulp characteristics. All this must be done while reducing the unit cost energy, steam, fresh water, amount of waste, and fiber loss [2, 3, 4, 5, 6]. Generally, these investigations can be divided into four categories: recycling operation, environment protection, product performance, and sheet properties.

Recycled paper has become the most important raw material on supply-chain for the paper and board production. The concept of paper grade was introduced by the waste paper and paper-making industry to help categorize waste paper for recycling and facilitate its trade, and effectively organizing its collection, sorting, and preparation as feedstock in papermaking. The highest recyclers worldwide (Volume of recovered paper in the country divided by paper apparent consumption) are South Korea (91.6%), Germany (84.8%), Japan (79.3%), United Kingdom (78.7%), Spain (73.8%), United States (63.6%), Italy (62.8%),Indonesia (53.4%), Finland (48.9%), Mexico (48.8%), Brazil (46.0%), Argentina (45.8%), China (40.0%), Russia (36.4%) and India (25.9%) [7].

The theoretical limit of paper and board recycling rate is around 81%, since 19% of the paper products are not collectable or recyclable for technical reasons. A rough estimation of the different sources indicates that 50% of the recovered paper is collected from industry and trade, 40% from households and 10% from offices which are becoming more heterogeneous. Nowadays, in some countries the paper industry cannot survive without recycled fibers [8, 9].

Fiber re-utilization creates extremely non-homogenous mixture of variously old fibers. Old paper is composed by all types of manufactured paper and board. Recycled paper is sorted into categories, such as Old News Paper (ONP), Old Magazine (OMG), Mixed Office Waste (MOW), and Old Corrugated Containers (OCC) by grade of recovered paper in 41% OCC grades, 26% Deinking grades, 20% Mixed grades and 13% High grades with different fiber yield on recycling from recovered paper [10]. However, ONP (newspaper), OCC (corrugated cardboard), and mixed paper all reach a recycling rate of 90% or higher by 2036 [11].

Recycled OCC

Old corrugated containers (OCC) consisting of corrugated container (54%), DLK-New double-liner kraft corrugated cutting (30%), Boxboard cutting (13%) are the most significant category of waste papers or post-consumer waste for recycling based to protect contents inside box from compression forces during packing, storage and distribution. The rest are sack kraft (3%), however, this type of recovered paper is relatively expensive and has a limited availability. Corrugated container paper is composed of two different materials: the corrugated core sheet of paperboard and the flat paper cover (linerboard) with high strength and identified by its brown color. A sheet of corrugated container and kraft bags can have different compositions of the corrugated medium and linerboard layers varying from unlined to double-faced, double-doubled, or triple-walled corrugated cardboard. It is 1/3 corrugated medium and 2/3 kraft linerboard, often contains sizing and strength additives to improve its durability, and it may have printing on its surfaces, although it does contain adhesives that hold the layers of facing and corrugation together.

OCC are made of unbleached softwood chemical long fibers that also have a low lignin content of about 10-15% and a high cellulose content of 50%, and recycled cardboard of different fraction by length, where the short fraction is used as the corrugated medium while the stronger long fraction is used for the liner.

However most OCC has unique characteristics: (a) high amount of fines and short fiber length (b) low water retention value, (c) poor drainage properties (below 200 mL CSF); (d) high amount of contaminants such as inks, stickies, plastics, inorganic particles and polymeric and non-polymeric materials; and high dissolved solid (mainly primary and secondary fines or material passing a 200 mesh screen). These characteristics could be derived from two reasons. First OCC contains various different kinds of pulps such as coated waste and MOW, which usually cause problems with the control of paper machine parameters as runnability and resulting paper qualities. The second is a severe hornification due to the increased number of recycling. Therefore, the simple separation of fines with whole or slit type fractionators is not believed to give the desired separation of the fines and contaminants from the OCC furnish [12, 13].

The recycling process (Stock preparation to restore papermaking ability of recycled fibers and to obtain pulp) for cardboard (without printing) and corrugating paper (fluting) takes place in stages of repulping in a pulper, defibration, kneading, flotation, washing, dispersion, screening and refining. The OCC recycling process have been mainly concentrated on the removal of contaminants like stickies, plastics and several inorganic substances derived from wastepaper, however, the presence of hydrophobic compounds on the surface of recycled fiber has been identified as a cause of reduced strength properties, because fibers became less flexible with increasing chemical.

Refining of OCC pulp generates fines and reduces the fiber length. Increase in fiber population per gram of pulp enhances fiber to fiber bonding, because of more surfaces available for bonding by fines. Therefore, it could be concluded that refining could fully restore bonding potential of recycled fibers, through generation of fines and fragmentation of fibers, but does not imply the restoration of the original state of the fibers.

The loss in tensile or burst strength of chemical pulps from OCC is about 30% after a few times recycling. Tear strength, by contrast, has a gain, which is about 30%. These strength changes are caused by the loss in fiber-to-fiber bonds [14, 15, 16].

Traditional methods to increase the strength of OCC recycled paper involve adding dry strength agents and refining. Fibers are also shortened during refining and more fines are produced, which leads to drainage problems and affects the productivity of the paper machine, therefore, current recycling processes have a limited capability to produce high-quality fiber from the available recycle grades and require high-cost upgraded raw material [17].

The greatest problems with utilization of OCC fiber (technical requirements) are a continually changing source, the lack of homogeneity and poor quality in the furnish as compared to virgin fiber, and a lower quality product through drying, higher level of contaminants (inks, wax, stickies, hydrophobic matter, wet strength resins, dyes), surface inactivation, cellulose chain cleavage, aging by acid hydrolysis and pH, fines formation, inorganic content (ash), fiber damage and hornification. The strength and papermaking properties are partiality achieved by the use of 25 to 30% long fiber wood pulp as reinforcement fiber and other virgin pulps [18, 19].

Hornification

Paper made from recycled, chemically pulped fibers typically has lower strength than paper made from virgin fibers; the loss of paper strength during recycling is a critical issue for the paper industry. Drying and rewetting cycles principally cause shrinkage of the natural fibers due to the formation of hydrogen bonds in cellulose. The strength loss of recycled paper limits the number of recycles of waste paper and paperboard, and it limits the usage of recycled fiber per unit production [20].

During recycling of chemical pulps (hardwood and softwood), deterioration of pulp properties occurs due to hornification. It’s a technical term used in wood pulp and paper research literature since Jayme (1944) to describe structural changes as fiber shrinkage and formation of internal hydrogen bonds (irreversible or partially irreversible), loss in flexibility and conformability of wet pulp fibers (wet-web strength) and change in fiber pore structure to different amounts of lignin and hemicellulose content. Scallan developed another cell wall model to explain the mechanism of hornification. This phenomenon is caused by irreversible structural changes taking place during drying which could be clearly observed as deteriorated fiber properties, loss of swelling and bonding capacity. Many studies have been devoted to this subject [21, 22], and good progress has been made.

Mechanical pulps are normally less susceptible to hornification than are bleached chemical pulps (low yield pulps) because the lignin content restricts the opportunity for intermolecular mobility and contact within the carbohydrates component. Also, fibers with high lignin content are initially more rigid because of the three dimensional structure and cross - linking characteristics of the lignin macromolecule, which result in less initial fiber collapse and bonding besides pulps with higher hemicellulose contents may have a lower tendency to hornify during recycling [23, 24].

A variety of techniques have been developed and modified continuously to study it, but it is still unclear how the internal cell wall structure of refined hornified pulps differs from that of never-dried pulps. This involves polysaccharide hardening at the molecular level in dried pulp and possible changes in the microstructure of the recycled fibers (water-fiber interaction). Recovering the bonding potential of dried fibers is not as easy as those of virgin fibers (never dried fibers). The carboxyl groups contained in the wood pulp have been shown to have a major influence on the hornification of kraft fibers. When in their hydrogen or acidic form, they promote more hornification. Many attempts [25, 26, 27] have been made and designed to improve and/or modify the pulp characteristics and to increase the suitability of recycled fibers for papermaking. These include various techniques of beating and chemical treatment of recycled fibers. There are four possible ways to recover the loss of bonding of recycled fibers: (1) beating and refining for internal fibrillation but refining does not completely reverse hornification, (2) chemical treatment, (3) blending with virgin fibers, and (4) fiber fractionation. Each method has its own advantages and disadvantages.

Fines removal as well as subsequent fines-free pulp refining are processes that segregate a blend of pulp fibers into two or more streams based on some physical properties such as length, flexibility, coarseness etc.; they are the most often suggested methods for the improvement of papermaking potential (recyclability) in the case of these fibers. On the other hand, the possibility of improving papermaking quality of fines-rich pulp and reduce recycling process energy consumption are very limited. Therefore, from a papermaking point of view, these fines (secondary fines) can be regarded as unwanted filler only resulting from the fact that the components having no papermaking potential should be removed. An inevitable growth in costs will be a consequence of this trend.

As the removal of fines itself has no impact on increasing the papermaking potential of fibers, it is necessary to use an additional technological operation for improvement of the papermaking potential of recovered fibers.

Any improvement in the strength properties of OCC pulp by fractionation requires either a loss of 10-20% raw material or re-use of short fraction in a lower grade as filler or as a raw material for the corrugated medium [28, 29, 30, 31].

However, the crystallinity of the fines fraction did change with recycling. It was found that the crystallinity of the primary fines was lower than the crystallinity of the secondary fines. The increase of fines crystallinity and changes in fines surface characteristics with recycling are thought to play an important role in the reduction of the strength (burst and tensile) properties of recycled pulps [32, 33, 34, 35].

Some aid strategies to minimize damage to fiber quality during the processes of paper manufacture drying, converting, use, and recycling are: Remove hemicellulose from woodchips prior to kraft pulping, refine gently emphasizing fibrillation, alkaline pH conditions during the forming and drying of paper, use dry-strength additives, such as cationic starch, avoid over-drying the paper. In practical industrial testing, several tests are currently used in order to assess the quality of packaging grade papers on the basis of their physical-mechanical characteristics, besides the physical-mechanical characterization of packaging grade papers, fiber anatomy and composition can be used successfully as a complementary practical test to predict the performance of papers [36, 37, 38, 39, 40].

Most researchers now agree that changes in pulp properties with recycling are due to changes in fiber structure, i.e., hornification. Although changes in the long fiber fraction could be reversed by refining, it was stated that this was an ineffective treatment for the fines fraction; i.e., fines hornification was irreversible and the strength properties, swelling, and bonding potential of fibers and paper are reduced upon recycling. Other studies suggest [41, 42, 43, 44, 45, 46] alkali treatment influences the swelling capacity of the fibers, which is a very important factor in terms of the bonding potential of the fibers. Recycled fibers from alkaline paper behave more like virgin paper and can make better recycled products.

It was observed that strength properties of recycled paper were improved after the treatment of oxygen delignification resulting from lignin, extractives and chemical removal with the treatments. Delignification and bleaching are keys to upgrading of OCC fiber potential for papermaking alone or mixtures with non-wood fiber as bagasse and other pulps grades [47, 48, 49, 50].

Studies on the effects of the alkali treatment of recycled fibers produced different results. Disagreements could be due to the fact that the alkali produces a favorable effect on swelling, concomitantly with a negative effect on the hemicellulose loss. Although the benefits of the alkali treatment of high temperature are widely claimed and improves pulp strength even at low alkaline charges, it has not been applied yet in industrial processes.

However, few studies placed great emphasis on two fundamental issues unique to conversion of OCC to paper and boards products with virgin pulps as bagasse pulp mixtures: (1) the composition of waste paper as long fiber and pollutants and (2) the effect of fiber hornification caused by drying in the paper production process and the inactivation of the fiber surface produces a loss in the bonding capacity of the recycled fibers with virgin pulps.

Bagasse pulp

Sugarcane is a valuable substrate for bio-products, because it produces high yields of fermentable sugars and because the plant’s fiber is also recovered (as bagasse from juice extracted from the sugarcane stalks) and used as an energy source in downstream processing and pulp and paper production. Bagasse is currently being explored in developed and developing countries as a viable raw material for pulp, paper and wood composite manufacturing. This industry has been mostly domestic focused. Bagasse pulp has a greater flexibility to be made into a wide range of paper grades (writings and printings, brown paper and paper board grades, corrugating medium, sanitary tissues and even newsprint) but the main factors that have to be considered in the use of bagasse pulp in paper making are: Slow drainage, short fiber length, high fines content, poor wet strength high ash content and low runnability on the machine, but bleached pulp requires little or no refining to bring about fiber uniformity out of heterogeneous fiber bundles to produce paper of quality, however, the fibers are not as long and they don’t bond as well as softwood kraft and may require changes to the forming section of the paper machine and by use of drainage aids.

Bagasse pulp is produced in integrated pulp and paper mills. Unbleached and bleached kraft softwood pulp is added (up to 20-30%) as a major component of mixture for sugarcane bagasse pulps on paper and linerboard, because the strength properties of bagasse pulp are relatively poor compared to wood pulp and therefore application to produce brown grades such as kraft sacks and liner board is generally avoided. However, other long fiber supply pulp, for strength increment as OCC may be used instead of softwood kraft or sulfite pulp, thus producing a 100% non-wood paper.

OBJECTIVE

The objective of the present paper was to assess the technical benefit of an improved unbleached and bleached OCC soda pulp addition to a bagasse pulp used in the production of several papers in terms of their physical properties.

MATERIALS AND METHODS

Recycled pulp characterization and chemical composition

The OCC fiber used in this study, after recycling cycles, was a mixture (50/50) of domestic and foreign (from USA) commercial source of old corrugated containers (OCC) as received (unprocessed), but both materials were analyzed separately. The OCC mixture was soaked in water at approximately 4% consistency to separate individual fibers in water suspension. The pulp was not beaten, only disintegrated and analyzed with the TAPPI Standard methods for chemical composition (Table 1).

Pulping of OCC

First it was necessary to reduce the lignin content on OCC pulps. The cooking trials were carried out in a batch stainless steel rotary digester, electrically heated with temperature control system and maximum pressure of 8.5 kg cm^{-2}. The white liquor used was prepared from sodium hydroxide (NaOH) at four levels of alkali (13, 15, 17 and 20% as Na_2O based on OD weight of pulp) with liquor to fiber ratio 5:1, Time to max. 30 min and Temperature: 170°C. At the end of pulping (lignin removal) the pulps were washed, disintegrated in a laboratory pulp mixer and screened with 0.15 mm slotted late. The papermaking potential, pulp properties and yield of OCC soda pulp were determined as dry matter obtained on the basis of oven dried raw material according TAPPI test (Table 2).

Table 1. TAPPI (Technical Association of the Pulp and Paper Industry) test for chemical composition.

Test	
Preparation of Wood For Chemical Analysis	TAPPI T 204 om-88
Ashes	TAPPI T 15 om-88
Acid-insoluble lignin in wood and pulp (Klason lignin)	TAPPI T 222 om-88
Holocelullose	Wise Method

Bleaching ECF of OCC soda pulp

The target of bleaching is a high and stable brightness on OCC soda pulp. The ECF meaning bleaching sequences in which chlorine dioxide consumption is low, however, an important reason for the limited use of some pulps is their low selectivity towards lignin. In their highly oxidizing environment, carbonyl and carboxylic structures may be formed within the polysaccharide chains inducing cleavage in these chains when the pulp afterwards is exposed to alkali. Thus, pulp viscosity and fiber strength are reduced. The OCC soda pulp with brightness of 31.7% ISO was

Table 2. TAPPI (Technical Association of the Pulp and Paper Industry) Test for pulp and paper properties.

Testing	
Kappa number of pulp	T-236-cm-85
Fiber Length of Pulp by Classification (Bauer-McNett)	T-233-cm-82
Forming handsheets for physical test of pulp	T-205-om-88
Standard conditioning and testing atmospheres for paper, board, pulp hand- sheets, and related products	T-402-om-93
basis weight or grammage	T-410-om-98
tensile strength	T-494-om-96
Bursting strength of paper	T-403-om - 91
Internal tearing resistance of paper	T-414-om-04
Forming handsheets for reflectance testing of pulp	T-218-om-91
Brightness of pulp, paper, and paperboard	TAPPI 525-om-98
opacity	T-519-om-96
CED viscosity	T-230-om-89
Brightness Reversion	T-um-200
Folding endurance	T-423
Pulp beating	T-248-wd-97
Refining level	SCAN-m3:65
Drainage time	T-205-sp-95
Porosity, Air permeability (Gurley Method)	T-460-om-96

Table 3. Bleaching conditions for OCC soda pulp.

Bleaching conditions	Bleaching Stages		
	O	D	P
Pulp conc. (%)	10	10	10
Temperature (°C)	90	70	80
Reaction time (min)	60	180	180
Kappa No. (initial)	35	16	7
Kappa No. (Final)	16	7	-
pH (Final)	9.5	6	11
NaOH (%)	3	-	3
ClO_2 (%) as Cl_2	-	2.4	-
H_2O_2 (%)	-	-	5
$MgSO_4$ (%)	0.5	-	0.5
Na_2SiO_3	-	-	1.5
O_2 pressure (Kg/cm^2)	4	-	-
Delignification ratio (%)	54	55	-
Screened yield (%)	89	98.6	95

Table 4. Fiber classification from sugarcane bagasse pulp.

Mesh	Unbleached bagasse pulp (%)	Bleached bagasse pulp (%)
30	0.5	1.8
50	26.9	28.3
100	30.6	36.2
200	19.7	14.6
<200	22.4	19.1

Table 5. Optical properties from sugarcane bagasse pulp.

Property	Pulp
Brightness	81.2
opacity	76
Brightness Reversion	77

employed according to the sequences ODP (delignification of oxygen, bleaching with ClO_2 and Hydrogen peroxide with DTPA intermediates and washing in between stages) (Table 3) in order to achieve a final brightness of 80% ISO. Pulps were then washed carefully with deionized water in between bleaching stages and after the bleaching sequence.

Mechanical properties of OCC

OCC soda pulp and OCC raw pulp (only recycled) were then refined to evaluation and improve the strength and conformability of individual fibers in sheet consolidation in a centrifugal mill (Jokro Mühle) at 150 rpm, using 16 g of oven-dried pulp per pot and 265 ml of water. The refining level was determined using the Schopper-Riegler scale (°S.R.).

Bagasse pulps

Unbleached and bleached bagasse soda pulp (Tables 4 to 7) prepared in a local pulp and paper mill located in Veracruz Mexico, were used to investigate the effect of OCC pulp on the bagasse pulp mixtures properties treated chemically (delignification and bleaching) during recycling. Physical properties were determined to obtain the initial strength properties (Tables 5 to 8). Pulps (OCC and bagasse) were refined separately at a consistency of 10% to obtain a Shoeper Riegler of 44 °S.R. (unbleached pulps) and 33 °S.R. (bleached pulps) as optimum refining, and mixed (80% bagasse and 20% OCC soda pulps) later forming handsheets for physical tests of pulp mixtures for strength and drainability properties which were tested in accordance with TAPPI standard methods [51].

Table 6. Unbleached bagasse pulp properties.

Refining degree (°S.R.)	Drainage Time (S)	Gurley Porosity (S/100 mL)	Breaking length (m)	Tear Index (mNm^2/g)	Burst Index (kPam^2/g)	Folding endurance (Double Folds)
17	4.75	5	3672	9.15	2.53	30
23	5.93	26	4243	8.87	3.47	84
32	7.70	53	6643	8.51	4.72	156
37	9.07	79	6546	8.31	4.94	172
44	12.08	135	6324	7.85	5.43	206

Table 7. Bleached bagasse pulp properties.

Refining degree (°S.R.)	Drainage Time (S)	Gurley Porosity (S/100 mL)	Breaking length (m)	Tear Index (mNm^2/g)	Burst Index ($kPam^2/g$)	Folding endurance (Double Folds)
20	5.09	11.1	4030	7.52	2.75	34
25	6.11	63.3	5070	5.81	3.41	52
29	7.19	149.4	6109	5.53	4.07	70
33	8.27	∞	7149	5.23	4.73	88

RESULT AND DISCUSSION

Chemical composition of OCC

Chemical composition OCC pulp varies with landfill location and can be influenced by both recycling technology and raw material (wood morphology, genetics, and growth conditions) from different sources (softwood and hardwood); however, Table 8 lists some of the chemical composition of OCC pulps from this work, clearly, wide ranges of properties occur in the published literature. Similar trends occur when comparing OCC from different domestic and foreign sources.

Table 8 showed that carbohydrate contents (holocellulose) vary about ±7%, lignin ±1%, ash ±0.3%, extractives ±1.6% and Brightness ±6%. The OCC have a low lignin proportion and a high holocellulose (cellulose and hemicelluloses) content.

Table 8. OCC pulp chemical composition.

Test	%
Holocellulose	72.7 - 80.5
Klason Lignin	9.6 - 10.5
Extractives on water	1.4 - 3.1
Extractives on ethanol-toluene	1.4 - 3.0
Ashes	2.3 - 2.9
Brightness ISO	17.8 - 23.6

Pulping process

All cooking trials from soda pulping processes in OCC pulp were conducted in accordance with an experimental design and are presented in Table 9. The delignification rate was observed by the kappa number, it was approximately reduced from 29 to 40 points (44.5% to 63.6%) but viscosity and yield decreased. However, these values are also within the recommended range for pulp production.

Mechanical properties of OCC soda pulps

The result illustrates the effect of pulping processes (alkaline delignification) on OCC pulp drainage and physical pulp properties respectively based on 60 g/m^2 hand sheets (Figures 1 to 6).

It was found that all of the OCC soda pulp strength parameters were increased in relation to the repulped OCC pulp (burst index 35%, tear index 17%, folding endurance 89% and breaking length 10% average). However drainage time of pulp was reduced 10% because the strength properties of a sheet of paper depend on its original qualities, strength of fibers and on the extent of bonding between fibers that make up the sheet. A paper sheet made from virgin pulp which has not undergone a form of mechanical treatment is characterized by low strength, bulkiness, after-refining surface roughness and not suitable for papermaking. This is an important finding. OCC soda pulps can be easily refined and tear resistance, tensile strength, folding endurance and bursting strength were found to be increased and improved. This treatment (alkaline pulping or delignification) eliminates residual lignin and increases the flexibility and retention of water of the fibers to make more fiber-to-fiber bonding and contributes to the improvement of the mechanical properties of the raw fiber material. This will be very important for runnability in paper machine, press room and converting machines.

Bleaching ECF of OCC soda pulp

The average yield from the final bleaching step was 83.4%, and the CED viscosity of the bleached OCC pulp was 6.29 cP (51% lower OCC soda

Table 9. Delignification (soda pulping) cooking conditions of recycled OCC pulp.

Active alkali as Na_2O (%)	Residual Active alkali as Na_2O (g/L)	Active alkali yield (%)	Final pH	Pulping yield (%)	Screening Coarse Rejects (%)	Kappa number	Residual Lignin (%)	Viscosity (cP)
0	-	-	-	84.8	4.5	64	9.6	12
13	0.9	96.2	12.5	73.3	0.64	35.5	5.33	13.1
15	2.5	91.9	12.9	72.4	0.49	31.8	4.77	12
17	4.6	86.7	13.1	70.8	0.38	26.5	3.98	11.6
20	7.5	81	13.4	70	0.36	23.3	3.5	10.2

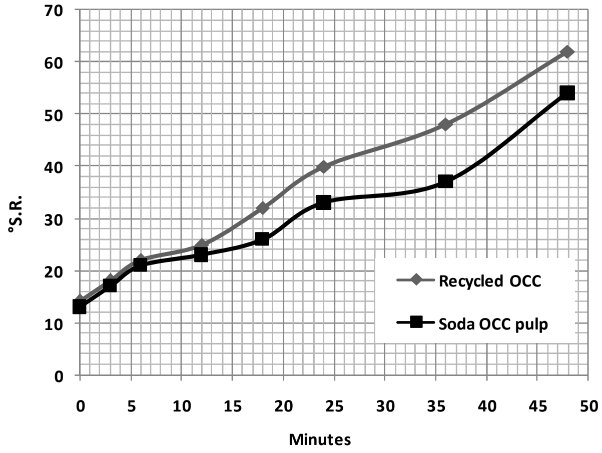

Figure 1. Refining time (minutes) from OCC pulps.

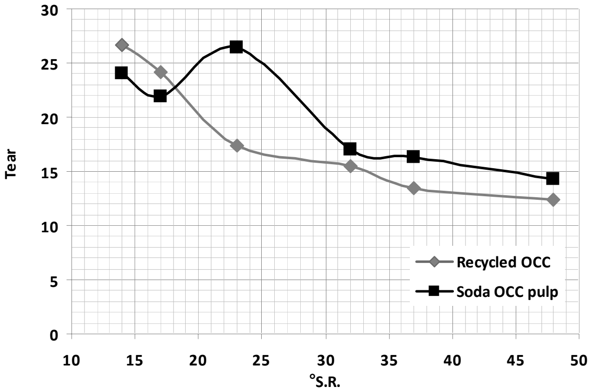

Figure 3. Tearing resistance (as Tear Index in mN m^2/g) from OCC pulps.

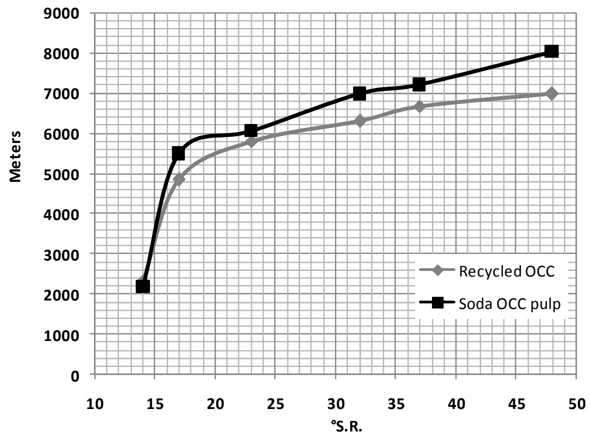

Figure 2. Tensile strength (as breaking length in meters) from OCC pulps.

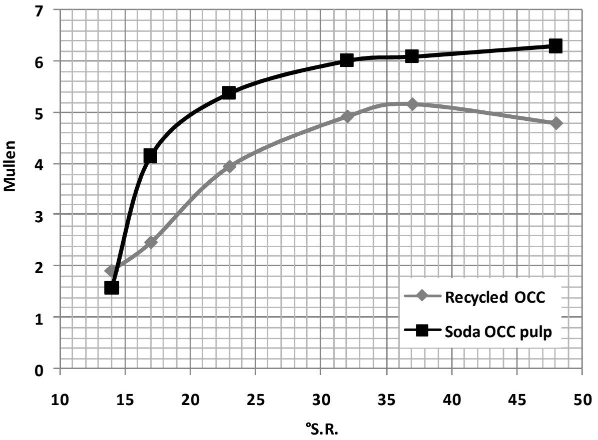

Figure 4. Bursting strength (as Burst Index in KPa m^2/g) from OCC pulps.

pulp). The results showed that alkaline digesting pretreatment of OCC pulp and ODP bleaching sequence can lead to the brightness of 80% ISO although only kappa values above 20 can be considered high for bleachable grades. Alkali digestion of OCC renders the pulp to be more readily bleached, to compensate for inherent disadvantages of recycled fibers (Table 10 and 11).

The final bleaching stage and the conditions used in this stage did not significantly affect brightness stability (Table 12).

In relation to these properties, the OCC soda pulp is a new long fiber resource for pulp and paper production.

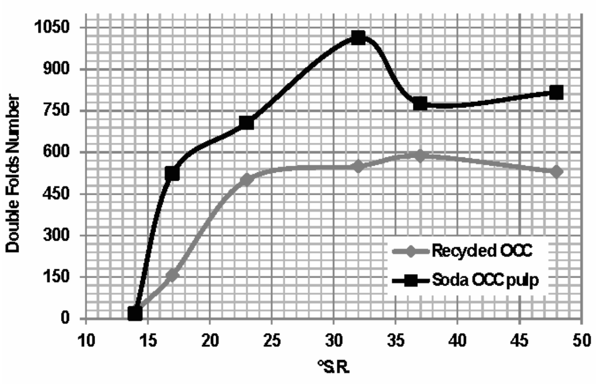

Figure 5. Folding endurance (Double Folds Number) from OCC pulps.

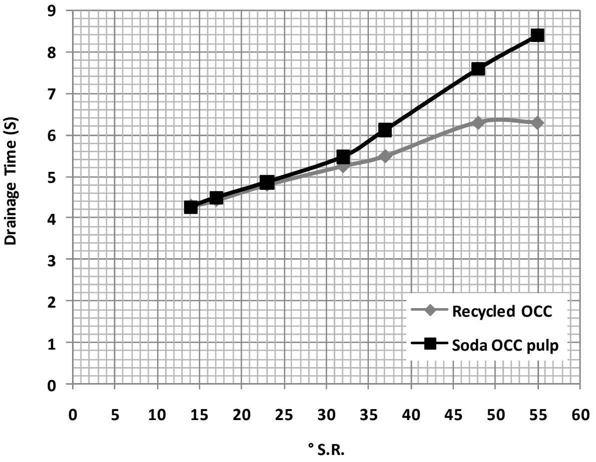

Figure 6. Drainage time (s) from OCC pulps.

Mixture bagasse/OCC pulps

These combination processes (alkaline delignification and bleaching) were found to be effective in improving strength, optical, and drainage properties of testliner based on 100% OCC and furnishes with sugarcane bagasse pulps. In this way, employment of OCC as a large fiber furnish in bleached paper grades with sugarcane bagasse pulps will be technically possible (Table 12).

The preliminary results show that with an addition of up to 20% of OCC pulp in the unbleached and bleached bagasse pulp, compared with the bagasse pulps, the OCC/bagasse pulps were found to give higher tensile strength, tear resistance, burst, and a lower drainability or dewatering and porosity resistance after achieving of optimal refining or beating degree to 44 and 33 °S.R. In particular, the increase in mechanical strength is mainly due to addition of enhanced OCC pulp with long fiber and interfiber bonding capacities and reduction of fines due to alkali treatment of delignification and the bleaching (Table 13).

This observation highlights the fact that the major mechanism of strength improvement in bagasse/OCC pulps is probably due to increase of inter fiber bonding as a result of substitution of inactive secondary fibers with active virgin fibers from bagasse in blend after refining. It is very important to optimize the amount of virgin bagasse pulp with OCC soda fibers, as a suitable reinforcement pulp.

The results suggest that it might be worthwhile exploring alternative alkaline pulping of OCC in integrated bagasse pulp mills. These findings promote understanding for a more effective formulation of treatment methods for recycled fibers and one possibility that might offer some advantage over current wood pulp as an effectiveness non-wood reinforcement pulp.

Table 10. Mechanical properties from Bleached OCC pulp.

Refining degree (°S.R.)	Drainage Time (S)	Breaking length (m)	Tear Index (mNm^2/g)	Burst Index (kPam^2/g)	Folding endurance (Double Folds)
20	4.54	3215	19.94	2.95	119
25	4.98	5410	12.25	4.64	395
29	5.42	6081	11.88	5.19	466
33	5.85	6528	11.64	5.56	554

Table 11. Optical properties from Bleached OCC pulp.

Property	Pulp
Brightness	80.1
opacity	80
Brightness Reversion	78.8

Table 12. Mechanical properties from Unbleached and Bleached mixtures bagasse/OCC pulps.

Physical Properties	Unbleached Pulps			Bleached Pulps		
	Bagasse	Bagasse/soda OCC pulp (80:20)	Difference	Bagasse	Bagasse/soda OCC pulp (80:20)	Difference
Drainage Time (S)	12.08	9.56	-20.86	8.27	7.16	-13.42
Gurley Porosity (S/100 mL)	135	156	+15.56	149	52.5	-64.77
Breaking length (m)	6324	9288	+46.87	7149	7413	+3.69
Tear Index (mNm^2/g)	7.85	9.4	+19.75	5.23	8.83	+68.83
Burst Index ($kPam^2/g$)	5.43	6.82	+25.60	4.73	6.18	+30.66
Folding endurance (Double Folds)	206	638	+209.71	88	414	+370.45

Table 13. Pulp classification.

Mesh	Recycled OCC pulp	Soda OCC pulp	Bleached OCC pulp
30	38.9 - 55.5	57	60.3
50	17.7 - 23.8	20.1	17.4
100	10.2 - 15.8	15.5	13.3
200	4.0 - 4.4	1.1	3.9
<200	12.6 - 17.1	6.3	5.1

CONCLUSIONS

The growth of paper production in the future will not be possible without utilization of recycled kraft pulp fibers and non-wood pulps.

The effect of recycling on pulp properties has been investigated and reported that pulp strength drops after the first recycle during the process of sheet formation, consolidation and drying, in the case of chemical pulps. This is because viscosity, bonding, flexibility and swelling potential or water retention of the recycled fibers are reduced, compared to never-dried or virgins pulps.

The objective and hypothesis of this paper was to find new ways to improve OCC mechanical, optical and drainage properties for use in printing, writing, and security paper production and for use as a source of long fiber on sugarcane bagasse pulps in stock preparation.

It was found that all of the OCC soda pulp strengths were increased to the repulped OCC pulp (burst index 35%, tear index 17%, folding endurance 89% and breaking length 10% average). Through this research, a new effective way could be to make high-value use of the large-quantity-reclamation old corrugated container OCC which had a fine physical ability of fiber.

OCC soda pulp was found to be very effective as reinforcement pulp (long fiber) in sugarcane bagasse pulp, because it has higher tensile strength, tear resistance, burst, and a lower drainability or dewatering and porosity resistance after refining.

Blending of bagasse and alkaline OCC pulp gave well-balanced pulp strength characteristics with good tensile and tear indices, widening the range of different end products from bagasse pulp.

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