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(54) **METHOD FOR PRE-PROCESSING AND PROCESSING PULP**

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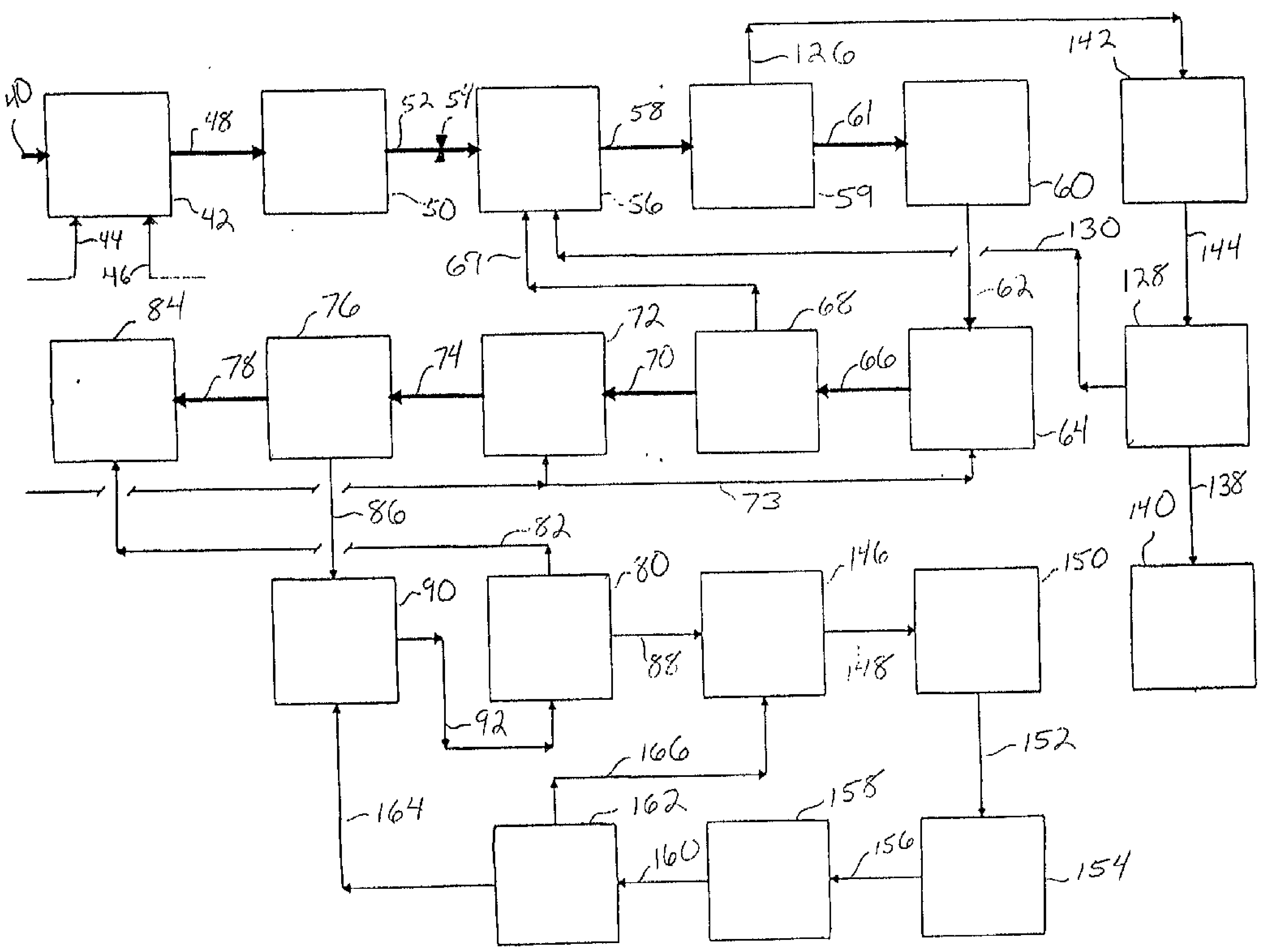
(57) **ABSTRACT**

the present invention provides a method for pre-processing and processing straw pulp and forming a byproduct suitable for animal consumption. The present invention also provides a paper product comprising straw pulp. According to the present invention, straw pulp is formed by steam exploding straw chips in the presence of either no caustic or a small amount of caustic.



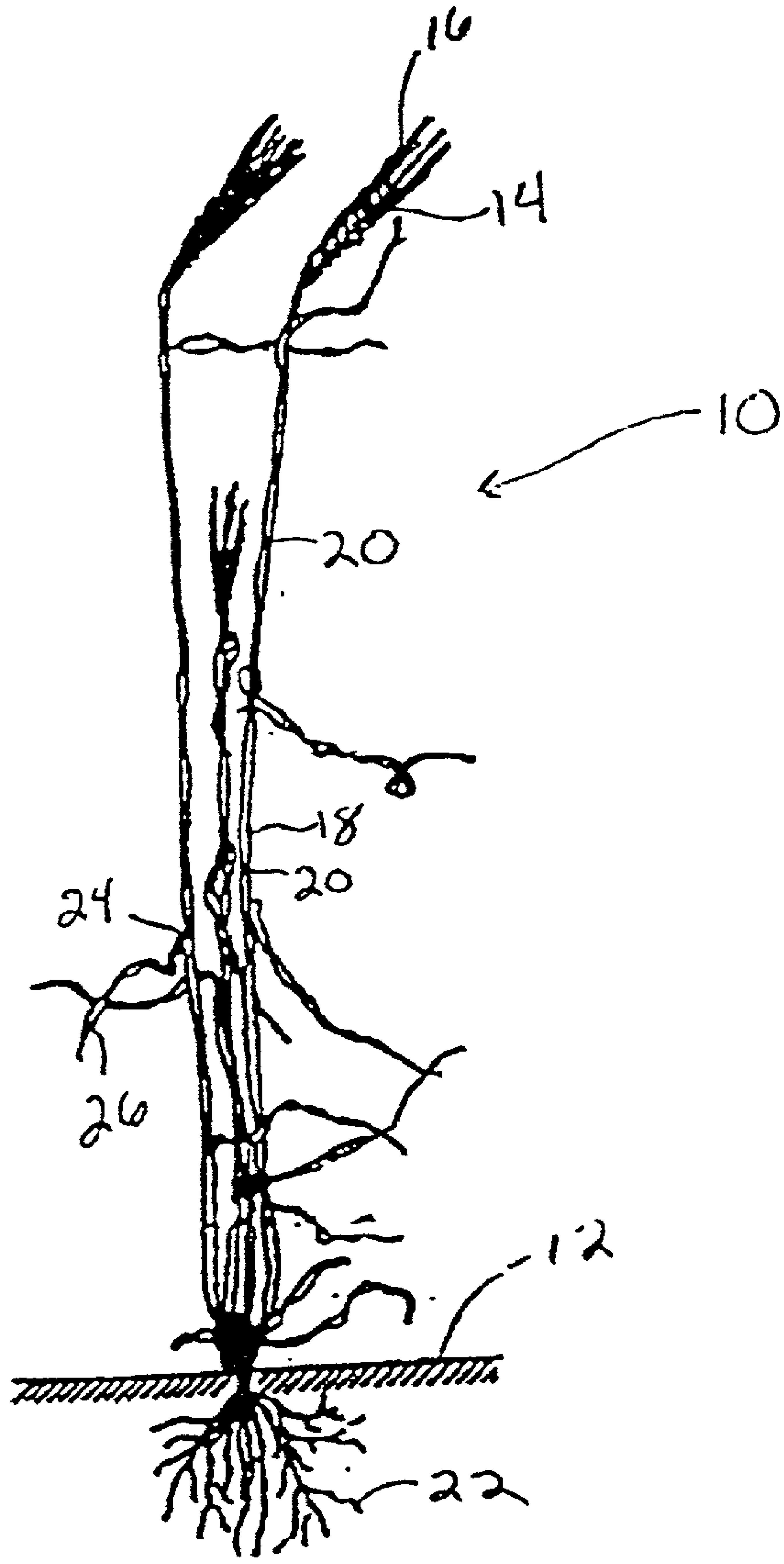


Fig. 1

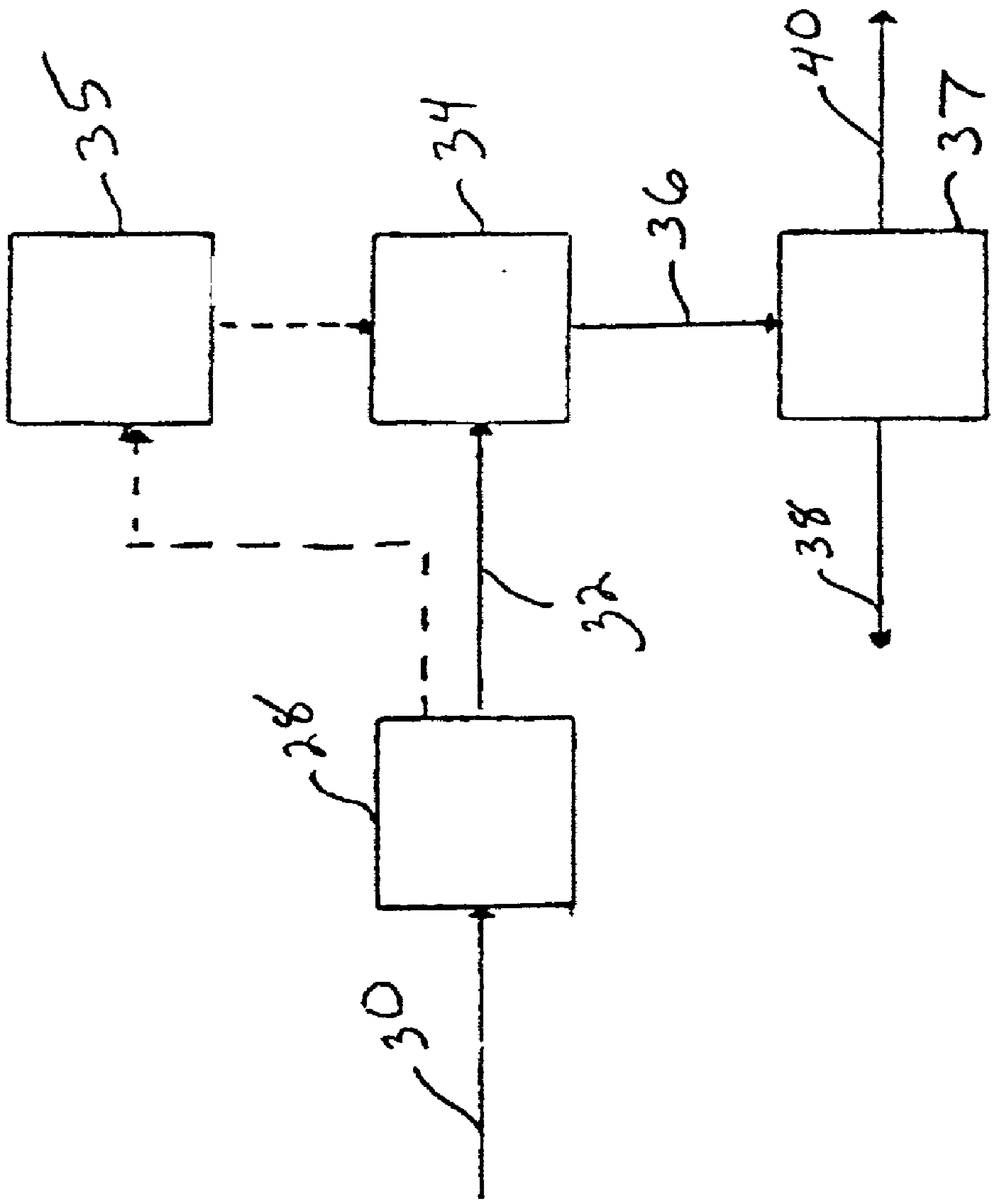


Fig. 2

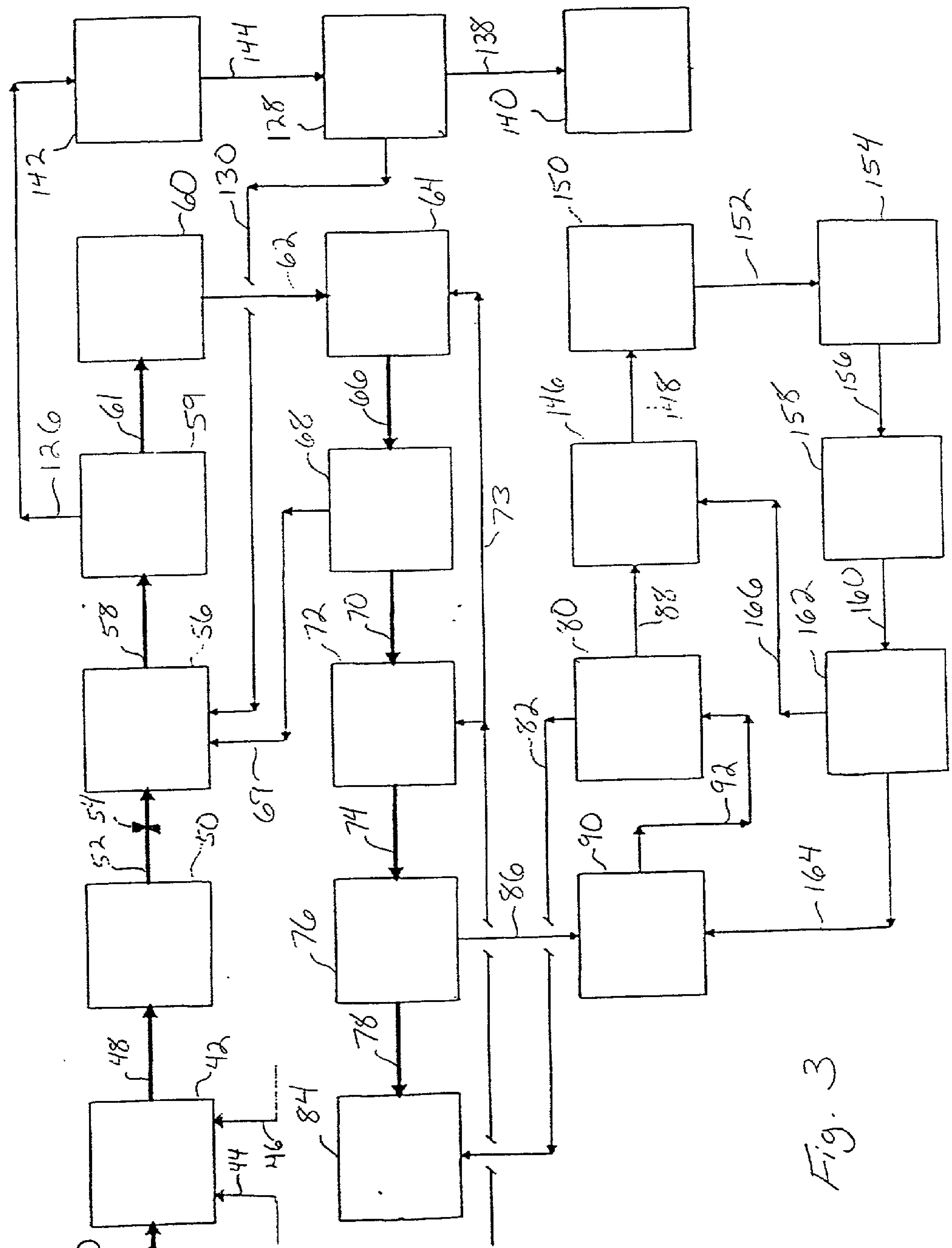

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Fig. 3

METHOD FOR PRE-PROCESSING AND PROCESSING PULP

BACKGROUND OF THE INVENTION

[0001] 1. Technical Field

[0002] This invention relates to a method for pre-processing and processing lignocellulosic material into pulp.

[0003] 2. Background Information

[0004] There is increasing interest in the incorporation of non-wood cellulosic fibers into paper products. There is a tremendous amount of non-wood fibers available for pulp production. It has been estimated that the world straw production is approximately 500,000,000 metric tons per year. Only about half of that amount is used for low value purposes, such as building materials, fuel, and cattle feed. Most of the remaining amount is wasted by burning, without energy recovery, or plowing back into the ground. However, among the limitations in making straw into paper is incorporating the lower quality fiber derived from straw into a product with sufficient strength, durability, and brightness for a marketable end product.

[0005] U.S. Pat. No. 4,040,899, issued in 1977 to Emerson, attempts to address the use of straw pulp in paper. Emerson teaches intertwining and crimping fibers into a paper web.

[0006] According to Pulp and Paper, published 1952, 1960, by Interscience Publishers, Inc.,

> [0007] "Straw is pulped by chemical processes and by a combination mechanical and chemical process known as mechano-chemical process. Among the different chemicals used for pulping straw are: (1) sodium hydroxide, (2) lime alone or in combination with other alkalies, (3) sodium sulfite plus other alkali, (4) chlorine, and (5) sodium hydroxide plus sodium sulfide (sulfite process). Other chemicals suggested for the pulping of straw are nitric acid and sodium chlorite. Sodium carbonate plus sulfur has been suggested for the preparation of a coarse pulp (straw Kraft) used for corrugated papers. There are four principal processes for making high grade bleachable straw pulp: (1) soda process, (2) sulfate process, (3) monosulfite process, and (4) the Pomilio chlorine process. The soda and sulfate processes produce good pulp, but in rather low yield."

DISCLOSURE OF THE INVENTION

[0008] The present invention provides a method for pulping straw chips and forming a usable byproduct. According to the method, straw chips are mixed with steam and water to form a mixture. The mixture is exposed to temperatures and pressures sufficient to significantly soften the straw chips to form straw pulp, lignins, and hemicellulose when exposed to a rapid decrease in pressure. The mixture is washed to separate a portion of the lignins and hemicellulose from the straw pulp such that a usable byproduct of water, lignins and hemicellulose, referred to as black liquor, is formed and passed through a mechanical refiner.

[0009] The straw chips may be mixed with a caustic before the mixture of straw chips, steam and water is exposed to temperatures and pressures sufficient to significantly soften the straw chips to form straw pulp, lignins and hemicellulose in the mixture when exposed to a rapid decrease in pressure. The caustic may be present in the mixture in about less than two percent by weight. It is more preferred that the caustic is present in the mixture in about less than one-half percent by weight. The caustic may comprise sodium hydroxide. Also, the caustic may comprise potassium hydroxide.

[0010] In one form of the method, the mixture may be exposed to temperatures and pressures sufficient to significantly soften the mixture when exposed to a rapid decrease in pressure for between about two and one-half minutes to about eight minutes.

[0011] In yet another form of the invention, at least about seventy percent by weight of the straw chips are formed into straw pulp.

[0012] In yet another form of the invention, the pressure sufficient to significantly soften the straw chips when exposed to a rapid decrease in pressure is between about 140 psig and about 200 psig.

[0013] In another form of the invention, the fiber chips may be selected from non-wood fibers such as ryegrass, wheat and a mixture of grain and cereal straws.

[0014] Straw chips for use in the method may be formed by chopping straw to form a mixture of straw chips, meal, ash and grit and screening the mixture to separate a substantial portion of the straw chips from the meal, ash and grit. The meal, ash, and grit may be used as animal feed. In a preferred form of the invention, the meal, ash, and grit may be mixed with the black liquor byproduct to form animal feed.

[0015] The straw pulp formed by this method has a Canadian Standard Freeness between about 200 and about 600.

[0016] The present invention also provides a paper product made from wood pulp and straw pulp wherein the straw pulp is produced by mixing straw chips with steam and water to form a mixture of straw chips, steam and water. The mixture is exposed to temperatures and pressures sufficient to significantly soften the straw chips into straw pulp when exposed to decreased pressures. The mixture is then refined and a substantial portion of the straw pulp is separated from the mixture. A portion of the wood pulp and the paper product may be derived from processed post-consumer waste.

[0017] The straw chips may be formed by chopping straw to form a mixture of straw chips, meal, ash and grit and screening the mixture to separate a substantial portion of the straw chips from the meal, ash and grit.

[0018] In yet another form of the invention, the straw pulp has a Canadian Standard Freeness (CSF) of between about 200 and about 600 and an STFI between about 14 and about 21.

[0019] These and other advantages and features will become apparent from the detailed description of the best mode for carrying out the invention that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] In the drawings, like element designations refer to like parts throughout the several views, and:

[0021] **FIG. 1** is an elevational view of a rye grass plant;

[0022] **FIG. 2** is a flow diagram of a pre-processing plant constructed according to the method of the present invention; and

[0023] **FIG. 3** is a flow diagram of a pulping plant constructed according to the method of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0024] The present invention provides an improved method for pre-processing and processing various lignocellulosic source materials. Suitable lignocellulosic materials include non-wood fibers such as grain and cereal straw, and corn stover. However, the methods of the present invention have been found to be particularly suited for lignocellulosic material derived from grass and straw, such as annual ryegrass, fescue, and wheat. As used herein, straw chips may refer to chips derived from any non-wood fibers such as grain and cereal straw, grass and corn stover. However, for simplicity, all such chips shall be referred to as straw chips.

[0025] Referring first to **FIG. 1**, by way of example, a ryegrass plant **10** is shown growing in soil **12**. The ryegrass plant **10** has seeds or kernels **14** held within ears **16**, hollow stems or internodes **18** between joints or nodes **20**, and an extensively branching fibrous root system **22**. Sheath portions **24** are formed on the stems **18** and attach leaves **26** to the stems **18**.

[0026] During harvest, the ryegrass plants **10** are cut or swathed about three to six inches from the ground, generally below the first of the joints or nodes **20**. Then, the cut ryegrass plants are left to cure in the fields for a few weeks. Seeds or kernels **14** may be harvested from the cut plants by use of a combine. After the combine has removed the seeds or kernels **14**, the remainder of the ryegrass plants, generally known as straw **30**, is dropped to the ground. The straw **30** may be recovered from the field and baled for storage prior to further processing.

[0027] Referring to **FIG. 2**, for pre-processing, straw **30** is fed into a tub grinder **28**. The straw **30** may be fed into the tub grinder **28** in bales. The tub grinder **28** breaks up the bales and chops the straw into pieces averaging roughly one inch in length. As the chopped straw **32** exits the mill **34**, the chopped straw **32** includes nodes **20**, leaves **26**, sheath portion **24**, and internodes **18**, as well as ash, silica, and grit.

[0028] After exiting the tub grinder **28**, the chopped straw **32** is sent into a mill **34** to reduce the chopped straw **32** to pieces averaging roughly one-half inches in length. The mill **34** grinds most of the nodes **20**, leaves **26**, and sheath portion **24** into powder.

[0029] The chopped straw **32** may be stored in a storage tank **35** before being sent to the mill **34** if the capacity of the mill **34** does not permit the chopped straw **32** to be fed directly from the tub **28** grinder to the mill **34**.

[0030] After exiting the mill **34**, milled mixture **36** is passed through multilayer screens **37**. Meal **38** is dislodged and removed from straw chips **40** by passing the milled mixture **36** through the multilayer screens **37**. The meal **38** includes non-fibrous particles and ash, enriched with silica and grit. The meal **38** may be used as an agricultural byproduct for feeding livestock.

[0031] The straw chips **40** are then ready for processing into pulp. The straw chips **40** may be stored before further processing. In addition, if the pulp processing is to be carried out at a place remote from where the straw chips **40** have been preprocessed, the straw chips **40** may be transported by any manner used to transport bulk materials, such as by the use of containers.

[0032] Referring to **FIG. 3**, for processing the straw chips **40** into pulp, the straw chips **40** are fed into a mixer **42** where they are mixed with steam and water **44** and any caustic or digestive additives **46**. Typically, the amount of digestive additives **46** utilized is calculated on a weight basis per amount of dry straw chips entering the system. Scales may be incorporated into the pulping process so that the straw chips **40** may be weighed as they enter the system and the amount of digestive additives **46** may be administered at the appropriate rate.

[0033] Preferably, the amount of digestive additives **46** mixed with steam and water **44** and straw chips **40** is between about zero and about 2.0 percent by weight. However, it is more preferable that the amount of digestive additives **46** is between about zero and about 0.5 percent by weight. Suitable digestive additives **46** for use in the present invention include sodium hydroxide and potassium hydroxide.

[0034] From mixer **42**, a stream **48** composed of straw chips **40**, steam and water **44**, and any digestive additives **46** is then fed into reactor **50**. In reactor **50**, stream **48** is exposed to temperatures and pressures sufficient for the steam **44** and any digestive additives **46** to penetrate the straw chips **40** such that when exposed to a rapid decrease in pressure, a mixture of softened chips, cellulose, lignins, hemicellulose and water is formed.

[0035] Suitable reactors for use in the present invention include continuous feed reactors such as those manufactured by Stake Technology, Ltd. of Oakville, Canada, and described in U.S. Pat. Nos. 4,798,651 and 4,947,743, the contents of which are incorporated herein by reference.

[0036] In the present invention, reactor products **52** may be exposed to a rapid decrease in pressure by passing the reactor products **52** into a blow tank **56**. The reactor products **52** may be metered from the reactor **50** into the blow tank **56** by a blow valve **54**. The reactor products **52** include softened straw pulp mixed with lignins, hemicellulose and water. In other words, straw chips are steam exploded as they pass through the blow valve **54** when exiting the reactor **50** to form straw pulp, lignins and hemicellulose.

[0037] Stream **58** from the blow tank **56** is sent into a screw press **59** where stream **126** of a straw pulp mixture is separated from the steam exploded straw chips. Stream **126** is composed substantially of black liquor and undissolved solids. Generally, stream **126** is substantially composed of water, reacted lignins and hemicellulose. Stream **126** is sent to a byproduct chest **142**. Stream **144** from byproduct chest **142** is passed through filtration system **128**. Solids **130** removed at filtration system **128** are sent to blow tank **56**. Liquid stream **138** from filtration system **128** are collected in storage tank **140**.

[**0038**] The black liquor collected in storage tank **140** constitutes a usable byproduct. This byproduct has usefulness as an animal feed additive. In a preferred form of the invention, the byproduct may be mixed with meal **38** from preprocessing to form animal feed. The animal feed may be formed into a mash or pellets by methods known in the art.

[**0039**] Stream **61** from screw press **59** is then defiberized. The defiberization may be carried out by a mechanical refiner **60**, such as an Ahlstrom MDR (frotopulper).

[**0040**] The pulp is then ready to be washed. The pulp may be washed by any method, such as dilution and extraction. For example, the refined pulp mixture **62** may be sent to a dilution tank **64** where it is diluted with water **73**. Then, diluted pulp mixture **66** from tank **64** may be thickened by use of a wash press **68**. Weak black liquor in stream **69** from wash press **68** is sent to blow tank **56**.

[**0041**] Thickened pulp **70** may then be screened to remove unwanted particles. In preparation for the screening, the thickened pulp **70** may be sent to a prescreening dilution tank **72** where it is mixed with water **73**. Diluted pulp **74** from the dilution tank **72** may then be passed into a primary screening **76**. Accepts **78** from the primary screening **76** may be collected in accepts tank **84**.

[**0042**] Rejects **86** from primary screening **76** may be passed to a primary screen rejects tank **90**. Rejects **92** from rejects tank **90** may be passed to a secondary screening **80**. Accepts **82** from secondary screening **80** may be collected in accepts tank **84**. Rejects **88** from secondary screening **80** are sent to drainer **146**.

[**0043**] Drained stream **148** is sent to a secondary rejects tank **150**. Stream **152** from secondary rejects tank **150** is sent to a rejects defiberizer **154**. Stream **156** from the rejects defiberizer **154** is collected in a tertiary screen feed tank **158**. Stream **160** from the tertiary screen feed tank **158** is passed through a tertiary screening **162**. Accepts **164** from tertiary screening **162** are collected in the rejects tank **90**. Rejects **166** from tertiary screening **162** are sent to the drainer **146**.

[**0044**] The nature and substance of the instant invention as well as its objects and advantages will be more clearly understood by referring to the following specific examples.

Example 1

[**0045**] Annual rye grass straw is obtained. The protein level of the straw is determined to be about three to four percent (3%-4%). The moisture content of the rye grass straw is determined to be approximately ten percent (10%). The annual rye grass straw is preprocessed and pulped according to the method described in the best mode of this application and as set forth herein.

[**0046**] Bales of the rye grass straw are fed into an agricultural tub grinder where the bales are broken up and the straw chopped into pieces averaging roughly one (1) inch in length. The agricultural tub grinder has grate plates with round holes sized between about one half (0.5) inches and about two (2) inches.

[**0047**] After exiting the agricultural tub grinder, the chopped straw is sent into a disc mill. The disc mill is a United Milling Systems mill which has milling gaps of between about 0.6 mm and about 1.0 mm. In the disc mill, the chopped straw is reduced into approximately one-half inch pieces. Also, the disc mill grinds most of the hard node, leaf and sheath of the straw into a powder. Ash and grit are determined to compose approximately two to five percent (2%-5%) of the straw fed into the tub grinder.

[**0048**] After leaving the milling machine, the straw is passed into a vibrating six-deck screen of **35** mesh. The screen is a gyratory screen equipped with fine mesh and ball decks for cleaning fines and dirt from the surfaces of the screen. Approximately eighteen percent (18%) of the straw mixture is removed at the screen as meal. Part of the meal removed is the powder formed in the disc mill by the hard node, leaf and sheath of the straw. The remainder of the straw chips leaving the screen averages approximately one half (½) inch in size.

[**0049**] The meal has a protein level of about eight to thirteen percent (8%-13%). The silica content is between about 8-15%. It is determined that the meal removed at the screen is usable as animal feed.

[**0050**] The preprocessed straw chips are then stored prior to pulping. The straw chips are preprocessed at a site remote from the pulping system. The preprocessed straw chips are transported to the pulping system in container trucks.

[**0051**] The preprocessed straw chips are fed into a pulping system at a rate consistent with the capacity of the pulping system. The preprocessed straw chips are fed into a mixer where they are mixed with steam and water to achieve a moisture content of about 40-50% based on the charge of preprocessed straw chips to the mixer. The preprocessed straw chips mixed with steam and water are fed into a Stake Digester steam explosion reactor. In the reactor, the preprocessed straw chips are exposed to pressure of about 160 psig for about five and a half (5½) minutes.

[**0052**] Pulp from the reactor is metered into a blow tank by a blow valve. Pulp from the blow tank is passed through a screwpress where black liquor is separated from the pulp. Then the pulp is defiberized or refined in an Ahlstrom frotopulper mechanical refiner. The refined pulp is sent to a dilution tank where it is mixed with liquid at a dilution factor of about 2.5. The diluted pulp is then thickened by use of a wash press. The thickened pulp is screened in a two-stage pressure screen with about 0.010 inch slotted plates.

[**0053**] It is determined that at least about seventy percent (70%) by weight of the straw chips are formed into straw pulp.

[**0054**] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI (Swedish Technical Forestry Institute) between about 14 and 21. As a comparison, OCC (pulp derived from recycled corrugated cardboard) is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 500 and STFI of between about 15 and about 22. Kraft pulp is determined to have a Canadian Standard Freeness (CSF) of between about 450 and about 750 and STFI of between about 21 and about 26.

[**0055**] Straw pulp with a Canadian Standard Freeness (CSF) between about 200 and about 600 and STFI between about 14 and about 21 is suitable to be blended with Kraft pulp and OCC to make liner board in standard mill grades. The straw pulp comprises about less than twenty percent (20%) of the liner board furnish.

Example 2

[0056] Example 1 is repeated using about one-half percent (0.5%) by weight sodium hydroxide in the mixer.

[0057] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI between about 14 and about 21.

Example 3

[0058] Example 1 is repeated using about one percent (1%) by weight sodium hydroxide in the mixer.

[0059] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI between about 14 and about 21.

Example 4

[0060] Example 1 is repeated using two percent (2%) by weight sodium hydroxide in the mixer.

[0061] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI between about 14 and about 21.

Example 5

[0062] Example 1 is repeated using about one-half percent (0.5%) by weight potassium hydroxide in place of the sodium hydroxide in the mixer.

[0063] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI between about 14 and about 21.

Example 6

[0064] Example 1 is repeated using about one percent (1%) by weight potassium hydroxide in place of the sodium hydroxide in the mixer.

[0065] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI between about 14 and about 21.

Example 7

[0066] Example 1 is repeated using about two percent (2%) by weight potassium hydroxide in place of the sodium hydroxide in the mixer.

[0067] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI between about 14 and about 21.

Example 8

[0068] example 1 is repeated allowing the preprocessed straw chips mixed water to remain in the reactor for about two and one-half minutes.

[0069] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI between about 14 and about 21.

Example 9

[0070] Example 1 is repeated allowing the preprocessed straw chips mixed water to remain in the reactor for about 4 minutes.

[0071] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI between about 14 and about 21.

Example 10

[0072] Example 1 is repeated allowing the preprocessed straw chips mixed with water to remain in the reactor for about six (6) minutes.

[0073] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI between about 14 and about 21.

Example 11

[0074] Example 1 is repeated allowing the preprocessed straw chips mixed water to remain in the reactor for about eight (8) minutes.

[0075] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI between about 14 and about 21.

Example 12

[0076] Example 1 is repeated with the preprocessed straw chips mixed with water to be exposed to a pressure of about 140 psig in the reactor.

[0077] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI between about 14 and about 21.

Example 13

[0078] Example 1 is repeated with the preprocessed straw chips mixed with water to be exposed to a pressure of about 180 psig in the reactor.

[0079] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI between about 14 and about 21.

Example 14

[0080] Example 1 is repeated with the preprocessed straw chips mixed with water to be exposed to a pressure of about 200 psig in the reactor.

[0081] After exiting the process, the straw pulp is determined to have a Canadian Standard Freeness (CSF) of between about 200 and about 600 and STFI between about 14 and about 21.

[**0082**] While specific embodiments of the present invention have been shown and described in detail to illustrate the utilization of the inventive principles, it is to be understood that such showing and description have been offered only by way of example, and not by way of limitation. Protection by Letters Patent of this invention in all its aspects is set forth in the appended claims and is sought to the broadest extent that the prior art allows.

What is claimed is:

1. A method for pulping straw and forming a usable byproduct, comprising:

mixing straw chips with steam and water to form a mixture;

exposing the mixture to temperatures and pressures sufficient to significantly soften the straw chips to form straw pulp, lignins and hemicellulose when exposed to a rapid decrease in pressure;

passing the mixture through a press to separate a portion of lignins and hemicellulose from the straw pulp such that a usable byproduct of water, reacted lignins and hemicellulose is formed; and

passing the straw pulp through a defiberizer to form a usable straw pulp.

2. The method of claim 1, wherein the straw chips are mixed with a caustic before the mixture of straw chips, steam and water is exposed to temperatures and pressures sufficient to significantly soften the straw chips to form straw pulp, lignins and hemicellulose in the mixture when exposed to a rapid decrease in pressure.

3. The method of claim 2, wherein the caustic is present in the mixture in about less than two percent (2%) by weight based upon the dry straw chips.

4. The method of claim 3, wherein the potassium hydroxide is present in the mixture in about less than one-half percent (0.5%) by weight based upon the dry straw chips.

5. The method of claim 2, wherein the caustic comprises sodium hydroxide.

6. The method of claim 2, wherein the caustic comprises potassium hydroxide.

7. The method of claim 1 wherein the mixture is exposed to temperatures and pressures sufficient to significantly softened the mixture when exposed to a rapid decrease in pressure for between about two and one half (2½) minutes to about eight (8) minutes.

8. The method of claim 1 wherein the straw chips are selected from the group comprising:

ryegrass;

wheat; and

a mixture of grain and cereal straws.

9. The method of claim 1 wherein at least about seventy percent (70%) by weight of the straw chips are formed into straw pulp.

10. The method of claim 1 wherein the pressures sufficient to significantly soften the straw chips when exposed to a rapid decrease in pressure from between about 140 psig and about 200 psig to about atmospheric pressure.

11. The method of claim 1, wherein the straw chips are formed by chopping straw to form a mixture of straw chips, meal, ash and grit and screening said mixture to separate a substantial portion of the straw chips from the meal, ash and grit.

12. The method of claim 11, wherein said separated meal, ash and grit is used as animal feed.

13. The method of claim 12, wherein said separated meal, ash, and grit is mixed with the usable byproduct to form an animal feed.

14. The method of claim 1, wherein the straw pulp has a Canadian Standard Freeness of between about 200 and about 600.

15. A paper product made from wood pulp and straw pulp wherein the straw pulp is produced by mixing straw chips with steam and water to form a mixture of straw chips, steam and water; exposing said mixture to temperatures and pressures sufficient to significantly soften the straw chips into straw pulp when exposed to decreased pressures; separating a substantial portion of said straw pulp from said mixture, and refining said straw pulp.

16. The paper product of claim 15, wherein a portion of the wood pulp is derived from processed post consumer waste.

17. The paper product of claim 15, wherein said straw chips are formed by chopping straw to form a mixture of straw chips, meal, ash and grit and screening said mixture to separate a substantial portion of the straw chips from the meal, ash and grit.

18. The paper product of claim 15, wherein said straw pulp has a Canadian Standard Freeness (CSF) of between about 200 and about 600 and an STFI between about 14 and about 21.

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