A new method for making pulp out of agricultural residue includes harvesting certain portion of plant stalk. The harvested plant stalk is bailed, transported and stored. At the mill, the plant stalk is chopped and goes through pulping process. The pulp is used to make varieties of papers with or without blending other wood based pulp.
Fig. 1. Chemical pulping process for corn stalk pulp

Harvesting

Drying
Chipping
Packing
Transportation

Pretreatment
- Washing (optional)
- Screw pressing (optional)
- Pre-impregnation (optional)

Cooking
- Active alkali 8-20%
- Cooking temperature 110-160°C
- Cooking time 130-180 min

HD cleaning

Screening

LD cleaning

Bleaching (optional)

Washing

Flash drying
Packaging for shipping
Fig. 2. Mechanical pulp (RMP, TMP, CTMP) and high yield pulp process for corn starch pulp.
Fig. 3. Papermaking process from corn starch pulp

Refining
- Corn starch pulp (optional)
- Softwood pulp (250-500 m LSF)
- Hardwood pulp (250-500 m LSF)

Stock Preparation
- Blending of pulps
- Filler loading (optional)
- Sizing (optional)

Cleaning

Screening

Papermachine

Surface sizing (optional)

Coating (optional)

Supercalendering (optional)
METHOD FOR PRODUCING CORN STALK PULP AND PAPER PRODUCTS FROM CORN STALK PULP

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a process for separating a portion of a corn plant and producing pulp from the plant for making paper products. More specifically, the present invention relates to a method for harvesting portions of corn plants, that is, harvesting portions from the ground up to about the ears of the corn plant. Additionally, the present invention relates to a versatile pulping process including at least one of mechanical, semi-chemical, and chemical processes in order to produce pulp suitable for various paper products and producing various paper products from the pulp.

[0003] 2. Discussion of the Related Art

[0004] Trees provide a major source of the fiber supply for paper and paperboard products industries. Softwood is a very suitable species for mechanical pulping. Chemical pulps of softwood are used where the strength of the pulp product is important. Hardwood, on the other hand, is used for chemical pulping, but usually for chemical and semi-chemical pulping. Hardwood chemical pulp is used in paper products where surface smoothness and optical properties are important. Wood based fiber is expensive as it incurs a high chemical charge for pulping, high energy input for cooking and refining, and high cost chemical recovery systems. Additionally, the environmental impact of wood based fiber is disadvantageous.

[0005] Agricultural residues such as cornstover offer a promising alternative source of fiber. In particular, they can serve as important raw materials for making paper products, including products for printing, writing, top linerboard, liner, tissue paper and other specialty grade paper. Additionally, environmental concerns have heightened the interest in using agricultural fibers. Exploitation of agro-based resources for making paper products is important to improve farm profitability and reduce environmental pollution from burning and land disposal. Currently, the use of agricultural plants for making paper products is negligible. This is especially true in the United States where nearly 284 million tons of total agricultural residues, including 150 million tons of cornstover are available annually. Cornstalk as a fiber source for papermaking is not popular in major pulp and paper producing countries as there are abundant and secure supplies of pulpwod meeting the raw material requirements for large-scale capital-intensive pulp mills. A large-scale pulp mill based on agricultural residues needs a large supply of bulky raw materials, thereby creating transportation problems. Additionally, agricultural residues are seasonal, thereby creating storage problems. Separation of appropriate parts of cornstalk residue during harvesting will reduce transportation and storage problems. A pulp mill based on cornstalk should be small scale and located in the vicinity. Optionally, a large-scale mill may be used depending on the availability of cornstalk and supply logistics.

[0006] The related art covering non-wood pulping and papermaking include U.S. Pat. No. 6,302,997 issued to Hurter et al. This describes methods of non-wood pulping for papermaking. Cornstover (stalks, leaves and husks) are used in this process and contain low quality fiber and a high quality of debris. Accordingly, transport and storage problems in the farm as well as in the mill are present in the related art. Additionally, pith, leaves, and husk contain a small quantity of good fibers. Therefore, tube grinders, conveyers, hydropulpers, pumps, magnetic separators, and dewatering screens have to handle huge volumes of unnecessary materials.

[0007] Accordingly, there is a pulp yield of 39.6%, which is substantially low due to the presence of large quantity of low quality fiber that are mostly removed during downstream processing. This low quality fiber consumes chemicals without giving any benefit to the pulp qualitatively and quantitatively and the mill faces huge disposal problems due to large quantity of rejects. The related art uses the traditional alkaline digestion process. The addition of an acid treatment step, ozone bleaching step and a peroxide-bleaching step makes this process expensive and complicated. The process also includes high doses of chemicals during hydrogen peroxide bleaching. Despite the disclosure of interesting process steps in the foregoing U.S. patent, the invention has a number of drawbacks, for example: 1) dealing with cornstover having materials such as pith, leaves and husk that have very little fiber value; 2) carrying the unnecessary mass to the mill creates transportation and storage and disposal problems of the large supply of reject materials; 3) low pulp yield; 4) high chemical consumption in acid stage, bleaching stage and in adjustments of pH; 5) the process involves extra steps that increases capital costs and operating expenses; and 6) the process saves energy during alkaline cooking but consumes more energy through refining.

[0008] The present invention focuses on non-wood paper making having an advantageous approach. By establishing harvesting, pressing and bailing processes on the farm and allowing for gathering places of goods and storage. Alternatively, it is to establish a mini mill at the center of the corn growing area where farmers will have their own storage facility and will transport the materials to the mill at a schedule set by the mill. Ideally, mill storage should not be more than about 15 days in order to optimize the mill spatially. The mill should use a simple and environmentally benign process with low capital and operating costs to compete with the larger wood based mills. These processes are not currently available in the art.

SUMMARY OF THE INVENTION

[0009] Accordingly, the present invention is directed to a process for producing pulp and paper products from pulp that substantially obviates one or more of the problems due to limitations and disadvantages of the related art. For example, a process for producing pulps suitable for use in papermaking, top white liner making, liner making and other specialty papermaking. The process includes a harvesting process for separating portions of the cornstalk that are most suitable as fiber source in the field, digesting the selected cornstalk portions with an alkaline pulping solution with or without the presence of anthraquinone and/or other catalysts, and treating the pulp with elemental chlorine free bleaching solution in order to produce bleached pulp suitable for papermaking. An advantage of the present invention is to provide a cornstalk harvesting process that will take the
bottom portion of the cornstalk plant below about the ears of the plant, which contains mostly the good fiber and less pith and leaving behind the rest of the plant in the field for traditional farm use.

[0010] Another advantage of the present invention is to chop the selected cornstalk section using a modified wood chipper.

[0011] Another advantage of the present invention is to separate the chopped leaves and piths from the chopped stem pneumatically.

[0012] Another advantage of the present invention is to reduce the cornstalk processing steps from harvesting to digestion.

[0013] Another advantage of the present invention is to accept up to 15% of pith in the digester to simplify the separation process.

[0014] Another advantage of the present invention is to provide a cornstalk pulping process that requires a minimum number of processing steps. Another advantage of the present invention is to provide a cornstalk pulping process that is cost effective and environmentally benign at small- to medium-scale level.

[0015] Another advantage of the present invention is to provide a cornstalk harvesting and pulping process that uses a minimal amount of readily available and inexpensive equipment.

[0016] Another advantage of the present invention is to provide a cornstalk processing system during harvesting to separate the bottom portion of the cornstalk plant, below about the ears of the cornstalk plant, from the rest of the plant, which is still available to the farmer for traditional farm use.

[0017] Another advantage of the present invention is to make compact square bales of dried cornstalk during the harvesting process to reduce bulk to avoid transport and storage problem.

[0018] Another advantage of the present invention is to develop a management system for transportation and storage of selected cornstalk.

[0019] Another advantage of present invention is to transport cornstalk from the collecting point to the mill.

[0020] Another advantage of the present invention is to leave portions of the cornstalk plant rejected during harvesting in the field for soil conditioning and other traditional farm uses.

[0021] Another advantage of the present invention is to reduce the contaminants in cornstalk during harvesting and compact baling processes in order to reduce hot water requirements in washing stage before chemical impregnation and digestion steps.

[0022] Another advantage of the present invention is to chop the cornstalk followed by hot water washing and compression in screw feeder where impregnated with cooking chemical before entering into the digester.

[0023] In yet another advantage of the present invention is to apply a compression step to eliminate water and hot water-soluble extractive from the materials, and also to increase the digester intake.

[0024] A further advantage of the present invention is to add cooking chemicals just after the compression step for better chemical impregnation of de-structured raw materials in a continuous digester.

[0025] Another advantage of the present invention is to apply a compression step to increase the digester input and to increase the liquor impregnation into the material.

[0026] Another advantage of the present invention is to use the standard paper mill equipment to process the cooked fiber.

[0027] Another advantage of the present invention is to digest the raw materials at low temperatures in the range of about 110 to 160° C, with a retention time of about 30 to 180 minutes.

[0028] Another advantage of the present invention is to add a pretreatment step just after the washing and compression step, where cellulose protecting agents such as 
MgCl₂ or MgCO₃, and the like, will be impregnated at a temperature in the range of about 60 to 100° C. for a period of time in the range of about 30 to 60 minutes.

[0029] Another advantage of present invention is to maximize the hemicelluloses content of cornstalk chemical pulp by introducing a pre-impregnation stage using cellulose protecting agents.

[0030] Another advantage of present invention is to take benefit of hemicelluloses content of cornstalk pulp in papermaking process by blending with softwood kraft pulp and using wet end chemistry.

[0031] Another advantage of present invention is to find the synergic effect of cornstalk pulp in a typical papermaking/boarding furnish.

[0032] Another advantage of the present invention is to use less chemicals, for example, 8 to 20% active alkali with or without the presence of catalyst such as anthraquinone and the like.

[0033] Another advantage of the present invention is to use less chemicals in the elemental chlorine-free bleaching process.

[0034] Another advantage of the present invention is to apply chlorine dioxide, alkaline extraction, peroxide, ozone, and oxygen bleaching stages to obtain about 80 to 95% of brightness.

[0035] Another advantage of the present invention is to avoid sulfur based chemicals in cooking liquor or in bleaching liquor to remain committed to environmentally benign pulping and bleaching processes.

[0036] Another advantage of the present invention is to fractionate the fiber after bleaching into long fibers (mainly from cornstalk skin) and into short fibers (mostly from pith). Another advantage of the present invention is to use the cornstalk pulp to produce various grades of paper without even fiber fractionation into long and short fiber fraction.

[0037] Another advantage of the present invention is the flexibility of using chemical pulp in a blend with bleached soft wood kraft pulp (with or without prior refining) and filler.
Another advantage of the present invention is that the long fiber fractions will be refined to approximately 250-500 ml CSF and then added to the short fiber fraction before papermaking step.

Another advantage of the present invention is a cornstalk pulping process that minimizes water use by reducing the number of washing stages and by minimizing the number of dilution and thickening stages, by recycling the internal water as much as possible.

Another advantage of the present invention is to improve the paper quality made from the bleached cornstalk pulp by adding bleached softwood kraft pulp approximately 5 to 20%, inorganic filler approximately 5 to 60%, starch approximately 0.25 to 4%, sizing agent approximately 0.025 to 0.5%, cationic, anionic and/or amphoteric retention aids, and the like.

Another advantage of the present invention is to use cornstalk chemical pulp with or without refining in a blend with bleached softwood kraft (with or without prior refining) and filler.

Another advantage of the present invention is to use the bleached cornstalk chemical pulp in a blend with bleached softwood kraft pulp, bleached hardwood chemical pulp and filler.

Another advantage of the present invention is to use the bleached cornstalk chemical pulp in a blend with hardwood CTMP (chemi-thermo mechanical pulp) and/or BCTMP (bleached chemi-thermo mechanical pulp) and filler.

Another advantage of the present invention is to use the bleached cornstalk chemical pulp in a blend with bleached hardwood mechanical pulp, bleached softwood kraft pulp and filler.

Another advantage of the present invention is to use the bleached cornstalk mechanical pulp in a blend with hardwood chemical pulp and/or bleached hardwood mechanical pulp, bleached softwood kraft pulp and filler.

Another advantage of the present invention is to use unbleached cornstalk chemical and/or semi-chemical pulp in a blend with unbleached softwood kraft pulp and/or unbleached softwood semi-chemical (kraft) pulp to prepare packaging grade paper.

Another advantage of the present invention is to apply the bleached cornstalk chemical pulp in a blend with bleached softwood kraft pulp (0 to 10%) and filler (10 to 60%) in the outer layer of the multi layer papers. The inner layer of the paper may contain inferior quality fibers, such as recycled fiber, inferior virgin fiber, pulp having extractions and pulp unsuitable for exposure on paper surface.

Another advantage of the present invention is to use the bleached cornstalk chemical pulp in top liner by blending with bleached softwood kraft pulp (0 to 10%) and filler (0 to 60%) along with very small quantities of starch, sizing agents and retention aid.

Another advantage of the present invention is to use the bleached cornstalk chemical pulp in an existing mill using the furnish consisted of hardwood and softwood pulp and filler in order to enhance the paper strength properties through superior fiber bonding capability of cornstalk pulp.

Another advantage of the present invention is to use the bleached cornstalk chemical pulp to increase the filler retention in the paper without compromising strength properties.

Another advantage of the present invention is to use the unbleached cornstalk chemical pulp with unbleached chemical or semi chemical softwood kraft pulp to enhance strength properties of papers such as sack paper, packaging paper etc.

Additional features and advantages of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the invention. The objectives and other advantages of the invention will be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention.

FIG. 1 is a flow chart describing a chemical pulping process for corn stalk pulp.

FIG. 2 is a flow chart describing a mechanical pulping and high yield pulping process for corn stalk pulp.

FIG. 3 is a flow chart describing a paper making process from corn stalk pulp.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Today the paper industry in the United States is in the same situation as steel industry was a few decades ago. Small-scale modern steel industries are more efficient than large-scale facilities. Accordingly, it is time to look for technology for the development of small-scale efficient pulp and paper industry. It is also time to look for inexpensive fiber sources to face the competition from high yield plantation trees such as eucalyptus, acacia, and the like. Agricultural residue such as cornstover can compete with eucalyptus and acacia as an inexpensive source of fiber. The potential worldwide supply of cornstover is approximately over 750 million tons per year, and the United States alone can provide approximately 150 million tons annually.

The present invention emphasizes the need of the paper industry to move to mini mill processes and to use agricultural residues, such as corn stalks, and the like as fiber sources. The process is a combination of compression impregnation and chemical processes to produce high quality pulps.

The term agricultural residue is used to identify the material remaining at the farm after separating the main crop from the plant. For example, cornstalk is an agricultural residue, as it remains in the field after harvesting the main
product corn. The residual cornstalk has very little or no commercial value at present. Of course, other agricultural residues may also be utilized and have been contemplated.

[0060] The present invention provides a cost effective and environmentally benign process. For example, one stage of compression impregnation and pulping and three to seven subsequent stages of bleaching convert the selected part of cornstalk into high quality, bright papermaking pulps of excellent strength, cleanliness, and drainage rate. The process utilizes a portion of the cornstalk plant below about the ears, for example, approximately the bottom 2 to 3 ft of cornstalk plant (without leaves and husk). These portions contain up to approximately 15% pith without using any type of mechanical or chemical de-pithing, thereby producing pulps having strength properties that are similar and/or superior to the properties of hardwood pulps in lab-scale trial. Additionally, a total pulp yield of about 46-50% may be achieved on selected cornstalk portions, which is equal to or better than the total yield value of hardwood pulps. The hardwood pulp process utilizes harsher pulping conditions and more costly pulping and bleaching processes. The processing of the present invention establishes a high yield using low chemical changes, temperature, and pressure.

[0061] Cornstalk Process Stages

[0062] The process of the present invention includes a unique harvesting process that separates portions of the cornstalk plant, that is portions from the ground up to about the ears of the plant. For example, the portion separated may be approximately the bottom 2 to 3 ft of cornstalk plant. Of course, this depends on the characteristics of the plant. The separated cornstalk portions are compacted into a bale. For example, they are compacted into a square or rectangular bales and stored at the farm until a predetermined time, when it is then transported to the mill.

[0063] The use of whole cornstalks including leaves and husk in pulping gives low yield and consumes more chemicals without any real benefit.

[0064] A compression impregnation step that is common in chemi-thermo-mechanical pulp, but never used in chemical pulping has been used for different purposes.

[0065] The alkaline pulping step used in the present invention in pulping is milder than that used in hard wood pulping process. The pulping step uses both batch and continuous processes. For example, a Pandia type continuous digester is suitable for alkaline pulping of cornstalk. Pulp from the digester contains low lignin, for example, kappa 8 to 10. Additionally, the pulp can be bleached to a high brightness by using fewer steps than hardwood pulp process and obtaining a similar yield.

[0066] The processes of the present invention may be done in the following order; however, variations from the order have also been contemplated.

[0067] Cornstalk Harvesting, Storage, and Transportation

[0068] In this process, the harvester removes a portion of the cornstalk plant. For example, the harvester cuts the cornstalk just below the ears. The first cut may be used for soil conditioning, animal bedding and other traditional farm uses. The second cut removes a portion of the cornstalk plant below about the ears of the cornstalk plant. This portion has moisture content of about 10 to 20% and is compacted into a bale. Typically, it is compacted into a rectangular bale or square bale, which is then transported to a storage facility. The bale is stored in a dry atmosphere in order to avoid fungi and the like.

[0069] Each farmer in approximately 50 mile radius relative to the pulp mill stores the compact bales on the farm until a predetermined time for delivering the materials to the mill. This allows the mill to keep an inventory of compact bales for a reduced time, for example, about 2 weeks. Of course the time of storage of the bales may be longer or shorter. This type of management will reduce storage requirements at the mill site. The mill may pay the farmers for storage time or some other form of contractual relationship may be established with the farmers.

[0070] Processing of Raw Materials

[0071] The next step in the process is to arrange the raw materials into a digester. In this process the compacted bales of cornstalk portions will be loosened and chopped to approximately 25 to 40 mm size. The chopped material is arranged, for example dumped, onto a lower part of an inclined conveyor belt. The conveyor belt may be fitted in a steel housing filled with hot water under constant circulation. The conveyor will transport the cornstalk within the liquid from one end of the conveyor to the other end of the conveyor. This is the process of wetting the cornstalk. In this process dirt and/or other foreign materials attached to cornstalk portions are loosened and separated via hot water soluble materials into the water media. The upper end of the conveyor may be slightly inclined and another conveyor may be fitted in a steel housing and having an incline of about 30 degrees. The conveyor belt leads to a hopper. However, the configuration of the belt may be in any suitable configuration leading to the hopper. For example, the incline may be less than or greater than 30 degrees. In-situ cleaning process is performed on the cornstalk as it is transported along the conveyor belt. For example, continuous hot water is sprayed onto the material being transported along the conveyor belt to clean off the residual dirt and any other foreign material. At the opposite end of the conveyor belt the cleaned material, which may be saturated with hot water, is arranged into the hopper. The material may be fed into the hopper with a plug screw feeder or any other suitable technique.

[0072] Pulping Process

[0073] The plug screw feeder compresses the cornstalk coming from the feeder and removes the excess water and hot water soluble extracts. At the end of the screw feeder, the compressed cornstalk comes in contact with cooking liquor, thereby providing better penetration of cooking liquor as it enters into the digester. In this zone the cooking liquor flow is controlled in order to have liquor to cornstalk ratio of about 3:1 to 7:1.

[0074] In case of pretreatment with cellulose protecting agents, an additional step before the addition of cooking liquor should be added to the pulping process.

[0075] A variety of different digesters may be used, for example, a Pandia digester and the like. The Pandia digester is a horizontal continuous digester that is well suited for the production of pulp from all different non-wood fiber raw materials and provides excellent results for high yield processing.
When using a continuous Pandia digester it may contain two to three horizontal tubes. The temperature may be raised to about 120 to 170° C. at the end of first tube and about 120 to 170° C. in the second tube for continuing the cooking, and in the third tube to about 100 to 110° C. for cooling down, before letting it blow to the blow tank. The ramp time in the first horizontal tube may vary from about 20 to 40 minutes, the cooking time at the second tube may vary from about 20 to 90 minutes, and cooling time in the third horizontal tube may vary from about 10 to 15 minutes. Optionally, the blow tank may include an agitator fitted to delineate the cooked fiber in a hot spent liquor media.

In a batch process, a plug screw feeder compacts the bulky cornstalk to allow for a maximum load. The load fills a rotating and/or stationary digester with a liquor to solid content of about 3:1 to 7:1. The cooking temperature varies from about 120 to 170° C. for a period between about 30 to 120 minutes. The ramp time for raising the temperature from feed temperature to cooking temperature varies from about 15 to 60 minutes. After the cooking, the temperature of the digester is lowered to about 100 to 110° C. and the pulp is released to a blow tank. In the blow tank, an agitator is fitted to delineate the cooked fiber in hot spent liquor media.

The cooking liquor includes about 2 to 20% active alkali. About 12 to 15% active alkali (on oven dry cornstalk basis) cooking solution may be used to obtain a bleachable grade corn stalk pulp of yield range of about 45 to 50%. To obtain liner pulp at the yield range of about 60 to 70%, the active alkalinity may be in the range of about 6 to 10%, and to obtain corrugating medium at the yield range of about 80 to 95%, the active alkalinity may be in the range of about 2 to 4%. The cooking liquor may contain any combination of catalytic anthraquinone, and/or other similar reagents.

Fiber Processing Step

For chemical pulps the agitator that may be fitted at the bottom accomplishes delibration in the presence of hot liquor. Defibrating separates the fiber for thorough pulp washing and the fibers might need to be further refined for papermaking. The chemical pulps especially for high yield chemical pulp, that is yields of about 60 to 70%, are refined after the cooking process to liberate the individual fibers. For ultra-high yield pulp of about 80 to 95% obtained for corrugating medium, the pulps are refined to separate the individual fibers.

Screening, Washing and Cleaning Stage

After disintegration in a blow tank, pulps will be sent through a coarse screen to remove uncooked and/or semi-cooked and/or fiber lumps before sending the pulp to washing stage. Black liquor will be separated at screening and washing stages and sent to a chemical recovery boiler for recycling. The chemical pulps require thorough washing in order to recover processing chemicals and to clean the pulp. The brown stock can be washed by the existing commercial washer. Screening and cleaning of corn stalk pulp are preferably done before bleaching. This will save bleaching chemicals and improve the bleachability of the pulp.

Bleaching

A moderate application of bleaching solution, for example, chlorine dioxide, alkaline hydrogen peroxide, and alkaline extraction solutions may be used to remove the residual lignin and to increase the pulp brightness to a predetermined level. Bleaching conditions such as temperature, time, and bleaching liquor concentration, typically depends on lignin content of the pulp and on the optimum conditions for particular bleaching agents.

For example, temperatures ranging from about 60 to about 90° C. are used when using chlorine dioxide or alkaline peroxide as a bleaching agent in a closed system. Typically, the bleaching processes last about 30 to 120 minutes, which includes the time required to adjust the pulp temperature to the desired temperature level. The bleaching temperature is maintained for about 30 to 120 minutes. A three step bleaching sequence (hereinafter “DED”) can raise the corn stalk pulps’ brightness to about 80 to 85% ISO level and addition of one of more bleaching stages such as peroxide, ozone, or oxygen bleaching stage can raise the brightness to about 86 to 95% ISO.

Papermaking

The bleached pulp is a mixture of long fiber mainly derived from corn stalk skin and short fiber derived mainly from pith. Refining of this mixture before papermaking will create more fines resulting in a water drainage problem because the fines hold more water than the fiber.

Short fiber does not need refining, whereas the long fibers might or might not need refining in order to develop bonding properties. The bleached fiber should be fractionated into long and short fiber fractions. The long fiber fraction will be refined and then mixed with the short fiber fraction before papermaking.

In an alternative way, when the bleached corn stalk pulp is mixed with bleached softwood kraft and/or bleached hardwood kraft pulp for papermaking, the fractionation is not necessary. Since the corn stalk pulp is softer, slimmer and require less energy to refine, mechanical action during mixing with softwood kraft pulp and/or hardwood kraft pulp lead to refining in some extent and develop fiber-fiber bonding properties. Depending on the end products, corn stalk pulp (bleached or unbleached) can be mixed with softwood kraft pulp (bleached or unbleached with or without refining) to various extent.

The bleached pulp is used to prepare paper, for example, printing and writing paper, photocopy paper, top white linerboard, tissue paper, base paper, wood free papers, coated paper, multiplayer paper/paper board, specialty papers, and the like. CTMP and BCTMP of corn stalk can be used to prepare newsprint by blending with softwood kraft pulp (5 to 20%). Bleached corn stalk CTMP can be blended with corn stalk bleached chemical pulp for preparing writing & printing grade paper. The high yield semi-chemical corn stalk paper can be blended with high yield softwood kraft pulp to produce sack paper, wrapping paper, packaging board, carton board etc. Dissolving pulp and useful by-products derived from hemicellulose can be produced from corn stalk.
Printing and writing paper, photocopy paper, and top white linerboard may contain approximately 5 to 20% bleached softwood Kraft pulp, having approximately 5 to 60% filler content. The filler may include any combination of calcium carbonate, clay, talc, kaolin, titanium dioxide, and the like. In addition to filler, any combination of sizing agents, dry strength agents, wet strength resins, and retention aids may be applied during the paper making. The sizing agents may include any combination of rosin emulsion, alkyl succinic anhydride (ASA), alkyl ketene dimmer (AKD), and the like. The dry strength agents may include any combination of starch, gums, soluble cellulose derivatives, and the like. The wet strength resins may include any combination of polyvinyl alcohol, latex, and the like. The retention aid may include any combination of polyacrylamide, polyethylene amine, and the like.

EXAMPLES

The examples presented below illustrate cornstalk pulp and paper quality compared to hardwood pulp. Certain aspects of the examples are described in terms of techniques and procedures found by the inventors to work well in the practice of invention. The examples are created through the use of standard laboratory practices of inventors. The examples presented are not meant to be limiting, and numerous changes, modifications or alterations may be applied without departing from the scope of the invention.

Example 1

The cornstalk portions were separated manually from the leaves and other unwanted materials. The cornstalk stems were then broken into small pieces mechanically. The mechanical separation was accomplished with two oppositely rotating devil teeth plates. The system separates the skin, however, a substantial quantity of pith remains with the skin. It is noted that any other suitable mechanical separating tool may be utilized.

Pulping experiments were conducted using the pith and skin as received from the process. The quantity of pith was about 23% of total cornstalk except leaves, cones and ears. In a few laboratory scale experiments, the cornstalk skin was separated completely, and in some cases 15% pith was added to the skin to verify the effects of pith on handsheet properties. In the experiments, the cornstalk pieces were cleaned in a pulper by using hot water and dried in air to obtain the desired cornstalk consistency. The consistency of the cleaned cornstalk is beneficial in order to adjust the quantity of cooking chemicals, liquor to cornstalk ratio, and to know the pulp yield.

In this series of experiment, a ramp time of approximately 60 minutes was applied, the cooking time was approximately 60 minutes, and cooking temperature was about 150°C. The cooking was done using a soda process. The quantity of sodium hydroxide expressed as active alkali was varied from about 12 to 15% to get acceptable pulps. Tables 1, 2, and 3 show the quantity of active alkali in cooking liquor, screened pulp yield, pulp freeness (CSF), and mechanical and optical properties of handsheets.

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<tr>
<th>Exp. No.</th>
<th>Active alkali (%)</th>
<th>Yield Screen (%)</th>
<th>PFI revolution</th>
<th>CSF (ml)</th>
<th>Density (kg/m^3)</th>
<th>Tensile index (N-m/g)</th>
<th>Tear index (mN-m/g)</th>
<th>Burst index (kPa-m^2/g)</th>
<th>Brightness (%)</th>
<th>Opacity (%)</th>
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<th>Exp. No.</th>
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<th>Opacity (%)</th>
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<td>90</td>
<td>6.5</td>
<td>5.9</td>
<td>39</td>
<td>83</td>
<td>15.6</td>
</tr>
<tr>
<td>CT-4 B2</td>
<td>14</td>
<td>45</td>
<td>1300</td>
<td>360</td>
<td>865</td>
<td>91</td>
<td>5.8</td>
<td>6.1</td>
<td>39</td>
<td>84</td>
<td>16.4</td>
</tr>
<tr>
<td>CT-4 B3</td>
<td>15</td>
<td>44</td>
<td>1300</td>
<td>370</td>
<td>845</td>
<td>91</td>
<td>5.9</td>
<td>6.0</td>
<td>38</td>
<td>83</td>
<td>15.0</td>
</tr>
</tbody>
</table>
The properties of pulps from cornstalk containing approximately 15% pith are of a slightly lower quality than pulp properties obtained from cornstalk without pith. The handsheet properties are close to that of hardwood pulp. These results demonstrate that cornstalk containing certain amount of pith is suitable to produce quality pulp. One can easily avoid the huge task and cost associated with the mechanical separation of pith from the skin. The existing process that could be used to separate skin from pith is hammer milling. This process generates lots of fines and dust, which will create environmental pollution, deteriorate the fiber quality and increase the loss of quality fiber. The development of new machine that will effectively separate the skin in an environmentally benign way and without cutting and losing of good fiber will be very expensive. This separation of cornstalk skin from pith is not necessary at all, as demonstrated in lab-scale experiments as shown in Table 1, 2 and 3. The kappa number of the pulps measured using Tappi Standard methods are between about 8 to 12, which is very low compared to Kraft softwood pulp (kappa number of about 27 to 30) and to hardwood pulp (kappa number of about 18 to 22) with a similar pulp yield. Accordingly, cornstalk pulp requires less bleaching chemicals than half of those required for softwood and hardwood pulp.

Example 2

The raw cornstalk material, from the bottom portion of the plant, comprises mostly skin and includes knots and pith. That includes, the lower portion of the cornstalk plant below about the ears of the plant, for example, about the bottom 2 to 3 ft of cornstalk. This consists of thick skin and relatively low pith. The leaves present in the lower part of cornstalk may be easily removed after chopping. The removal or separation of the leaves may be done by blowing air due to the difference in density of chopped cornstalk and leaves. The fiber quality is not significantly affected due to the presence of a small quantity of pith in the lower part of the cornstalk as shown in example 1.

In this experiment, 1.27 kg (oven dry basis) of selected cornstalk, as described above, was cooked using about 14% active alkalai. This was done with a liquor to cornstalk ratio of about 7:1, a cooking temperature of about 150°C, a cooking time of about 60 min, and ramp time of about 60 min in order to raise the temperature from about 80 to 150°C. The screened pulp yield was about 46%. The pulp was screened on a slot type screen of 0.008 inches and dewatered on a 200 mesh screen to remove the fines from the pulp. The pulp from this cook is shown as (CT-D1) and was subjected to bleachability tests. Two of the bleached pulp samples were processed to prepare handsheet in order to determine the mechanical and optical properties.

Six samples, of about 10 g each represented in the Table 4 below as CT-d-1-1, CT-d-1-2, CT-d-1-3, CT-d-1-4, CT-d-1-5, CT-d-1-6. These samples were bleached using a variety of chlorine dioxide concentrations in the (D1) stage, followed by similar concentrations of sodium hydroxide in an extraction stage (E), and similar concentrations of chlorine dioxide in the (D2) stage. Additionally, three of the six samples were further bleached using a hydrogen peroxide (P) stage of similar chemical composition in all three cases. The bleaching conditions, chemical concentrations, and chemicals used in the different bleaching stages and the final brightness are presented in Table 4.

### TABLE 3

<table>
<thead>
<tr>
<th>Expt. No.</th>
<th>Active alkali (%)</th>
<th>Yeld Screen (%)</th>
<th>PFI revolution (mi)</th>
<th>CSF (ml)</th>
<th>Tensile index (N-mm/g)</th>
<th>Tear index (mN-mm)</th>
<th>Burst index (kPa-mm)</th>
<th>Brightness (%)</th>
<th>Opacity (%)</th>
<th>Scattering Coeff. (m²/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT-2 B1</td>
<td>13</td>
<td>44</td>
<td>443</td>
<td>757</td>
<td>90</td>
<td>5.3</td>
<td>5.6</td>
<td>39</td>
<td>89</td>
<td>19.6</td>
</tr>
<tr>
<td>CT-2 B2</td>
<td>14</td>
<td>44</td>
<td>440</td>
<td>788</td>
<td>94</td>
<td>6.6</td>
<td>5.9</td>
<td>39</td>
<td>89</td>
<td>19.6</td>
</tr>
<tr>
<td>CT-2 B3</td>
<td>15</td>
<td>45</td>
<td>467</td>
<td>786</td>
<td>93</td>
<td>6.0</td>
<td>5.8</td>
<td>40</td>
<td>89</td>
<td>19.8</td>
</tr>
</tbody>
</table>

### TABLE 4

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>D₁ Stage</th>
<th>E₁ Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kappa factor</td>
<td>Chlorine equivalent</td>
</tr>
<tr>
<td>CT-d-1-1</td>
<td>0.20</td>
<td>1.90</td>
</tr>
<tr>
<td>CT-d-1-2</td>
<td>0.25</td>
<td>2.00</td>
</tr>
<tr>
<td>CT-d-1-3</td>
<td>0.30</td>
<td>2.40</td>
</tr>
<tr>
<td>CT-d-1-4</td>
<td>0.35</td>
<td>2.80</td>
</tr>
<tr>
<td>CT-d-1-5</td>
<td>0.35</td>
<td>2.80</td>
</tr>
<tr>
<td>CT-d-1-6</td>
<td>0.30</td>
<td>2.40</td>
</tr>
</tbody>
</table>
TABLE 4-continued

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>CT-d-1-1</th>
<th>CT-d-1-2</th>
<th>CT-d-1-3</th>
<th>CT-d-1-4</th>
<th>CT-d-1-5</th>
<th>CT-d-1-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. Stage</td>
<td>Kappa factor</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Chlorine equivalent</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Temperature (°C)</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>Time (min)</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>P stage</td>
<td>H₂O₂ (%)</td>
<td>2</td>
<td>—</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NaOH (%)</td>
<td>1.5</td>
<td>—</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Na₂SiO₃ (%)</td>
<td>1.5</td>
<td>—</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MgSO₄ (%)</td>
<td>0.05</td>
<td>—</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Final Brightness (%)</td>
<td>87.5</td>
<td>84</td>
<td>88</td>
<td>87</td>
<td>85</td>
</tr>
</tbody>
</table>

[0102] The results demonstrate that cornstalk pulp can obtain a high brightness level while using low amounts of chemicals. The results are due to lower lignin content of the pulp compared to one third of softwood and hardwood chemical pulps. The cornstalk needs less cooking chemicals, lower cooking temperatures and less cooking time compared to the wood. The cornstalk processing cost will be similar to that wood when using a selected portion of the lower part of cornstalk. Additionally, the cost of storage and transportation will be minimized by low cost of cornstalk and ultimately the cost of cornstalk at the mill gate will be much lower than that of wood.

[0103] Below is described about bleaching of cornstalk pulp on mechanical and optical properties of handsheets.

Example 3

[0106] In pilot-scale cooking, about 21.56 kg chopped cornstalks (oven dry basis) were packed in a rotating digester. A vacuum was created in the digester allowing for better impregnation of the liquor (cooking solution) into the cornstalk. The digester was rotated for about 30 minutes, allowing the temperature to rise from ambient to about 80° C, for good impregnation. The ramp time was about 30 minutes to allow the temperature to rise from about 80 to 150° C, and cooking time was about 60 minutes at approximately 150° C. The cooking liquor includes about 14% active alkali. At the end of the cooking period the pipeline between the digester and blow tank was connected and the pressure was slowly released to reduce the pressure corre-

TABLE 5

<table>
<thead>
<tr>
<th>Sample</th>
<th>CSF (m²/g)</th>
<th>Density (kg/m³)</th>
<th>Tensile Index (N/m²)</th>
<th>Tear Index (mN)</th>
<th>Burst Index (kPa)</th>
<th>Brightness (%)</th>
<th>Opacity (%)</th>
<th>Scatt. Coeff. (m²/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT-d-1 (DED)</td>
<td>320</td>
<td>866</td>
<td>104</td>
<td>7.4</td>
<td>7.2</td>
<td>82.4</td>
<td>61</td>
<td>18.4</td>
</tr>
<tr>
<td>CT-d-1 (DEDP)</td>
<td>335</td>
<td>875</td>
<td>91</td>
<td>5.8</td>
<td>5.9</td>
<td>87.2</td>
<td>61</td>
<td>18.4</td>
</tr>
</tbody>
</table>

[0104] The Canadian Standard freeness (CSF) of bleached cornstalk pulps were in the range of about 540 ml. These CSF values came down to about 330 ml by refining in PFI mill with only 1000 revolutions, which is less than one-tenth of those required for bleached eucalyptus (hardwood) chemical pulps. This indicates that cornstalk pulp has great advantage in terms of reduced refining energy consumption.

[0105] The addition of one peroxide step increased the brightness of the pulp from about 82.4 to 87.2%, but the strength properties of handsheets decrease significantly. As a result, it will be necessary to evaluate the brightness requirement of final product in order to select the bleaching sequence and number of stages. For example, writing and printing papers contain about 15 to 25% calcium carbonate as a filler to improve paper surface smoothness, printing opacity, and brightness. Wet web strength and dry strength of paper can be easily manipulated by using wet end chemistry.

Sponging to a temperature of about 100 to 105° C. At this point the valve was opened completely to blow all of the pulp from the digester to the blow tank via the pressure differential. The blow tank includes a screen at the bottom to facilitate washing the pulp with hot water after the transfer of the pulp to the blow tank. The pulp was washed with hot water and then transferred to a large screen having 0.008 inches wide slots. The screen reject was less than about 0.07%. The pulp was then dewatered under pressure to about 30% solid content. The dewatered pulp was then shredded and kept in a cool room for future use. The screened pulp yield was around 46.5%, which was similar to lab scale studies. Three samples, each of about 30 g on oven dry basis, were refined at 400, 700, and 1000 revolutions in a PFI mill. Handsheets were prepared and tested according to TAPPI standard methods. Table 6 shows the results from the three samples refined at 400, 700, and 1000 revolutions in PFI mill, respectively.
TABLE 6

Physical, mechanical and optical properties of screened unbleached pulp from pilot scale pulping.

<table>
<thead>
<tr>
<th>Sample</th>
<th>CSF (ml)</th>
<th>Density (kg/m³)</th>
<th>Elongation (%)</th>
<th>Tensile Index (N/m/g)</th>
<th>Tear Index (mN · m/g)</th>
<th>Burst Index (kPa · m/g)</th>
<th>Brightness (%)</th>
<th>Opacity (%)</th>
<th>Scatt. Coeff. (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD-2 (400)</td>
<td>380</td>
<td>674</td>
<td>3.00</td>
<td>83</td>
<td>4.2</td>
<td>5.7</td>
<td>27</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>BD-2 (700)</td>
<td>360</td>
<td>733</td>
<td>3.02</td>
<td>82</td>
<td>4.5</td>
<td>5.4</td>
<td>30</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>BD-2 (1000)</td>
<td>350</td>
<td>728</td>
<td>3.10</td>
<td>81</td>
<td>4.5</td>
<td>5.5</td>
<td>27</td>
<td>94</td>
<td></td>
</tr>
</tbody>
</table>

[0107] The handsheet demonstrates very good mechanical properties with tensile index: 82 N/m/g, tear index 4.5 mN·m/g, and burst index 5.5 kPa·m/g. It is important to note that during lab-scale pulping, cornstalks were washed well with hot water and pith contents were adjusted manually. However, during the pilot scale trial we could not wash and adjust the pith content due to large amount of materials involved. As a result, cornstalk used in pilot scale cooking might contain higher percentage of dirt and pith compared to cornstalk used in lab-scale cooking. This is one of the reasons of getting slightly inferior pulp and low initial brightness compared to lab-scale pulp. These problems can be solved if pulp is produced at the pulp mill and incorporated with a full set of washing, screening and cleaning systems.

Example 4

In this example, properties of bleached cornstalk pulp were compared to equivalently bleached hardwood pulps. Moreover, two sets of copy paper with grammage of about 75 g/m² were prepared using filler, for example, precipitated calcium carbonate, starch, sizing agent, retention aids, etc, to see the properties. It is observed from the table that cornstalk pulp gives significantly higher tensile and burst index values than eucalyptus and aspen pulps. However, the tear values of eucalyptus are significantly higher than that of cornstalk pulp. The results are shown in Table 7.

TABLE 7

Mechanical and optical properties of bleached cornstalk pulp and bleached kraft eucalyptus pulp, and bleached kraft aspen pulps.

<table>
<thead>
<tr>
<th>Sample</th>
<th>CSF (ml)</th>
<th>Density (kg/m³)</th>
<th>Elongation (%)</th>
<th>Tensile Index (N/m/g)</th>
<th>Tear Index (mN · m/g)</th>
<th>Burst Index (kPa · m/g)</th>
<th>Brightness (%)</th>
<th>Opacity (%)</th>
<th>Scatt. Coeff. (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD-2 (DED)</td>
<td>350</td>
<td>680</td>
<td>3.2</td>
<td>81</td>
<td>4.5</td>
<td>5.7</td>
<td>82</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>BD-2 (DEDP)</td>
<td>355</td>
<td>820</td>
<td>2.58</td>
<td>82</td>
<td>4.36</td>
<td>4.93</td>
<td>82.9</td>
<td>65.2</td>
<td>21.1</td>
</tr>
<tr>
<td>BD-2(DEDP)</td>
<td>300</td>
<td>850</td>
<td>2.95</td>
<td>91.2</td>
<td>4.54</td>
<td>4.99</td>
<td>82.5</td>
<td>60.9</td>
<td>18.3</td>
</tr>
<tr>
<td>BD-2(DEDP), Filler: 6.6%</td>
<td>—</td>
<td>719</td>
<td>4.92</td>
<td>76.1</td>
<td>5.35</td>
<td>5.52</td>
<td>82.6</td>
<td>81.2</td>
<td>34.5</td>
</tr>
<tr>
<td>BD-2(DEDP), Filler: 15.1%</td>
<td>—</td>
<td>640</td>
<td>3.24</td>
<td>62.6</td>
<td>5.66</td>
<td>4.08</td>
<td>85</td>
<td>88.8</td>
<td>48.1</td>
</tr>
<tr>
<td>Eucalyptus (bleached)</td>
<td>420</td>
<td>685</td>
<td>3.21</td>
<td>55.3</td>
<td>6.7</td>
<td>3.53</td>
<td>88</td>
<td>74</td>
<td>35.6</td>
</tr>
<tr>
<td>Aspen (bleached)</td>
<td>600</td>
<td>—</td>
<td>—</td>
<td>35</td>
<td>4.4</td>
<td>1.93</td>
<td>82.5</td>
<td>78</td>
<td></td>
</tr>
</tbody>
</table>

Note-1:
BD-2 (DEDP), Filler 6.6%: Handsheets of grammage 75 g/m², like copy paper, were prepared by using 86.6% cornstalk, 6.6% bleached softwood kraft pulp and 6.6% precipitated calcium carbonate as filler. 20 kg/ton (o.d. basis) of cationic potato starch, 2 kg/ton of AKD sizing agents and cationic and anionic retention aid were used during handsheet making.

Note-2:
BD-2 (DEDP), Filler 15.1%: Handsheets of grammage 75 g/m², like copy paper, were prepared by using 77.4% cornstalk, 7.5% bleached softwood kraft pulp and 15.1% precipitated calcium carbonate as filler. 20 kg/ton (o.d. basis) of cationic potato starch, 2 kg/ton of AKD sizing agents and cationic and anionic retention aid were used during handsheet making.
These two experiments show that paper made from cornstalk pulp can be improved significantly by judicial use of wet end chemistry during papermaking. The opacity of handsheets, an important requirement for printing and writing grade paper, was improved largely due to filler (precipitated calcium carbonate) integration in fiber matrix.

**Example 5**

In this example, physical, optical and mechanical properties of papers prepared in pilot scale paper machine from bleached cornstalk pulp and bleached mixed hardwood kraft pulp has been illustrated for comparison. Pulping of cornstalk was carried out in pilot scale digester and was subjected to washing, screening, dewatering and bleaching. The brightness of corn stalk pulp ranged from 88 to 90% as illustrated in example 2.

The furnish for the preparation of cornstalk paper is as follows: Bleached cornstalk chemical pulp: 60%, Bleached northern softwood kraft pulp (commercial grade): 20%, filler (precipitated calcium carbonate): 20%; starch: 0.5% (based on o.d. fiber basis); Hercon size 79 AKD (0.5%): 0.2% (o.d fiber basis) and Nalco 7520 Retention aid (0.1%) was added. The furnish was mixed in such a way that the post retention was 80% of the original furnish.

**Table 8**

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Grammage (g/m²)</th>
<th>Density (kg/m³)</th>
<th>Brightness (%)</th>
<th>Opacity (%)</th>
<th>Scattering coefficient (kg/m²)</th>
<th>Absorption coefficient (kg/m²)</th>
<th>Gurley porosity (sec/100 ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>wood</td>
<td>80.4</td>
<td>698</td>
<td>87.4</td>
<td>89.8</td>
<td>0.17</td>
<td>0.17</td>
<td>7.1</td>
</tr>
<tr>
<td>cornstalk</td>
<td>76.9</td>
<td>784</td>
<td>88.7</td>
<td>87.2</td>
<td>0.14</td>
<td>0.14</td>
<td>171</td>
</tr>
</tbody>
</table>

Table 8 shows that the density of cornstalk pulp was higher than those of wood pulp. Brightness of cornstalk pulp is nearly 1 point higher than wood pulp, but the printing opacity is more than 2 points lower. Both scattering coefficient and absorption coefficient for wood pulp were slightly higher than cornstalk pulp. Scattering coefficient is inversely related to paper bonding property. Porosity for cornstalk pulp is 171 sec/100 ml compared to 71 sec/100 ml for wood pulp. That means wood pulp result in much more porous structure than cornstalk pulp.

**Table 9**

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Brightness (%)</th>
<th>Opacity (%)</th>
<th>Scattering coefficient (kg/m²)</th>
<th>Absorption coefficient (kg/m²)</th>
<th>L</th>
<th>A</th>
<th>b</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
<th>CIE Whiteness</th>
<th>CIE Tint</th>
</tr>
</thead>
<tbody>
<tr>
<td>wood</td>
<td>87.35</td>
<td>91.14</td>
<td>64.16</td>
<td>0.17</td>
<td>95.21</td>
<td>0.11</td>
<td>2.96</td>
<td>96.26</td>
<td>0.05</td>
<td>3.00</td>
<td>77.27</td>
<td>-1.96</td>
</tr>
<tr>
<td>cornstalk</td>
<td>88.63</td>
<td>88.95</td>
<td>58.01</td>
<td>0.15</td>
<td>95.29</td>
<td>0.25</td>
<td>2.09</td>
<td>96.33</td>
<td>0.19</td>
<td>2.14</td>
<td>81.35</td>
<td>-1.66</td>
</tr>
</tbody>
</table>

Table-9 shows that CIE Whiteness of cornstalk pulp was about 4 points higher than wood pulp and CIE Tint was lower than wood pulp. Brightness, opacity, scattering coefficient, absorption coefficient of cornstalk pulp and wood pulp were similar. L* that represents lightness increasing from zero for black to 100 for perfect white, is similar for both cornstalk pulp and wood pulp; a*, that represents redness when plus, is higher for cornstalk pulp than wood pulp; b*, that represents yellowness when plus, is higher for wood pulp than cornstalk pulp.
Table 10 shows the comparison of strength properties of wood pulp and cornstalk pulp both in machine-direction (MD) and cross-direction (CD). All of the strength properties of cornstalk pulp are 40% to 300% higher than that of wood pulp. Tensile strength properties of cornstalk pulp in machine direction was about 50% higher, and in cross-direction is 122% higher than those of wood pulp. Stretch value of cornstalk pulp in MD and CD directions were respectively 50% and 100% higher than those of hardwood pulp. TWA (tensile energy absorption) value of cornstalk pulp in MD direction is 130% and in CD direction is 200% higher than those of hardwood pulp. Similarly tear index of cornstalk pulp in MD direction is 55% higher and CD direction is 36% higher than those of hardwood pulp. Filler, in general, are responsible for weak bonding properties of paper. Although cornstalk pulp retained 22% filler compared to 17% filler in wood pulp, cornstalk pulp was much stronger than wood pulp. Pilot paper machine trial has further demonstrated that cornstalk pulp can hold the filler in the fiber matrix more efficiently than does wood pulp.

Table 11 shows the Sheffield smoothness, burst index, Taber stiffness, and number of double folds of both cornstalk and hardwood pulp. Sheffield smoothness of cornstalk pulp and hardwood pulp were similar in the felt direction, whereas in wire direction cornstalk pulp was more smooth than hardwood pulp. Burst strength of cornstalk pulp was more than 100% stronger than hardwood pulp. Number of double folds for cornstalk pulp in MD and CD directions are respectively 41 and 19 compared to 23* and 8* for wood pulp. Since wood pulp is too weak to fold under 1 kg tension, 0.5 kg tension was applied. 8* is actually equivalent to 1 number of fold and 23* is equivalent to only 8 number of fold, if measured under 1 kg tension.

[0117] Table 10 shows the comparison of strength properties of wood pulp and cornstalk pulp both in machine-direction (MD) and cross-direction (CD). All of the strength properties of cornstalk pulp are 40% to 300% higher than that of wood pulp. Tensile strength properties of cornstalk pulp in machine direction was about 50% higher, and in cross-direction is 122% higher than those of wood pulp.Stretch value of cornstalk pulp in MD and CD directions were respectively 50% and 100% higher than those of hardwood pulp. TWA (tensile energy absorption) value of cornstalk pulp in MD direction is 130% and in CD direction is 200% higher than those of hardwood pulp. Similarly tear index of cornstalk pulp in MD direction is 55% higher and CD direction is 36% higher than those of hardwood pulp. Filler, in general, are responsible for weak bonding properties of paper. Although cornstalk pulp retained 22% filler compared to 17% filler in wood pulp, cornstalk pulp was much stronger than wood pulp. Pilot paper machine trial has further demonstrated that cornstalk pulp can hold the filler in the fiber matrix more efficiently than does wood pulp.

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[0119] Paper machine trial has clearly demonstrated that cornstalk paper prepared under identical condition as hardwood paper, is much superior in terms of strength properties than that of hardwood paper, and similar to each other in terms of optical properties.

[0120] It is understandable that various details of the invention might be changed without deviating from the scope of this invention. Moreover, the above-mentioned descriptions in various examples are for the purpose of illustration only, not for the purpose of limitation. Various modifications can be made in the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A method for producing pulp from agricultural residues, comprising:
harvesting a portion of a cornstalk plant, wherein the harvesting includes removing a portion of the cornstalk below about at least one of a ear on the cornstalk plant;
drying the cornstalk portions; 
chopping the cornstalk portions; 
washing of the chopped cornstalk portions; 
compacting the washed cornstalk portions in a screw feeder to remove water; 
extracting pulp from the compacted cornstalk portions with an alkaline pulping solution at predetermined conditions; 
fiberizing the pulp; 
washing the pulp; and 
treating of the fiberized and washed pulp with a bleaching solution, wherein the bleaching solution removes residual lignin and color for increasing the brightness to greater than about 70% ISO.

2. The method of claim 1, wherein batch processes of at least one of trembling, stationary digester, and super batch digester is utilized.

3. The method of claim 1, wherein continuous processing of at least one of Pandia digester and Kymer digester are utilized.

4. The method of claim 1, wherein the cooking of cornstalk in the alkaline solution is done at a temperature ranging from about 120 to 160°C for about 30 min to 120 min.

5. The method of claim 4, wherein the alkaline solution comprises an alkaline hydroxide solution including at least one of sodium hydroxide, potassium hydroxide, ammonium hydroxide, and calcium hydroxide.

6. The method of claim 4, wherein the alkaline solution further includes at least one of sodium carbonate and sodium bicarbonate.

7. The method of claim 6, wherein the alkaline solution further includes sodium hydroxide.

8. The method of claim 7, wherein the alkaline solution further includes anthraquinone.

9. The method of claim 7, wherein the sodium hydroxide has a concentration in the range from about 2% to 18% active alkali and the anthraquinone has a concentration in the range from about 0.0% to 0.5%.

10. The method of claim 7, wherein a pretreatment step involving compacted cornstalk material with cellulose protecting agents such as MgCl₂, CaCO₃ at a temperature between about 60 to about 100°C for about 30 to about 60 minutes might be used in order to protect the hemicellulose during alkaline digestion of cornstalk.

11. The method of claim 1, wherein the bleaching solution comprises chlorine dioxide.

12. The method of claim 1, wherein the treating of the fiberized and washed pulp with a bleaching solution is performed at a temperature ranging from about 50 to 100°C for about 30 to 120 minutes.

13. The method of claim 1, wherein the alkaline pulping solution includes a concentration ranging from about 1% to 3% sodium hydroxide.

14. The method of claim 1, wherein a chlorine dioxide-alkaline extraction-chlorine dioxide (DED) bleaching sequence raises the pulp brightness to about 80-85% ISO.

15. The method of claim 14, wherein after the DED sequence one of a hydrogen peroxide bleaching solution (O), ozone solution (Z) and oxygen solution (O₂) is used for raising the pulp brightness to about 86 to 95% ISO.

16. The method of claim 15, wherein the chlorine dioxide bleaching solution comprises a dosage of chlorine dioxide equivalent to pulps' kappa factor ranging from about 0.01 to 0.5.

17. The method of claim 16, wherein the hydrogen peroxide bleaching solution comprises:

- hydrogen peroxide of about 1 to 3% of o. d. pulp weight;
- sodium hydroxide of about 1 to 3% of o. d. pulp weight;
- sodium silicate of about 1 to 3% of o. d. pulp weight;
- magnesium sulfate of about 0.02 to 0.06% of o. d. pulp weight; and
- trace amounts of chelant

18. The method of claim 17, further comprising:

- a bleaching stage to improve the brightness of cornstalk pulp,

wherein the bleaching stage uses bleaching reagent, such as ozone of about 0.05 to 5% (of o. d. pulp weight) and oxygen of about 0.1 to 2% (of o. d. pulp weight).

19. A method for making paper out of pulp from agricultural residue, comprising:

- refining pulp from agricultural residue;
- blending the pulp from agricultural residue;
- cleaning;
- screening; and
- rolling in the paper machine,

wherein the pulp from agricultural residue is cornstalk pulp.

20. The method of claim 19, wherein the cornstalk pulp has freeness level of at least 250 ml or greater.

21. The method of claim 19, wherein the cornstalk pulp has a kappa number in a range of about 7 to 80.

22. The method of claim 19, wherein the cornstalk pulp has a kappa number in a range of about 2 to 7.

23. The method of claim 19, wherein the cornstalk pulp has a kappa number below about 2.

24. The method of claim 19, wherein cornstalk pulp can be used without refining and/or with refining to 250-500 ml CSF before combining with wood pulp to provide the specific properties that can meet the end-uses of paper products.

25. The method of claim 19, wherein cornstalk pulp can be fractionated into long fiber and short fiber fractions and reblended depending on the properties of end-uses to maximize the performance of cornstalk pulp.

26. The method of claim 19, wherein writing and printing paper, photocopy, specialty papers, and envelope papers can be produced from bleached cornstalk pulp by the blending with one or more pulp and/or additives from a group comprising:

- bleached softwood chemical pulp;
- bleached hardwood chemical pulp: 0-20%;
- filler (precipitated or grounded calcium carbonate, clay, kaolin, talc, titanium dioxide, etc.): 0-30%;
- dry strength chemicals (starch or other polymeric materials): 0-4%.
sizing agent (rosin emulsion, AKD, ASA or others): 0.05–5%; and
cationic and/or anionic polymeric retention aids (starch, poly acryl amide, poly ethylene imine, colloidal silica, bentonite, organic micro-particles, etc): 0-5%.

27. The method, of claim 19, wherein top white liner can be produced from bleached cornstalk pulp by blending with one or more additives from a group comprising:
bleached softwood chemical pulp: 0-30%;
bleached hardwood chemical pulp: 0-30%;
filler (precipitated or ground calcium carbonate, clay or kaolin): 0-20%;
dry strength agent (starch or other polymeric materials): 0-4%;
sizing agent (rosin emulsion, AKD, ASA or others): 0.05-2%; and
retention aid (starch, poly acryl amide, poly ethylene imine, colloidal silica, bentonite, organic micro-particles, etc): 0-5%.

28. The method of claim 19, wherein carton package for milk, juice, and other beverages can be produced from bleached cornstalk pulp by blending with one or more additives from a group comprising:
bleached softwood chemical pulp: 0-20%;
sizing agents (rosin emulsion, AKD, ASA or others): 0.01-5%; and
retention aid (starch, poly acryl amide, poly ethylene imine, colloidal silica, bentonite, organic micro-particles, etc): 0-5.5%.

29. The method of claim 19, wherein linerboard can be produced from unbleached cornstalk chemical or semi-chemical pulp without or with unbleached softwood chemical or semi-chemical pulp.

30. The method of claim 19, wherein corrugating medium can be produced from high yield cornstalk pulp mixed with high yield hardwood pulp.

31. The method of claim 19, wherein tissue papers, wet strength papers, and industrial papers can be produced from bleached cornstalk pulp by blending with one or more additives from a group comprising:
bleached softwood chemical pulp: 0-30%;
bleached hardwood chemical pulp: 0-20%;
sizing agents (rosin emulsion, AKD, ASA or others): 0.01-5%; and
retention aid (starch, poly acryl amide, poly ethylene imine, colloidal silica, bentonite, organic micro-particles, etc): 0-5.5%.

32. The method of claim 19, wherein photocopy papers, specialty papers, and envelope papers can be produced from bleached cornstalk pulp by blending with one or more additives from a group comprising:
bleached softwood chemical pulp: 0-30%;
bleached hardwood chemical pulp: 0-20%;
filler (precipitated or ground calcium carbonate, clay or kaolin): 0-40%;
dry strength agent (starch or other polymeric materials): 0.05%;
sizing agents (rosin emulsion, AKD, ASA or others): 0.01-5%; and
retention aid (starch, poly acryl amide, poly ethylene imine, colloidal silica, bentonite, organic micro-particles, etc): 0-5.5%.

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