

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
24 June 2010 (24.06.2010)

(10) International Publication Number  
**WO 2010/071440 A1**

PCT

(51) International Patent Classification:  
*C10L 5/44* (2006.01) *C10L 9/08* (2006.01)

(21) International Application Number:  
PCT/NO2009/000346

(22) International Filing Date:  
5 October 2009 (05.10.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
20085249 15 December 2008 (15.12.2008) NO  
20092136 2 June 2009 (02.06.2009) NO

(71) Applicant (for all designated States except US): **GLOM-MEN SKOG BA** [NO/NO]; Grindalsveien 3, P.b. 1329, N-2405 Elverum (NO).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **GRØNN, Arne Johannes** [NO/NO]; Kåra 11, N-7650 Verdal, Norway (NO).

(74) Agent: **ZACCO NORWAY AS**; Postboks 2003 Vika, N-0125 Oslo (NO).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: A METHOD FOR THE PRODUCTION OF PELLETS OR BRIQUETTES

(57) Abstract: A method is provided for the production of pellets or briquettes from lignin containing material in the form of processable particles wherein the method comprises the steps of: passing the material, if it has a relative moisture content of more than about 30%, alternatively more than about 20% by weight, to a drying step and drying it to a relative moisture content of about 0-30%, alternatively about 0-20 % by weight; passing the material, optionally via an intermediate storage step, to a heat treatment step and heating the material to about 180-235°C by injecting steam into a reactor; maintaining the material in the reactor at the temperature reached for a sufficient time to soften the material and release lignin; reducing the pressure in the reactor in at least one step; and pelletizing or briquetting the treated material. The invention also concerns pellets or briquettes produced by the method.



WO 2010/071440 A1

## **A method for the production of pellets or briquettes**

The present invention relates to a method for the production of pellets and briquettes, from lignin containing material, such as from raw materials of wood, bamboo, bagasse,  
5 straw, or grass.

In recent years there has been a steadily increasing focus on the environment and in particular on the emission of "fossil" CO<sub>2</sub>. There is therefore a strong commitment internationally to achieving the transition from fossil energy sources (oil, gas, coal and  
10 coke) to biological or renewable energy sources in order to reduce the emissions of "fossil" CO<sub>2</sub>.

Fuel pellets of wood are one of the fastest growing forms of bioenergy. Wood pellets and briquettes have also several other applications, but the most common field of use is  
15 as fuel pellets. Today, wood pellets are produced in substantial volumes at a large number of plants, especially in Europe and North America.

Traditionally, the raw materials are primarily sawdust, with a typical particle size of less than 3 mm and a typical relative moisture content of about 50-55% by weight, and raw  
20 materials which are residual products from planing mills, furniture factories etc, with a typical relative moisture content in the range of about 10-18% by weight.

### **Mechanical process**

The main features of the most common method for producing pellets, which is a  
25 mechanical process including fine grinding and compression, are as follows:

#### Drying

Raw materials with a relative moisture content of more than about 18-20% by  
30 weight are dried prior to pelletization. These materials constitute the major portion of the raw materials, which today are mostly sawdust. The drying is usually carried out in drum dryers into which the raw materials are introduced and into which there are injected flue gases from a combustion plant fuelled by chips/bark or the like, direct drying taking place on the basis of flue gases.

35 However, several types of dryers are in use, including low temperature dryers.

### Grinding

The next step is mechanical fine grinding of the raw materials, down to a typical particle size of less than about 2 mm. This is usually done in an impact mill (hammer mill).

### Pelletization

The material is then passed to pellet presses, where pelletization typically is carried out in that the material is pressed through cylindrical holes in a ring die, and the compressed material that comes out is cut into pellets.

### Cooling

The newly produced pellets, which have a high temperature and a soft consistency, are then passed to a cooler, which is a vessel through which air is passed, so that a controlled cooling of the pellets is obtained, and at the same time the volume of fines is reduced. Finished pellets then exit the cooler.

For pellets that are produced in this way, the volume of fines (dust) is often higher than desirable, especially after transport and handling. Therefore, binding agents have, to a certain degree, previously been added during the pelletization process, often lignosulfonates, by-products from wood processing. However, this gives an undesirable addition of chemicals.

US 4,502,227 and GB 2 402 398 describe drying and pelletization of wood pellets.

Briquettes are produced from the same raw materials as pellets. While pellets have a typical diameter of about 6.8 or 12 mm and a length of about 10-20 mm, briquettes are larger, with a typical diameter of about 50 mm, and a length from about 20 mm and upwards to about 300 mm. Briquettes are not produced in ring dies, but in separate briquette presses where the raw material is compressed. The briquettes typically have a lower volumetric weight than pellets.

### **Steam explosion**

From NO 320971/EP 1776440 there is known a method in which the raw materials are first dried to a relative moisture content of 30-45% by weight, then passed to a reactor to which steam is supplied until the material is maintained at 200-300<sup>0</sup> C for sufficient time to soften the material, after which a depressurization is carried out in at least two

steps so that the material is “steam-exploded”. The material is then defibrated and lignin is released. The material subsequently passes to a new drying step, after which the material is optionally pelletized. This method is the production method that is used commercially today.

5

One of the main reasons this technology is still in use is that in the technical field the view is held that there must be “sufficient residual moisture” in the material to enable it to be defibrated in a pressure tank, given as 30-45%, and thus that there is not sufficient moisture for defibration at lower moisture levels. In NO 320971/EP 1776440 it is  
10 indicated that even with a relative moisture content of 30-45% according to said invention, as against the conventional 45-65%, there is still sufficient residual moisture for defibration by pressure reduction. It has therefore been assumed in the art that excessively low moisture content, i.e. below 30 %, does not provide a steam explosion of sufficient force.

15

Furthermore, it has been observed that the friction between the material and the escape pipe of the reactor increases at lower moisture levels, and practical experience has shown that during trial runs with materials drier than 30% there were problems emptying the reactors at plants.

20

Moreover, according to the prior art two drying steps have been used, both one before and one after steam explosion, to ensure that the distribution of moisture in the material as a result of condensation after discharge is sufficiently even for pelletization.

25

In the temperature ranges used in the methods above, there starts after a short time a certain hydrolysis of the organic material and a loss of dry matter that is undesirable, as the material hydrolyzed, and thus the energy content thereof, disappears or is oxidized either in after-drying or during the heating in the pelletization process. With the prior art methods, this dry matter loss is of several percent.

30

### Summary of the invention

The term “lignin containing material” should be understood as any material containing  
35 lignin which may be used in the invention, such as lignocellulosic materials, wood comprising materials, for example wood, bamboo, bagasse, straw, or grass. The lignin containing material may be in any suitable and processable form, such as in the form of

powder, dust, sawdust, chips, splinters, chippings, shavings, cuttings or similar particles.

According to the invention there is thus provided a method for the production of pellets  
5 or briquettes from lignin containing material, characterized by comprising the steps of:

- (a) passing the material, if it has a relative moisture content of more than about 30%, alternatively more than about 20% by weight, to a drying step and drying it to a relative moisture content of about 0-30%, alternatively about 0-20% by weight;
- 10 (b) passing the material, optionally via an intermediate storage step, to a heat treatment step and heating the material to about 180-235°C by injecting steam into a reactor;
- (c) maintaining the material in the reactor at the temperature reached for a sufficient time to soften the material and release lignin;
- 15 (d) reducing the pressure in the reactor in at least one step; and
- (e) pelletizing or briquetting the treated material.

Preferred embodiments of the method are set forth in the dependent claims, wherein one aspect relates to a method wherein the material is chosen from the group comprising:  
20 lignocellulosic material, wood comprising material, wood, bamboo, bagasse, straw, or grass. The material may also be chosen from group comprising: dust, saw dust, chips, splinters, coarse particles, chippings, shavings or cuttings.

In another aspect the invention concerns a method the steam injected into the reactor is  
25 superheated unsaturated steam, which further reduces the moisture of the material during the heat treatment, such as in the range of about 1-5 percent units, about 4-5 percent units and alternatively about 5 percent units of relative moisture of the material. The super heated unsaturated steam is for example injected to the reactor at about 350 °C and about 20 bars.

30 Possibly, the treated material may in a step (d2) also be emptied between the steps (d) and (e), from the reactor and received in a receiving tank or cyclone where the steam is separated from the material, so that as little condensate from the steam as possible is brought along as moisture further in the process or product. Further, the treated material  
35 may be mixed with additional treated or non-treated lignin containing material, in a step (d3) between step (d) and (e), preferably after the step (d2).

The material may in one embodiment be dried to a relative moisture content of about 5-15 % by weight, alternatively about 2-12% by weight before it passes to the reactor step (b). The retention time in the reactor may be within the range of about 10 seconds to 2 hour, about 30 seconds to 60 minutes, about 1-30 minutes, about 1-20 minutes, about 1-15 minutes and alternatively about 1-12 minutes.

In one embodiment the last pressure reduction of the reactor takes place suddenly by steam explosion so that the material is defibrated, while in another embodiment the depressurization of the reactor takes place slowly without steam explosion.

10

The material may be coarse particles, such as cellulose chips, such as with a length of about 25 mm. The material may also be finely divided before the reactor step, such as in the form of dust or sawdust or more finely divided material, such as with a length of less than about 3 mm.

15

Possibly, the admixed lignin containing material, has a moisture content of less than about 18% by weight and/or a typical particle size of less than about 2 mm.

In another aspect the invention concerns a method as above, wherein the method comprises an additional step of:

20

- (f) passing the pellets or briquettes to a cooler, through which air is passed for a controlled cooling of the pellets or briquettes, whereby the volume of fines is reduced.

In another aspect, the invention concerns pellets or briquettes which are produced as described over. The pellets or briquettes may contain a relative moisture content of about 5% by weight or less, or about 2% by weight or less and possibly have an energy content of about 5.0 MWh/tonne or more, or about 5.2 MWh/tonne or more.

30

#### Drying

35

The material that is to be used may be pre-dried, or have a relative moisture content of less than 30%, or less than 20% by weight, and thus not require drying. If the moisture is above 30%, or above 20% the material is dried as a step in the process itself. The material that is fed into the reactor thus has a substantially lower moisture content than has previously been used in the prior art. The present invention discloses a moisture content after drying of about 0-30%, alternatively about 0-20%, as against 30-45% in the prior art, thereby

overcoming some major objections still in existence in the art as explained introductory. The reduced moisture in the material results in lower steam consumption in the reactor, which gives lower production costs. The relative moisture content of the material entering the reactor is preferably in the range of about 5-15 % by weight, or about 2-12% by weight.

By drying the material down to a range according to the invention, there will be so little condensation that the problems of unevenness in the moisture distribution in relation to pelletization mentioned above are eliminated. Thus, drying can be carried out in one step (only prior to steam explosion) instead of in two steps as in the prior art (which comprises drying prior to steam explosion and drying before the material passes into the pellet press), which gives substantially lower investment costs than if two drying steps are used as earlier.

In order to reduce the moisture in the final product it is possible to dry the processed material further down after steam explosion, which primarily is current if the moisture content in the reactor is in the upper half of the interval of 0-30 % in mass.

Some drying may occur by injecting superheated (unsaturated) steam into the reactor, instead of dry saturated steam, such as for example after step (d) of the method above. This will result in dry material evaporating until the steam has been saturated, and that the moisture in the material after processing in the reactor is lower than if only saturated steam had been injected.

#### Heat treatment

By limiting the temperature range for the treatment to about 180-235 °C, as compared to the known ranges of 200-300 °C, undesirable reactions in the material that occur above 235 °C are also avoided, whilst remaining within operationally optimal temperatures in relation to energy consumption and especially production of steam.

The retention time in the reactor is advantageously about 1-12 minutes.

#### Pressure reduction

The reduction of pressure in the reactor takes place either:

(1) in that the last pressure reduction takes place suddenly, thereby obtaining a steam explosion in which the material is defibrated and lignin is released; or

(2) by a gradual reduction of pressure where this reduction per se does not result in defibration of the material, but wherein lignin is nonetheless released because the material has been heated for a sufficient length of time at a temperature range as mentioned above, about 180-235<sup>0</sup>C.

Method (2) is most appropriate when the material is relatively finely divided prior to treatment in the reactor (as e.g., sawdust with a typical length of less than 3 mm, or even more finely divided material), whereas method (1) is preferable when there are coarser particles (as e.g., cellulose chips, with a typical length of about 25 mm). This is due to the fact that with method (1), there is no need for mechanical fine grinding after the treatment in a reactor even though the raw materials are of the size of cellulose chips. However, if method (2) is used, the raw materials should be more finely divided than cellulose chips if the material is to be able to pass directly to pelletization without any further mechanical grinding.

Although the defibration that takes place in method (2) is less substantial than in the prior art, by using a material with lower residual moisture content, it is still sufficient for pelletization.

If the material is sufficiently finely divided beforehand, a sufficiently good result is obtained with method (1) by carrying out such a gradual pressure reduction in the reactor that there is no steam explosion, only a heat treatment of the material with steam in the reactor.

Defibration by steam explosion is just one of the parameters that are of primary importance in rendering the material suitable for pelletization. Tests show that an increase in temperature and in particular in retention time not only makes it easier to defibrate material by steam explosion, but also makes the material softer and gives more released lignin even without steam explosion, which thus renders the material more suitable for pelletization.



The design of the reactor and equipment associated therewith permits discharge when the material has low moisture content. It is quite possible to equip the reactor so that it can be emptied even without a sudden reduction in pressure (steam explosion) in the last step.

5

Pelletization - briquetting

Lastly, the treated material is pelletized, optionally after it has been mixed with other lignin containing material, for example, non-steam exploded lignin containing material. The admixed lignin containing material advantageously has a moisture content no higher than 18% by weight and a typical particle size no greater than 2 mm. Alternatively, the treated material may be briquetted instead of pelletized in a briquette press.

10

By using the present invention, the early and major reduction in moisture results in the heat-induced hydrolysis of the organic material starting later and being weaker than in the known methods. Thus, the present invention reduces the loss of dry matter that is a problem in the prior art.

15

Today, normal moisture in pellets is about 8-10%, and in practice there are no pellets with moisture content below 5%. This is due to the fact that for pelletization without the lignin in the material being released, a certain moisture content is essentially required. By means of the present invention, pellets or briquettes can be obtained with a moisture content of 2% and lower which have the same good binding properties as other known pellets prepared from steam-exploded wood.

20

25

Today's pellets with a moisture content of 8% have an energy content of 4.8 MWh/tonne whilst pellets or briquettes obtained in the present invention with a 2% moisture content have an energy content of 5.2 MWh/tonne, and at 5% moisture, the energy content is 5.0 MWh/tonne. This is a major advantage in connection with transport and storage, and also that higher output can be obtained in combustion plants as a result of a higher concentration of energy in the combustion chamber.

30

The invention also results in a number of advantages compared with mechanical production of wood pellets and briquettes. The advantages over the mechanical process for the production of pellets reside in higher quality and higher capacity. Higher quality consists in the treated pulp having binding properties which far exceed the previously obtained pulps and the improved binding properties of the pellets lead to a lower

35

volume of fines (dust), and a better cohesion. Higher capacity of the pellet presses or briquette press, with the same electricity consumption, is obtained because the pulp in the present invention has a softer consistency and is easier to pelletize than mechanically finely ground wood, and the bulk weight of the pellets or briquettes can also be increased without increasing the consumption of electricity.

A further major advantage compared with pellets and briquettes produced by mechanical production is that pellets prepared according to the invention are virtually non-hygroscopic. Mechanically produced pellets and briquettes absorb moisture so easily that they must be stored and handled in dry conditions. If they come into contact with water, they will lose their form and revert to a form of wood powder or sawdust. The pellets and briquettes according to the invention, on the other hand, can be handled and stored without contact with water or moisture being a problem; they retain their shape and only absorb water to a slight degree, and only after a long time. This means in practical terms, inter alia, that where wood pellets and/or briquettes are used as a supplementary fuel in a coal combustion plant, with pellets and briquettes of the present invention it is possible to use the same storage and transport facilities those already present for coal. With mechanically produced pellets, on the other hand, separate facilities must be provided to ensure dry handling during storage and transport. For the pellet plants, the present invention also means that the storage facilities can be made far more cheaply than today.

The present invention thus provides an improved method that obtains an improved product as disclosed above. The method provided according to the invention can be accommodated to existing pellet or briquette plants which today use neither steam explosion nor elevated temperature treatment with steam for pelletization.

### **Detailed description of the invention**

30

A description of example embodiments follow below, which are not meant to limit the scope of the invention.

### Drawings

35

Fig. 1 shows a graph where temperature is plotted against time for two separate processing courses.

Examples of embodiments

The raw materials may be any kind of lignin containing material. Raw materials that have not been dried artificially or naturally normally have a relative moisture content of about 45-55% by weight, whilst naturally dried raw materials have a typical relative  
5 moisture content of about 15-35% by weight, or even about 28-35% by weight.

An advantageous method according to the invention comprises the following steps:

10 (a) Raw materials with a relative moisture content of more than about 30%, alternatively more than about 20% by weight are dried to a relative moisture content of about 0-30%, alternatively about 0-20% by weight. This is done typically as direct drying in a drum dryer into which flue gases are injected, but other drying methods may also be used.

15 (b) The raw materials are then passed from the drying step directly, or optionally after intermediate storage, to a reactor in which the raw materials are heat-treated, optionally steam-exploded. This takes place in that after the raw materials have been introduced into the reactor, the filling valve for chips is  
20 closed, and steam is injected into the reactor until the temperature has reached about 180-235°C, and at a pressure of for example about 20 bar.

Normally, saturated aqueous steam is used in the drying step at a temperature in the range given above. However, in the present invention, it has been  
25 found that if the steam supplied to the reactor is superheated (unsaturated) steam, the moisture of the material may be further reduced during the heat treatment itself.

(c) This temperature is subsequently maintained for about 1-12 minutes.

30 (d) A pressure reduction is then carried out in one or more steps. In the last pressure reduction, the pressure is reduced to atmospheric pressure, and the treated material is discharged from the reactor.

35 The material has then been transformed into a pulp, in the case of wood as raw materials into a brown-coloured "wood pulp", with a substantially softer consistency than the ingoing raw material. If the last pressure reduction takes

place as a sudden drop in pressure, this is a steam explosion in the traditional sense. If the last pressure reduction takes place gradually and cautiously, there is no steam explosion that defibrates the material, but the material is nevertheless given a softer consistency and a characteristic brown colour. The brown colour is due to the fact that the lignin has been softened and partly released through retention in the temperature range mentioned above.

(d2) Possibly, the pulp that is discharged from the reactor may be received in a receiving tank or cyclone where the steam is separated from the pulp, so that minimum condensate from the steam remains as moisture further in the process or product.

(d3) The material is then optionally mixed with dried raw materials that have been ground down in an impact mill to a particle size suitable for pelletization. The optionally admixed lignin containing material advantageously has a moisture content that is no higher than 18% by weight and a typical particle size no larger than 2 mm. This mixed pulp or optionally unmixed material is then passed to pelletization or briquetting.

(e) The material (the mixed mass or possibly the unmixed material) is subsequently passed to pellet and/or briquetting presses, where the pelletization typically takes place in that the material is pressed through cylindrical holes in a ring die and the compressed material that comes out is cut into pellets, or the material is alternatively pressed into briquettes in a briquetting press.

(f) The newly produced pellets or briquettes, which have a high temperature and a soft consistency, are then preferably passed to a cooler, which is a vessel through which air is passed, so that a controlled cooling of the pellets is obtained, and at the same time the volume of the fines is reduced. Finished pellets /briquettes then exit the cooler.

In the present invention, the process in the reactor can be optimized in a number of ways. The basic relations are that:

- If the temperature of the reactor is increased, the retention time can be reduced; if the temperature is lowered, the retention time must be increased. By increasing the temperature, capacity can be increased through a shorter retention time.
- The lower the ingoing moisture, the lower the steam consumption, and the lower the energy consumption and the shorter the filling time for steam, thus the higher the production capacity.
- If particle size is increased, the temperature and/or the retention time must be increased.

The optimum treatment conditions are different for different types of lignin containing material, even for different types of wood. There are also local variations (inter alia, on the basis of growth conditions) within the individual material types, which means that the optimization of the process conditions give best results when done for the individual plant.

In Fig. 1, the principles of the relation or dependency between processing parameters are illustrated for two different ways of processing a certain material, in this case temperature and retention time at a certain pressure. Curve A "Light processing" illustrates the temperature and time relation for processing a certain material in a "mild" manner. For all the combination of temperatures and retention times on Curve A, the degree of processing will be about the same, i.e. a mild processing, which may be optimal in some markets, such as for pellet ovens. Correspondingly, Curve B "Intense processing" represents parameters that provide a more vigorous treatment which for a given retention time always is treated at a higher temperature compared to a "mild processing", and which may be optimal for other markets, such as bulk supplies which involves more severe handling. Pellets/briquettes treated in a "severe processing" have a higher bulk weight than pellets/briquettes treated by a "light processing".

If the particle size of the raw material is increased, the curves will move outward in the diagram, i.e. away from origo, in order to provide the same degree of processing.

For different types of raw materials, the change in retention time and temperature will generally follow the same type of shape or course of the curves. However, the displacement will be different for each type of material, and sub type of material, such

as for different types of wood. The curve will have the same structure, but a different position and somewhat different course in the diagram. For example, there are important differences in the curves for soft and hard wood, and even a certain difference between spruce/fir and pine. The curve for pine will for example be further away from origo than  
5 the curve for spruce/fir for the same degree of processing.

Hence the processing parameter of a retention time of about 1-12 minutes is only a preferred interval, based on desired processing time in a plant and the degree of processing, in relation to a practical temperature and pressure ranges. In most cases, it  
10 will be preferable to remain within these ranges, but in some cases other conditions outside of these ranges may be preferable. Such ranges may for example be within about 10 seconds to 2 hour, or about 30 seconds to 60 minutes, about 1-30 minutes, about 1-20 minutes or about 1-15 minutes and any ranges in between. For example, a small producer may prefer to work at the lowest possible pressure and temperature  
15 ranges for steam, so that less costly steam equipment may be used, and security and competence for operators are less strict, although for most producers, higher temperatures would be more profitable. The longer retention time needed for working at low temperature/pressure reduces the production capacity. Still, this may be preferable for example if supply of steam is limited. Also, longer retention time at low  
20 temperatures, such as at about 180°C may also be used for a certain time only, such as during start-up or ending of the process run, as processing starts at about 180°C and continues as long as the temperature is kept above 180°C.

The advantages over a mechanical process for production of pellets and briquettes  
25 reside in higher quality and higher capacity. Higher quality consists in the steam-exploded/heat-treated pulp having natural binding properties that far exceed the binding properties the wood has when it is compressed mechanically without any preceding steam explosion. This is due to the fact that cellulose, hemicellulose and lignin are to some extent released. The best binding properties are obtained when pelletizing steam-  
30 exploded pulp without any addition of non-steam exploded pulp. The increase in binding properties for pellets produced from a mixture of mechanically finely ground lignin containing material, such as wood, and damp-exploded/heat-treated pulp of the present invention compared with pellets/briquettes produced from purely mechanically finely ground wood is, however, so great that it gives a sufficient increase in quality in  
35 relation to large parts of the pellets/briquette market. The improved binding properties lead to a lower volume of fines, and better cohesion. This is one of the most central quality criteria for pellets. Higher capacity in the pellet and briquette presses, with the

same electricity consumption, is obtained because steam-exploded pulp has a softer consistency and can more readily be pelletized than mechanically finely ground wood, and it is also possible to increase the bulk weight of the pellets and briquettes without increasing the consumption of electricity.

5

The optimal mixture ratio of steam-exploded/heat treated pulp to other lignin containing materials, such as wood, in pellets/briquettes depends upon a number of factors, which are often different for each individual plant. The type of lignin containing material, such as wood, used is a major factor, as is the availability of raw materials at the plant in  
10 general. The relation between electricity costs and the thermal energy used in the reactor process is also important because the portion that is mixed with the steam-exploded pulp is finely ground in an impact mill in advance, which requires electrical energy. It is also of major importance which market the products, pellets or briquettes are destined for, as the relative importance of the increase in quality may be different. For some  
15 markets, it will be optimal that nothing is admixed, i.e., that only steam-exploded pulp and/or only heat-treated pulp is used, whilst for other markets an admixture of about 20-25% may be optimal. In other cases, only about 10-20% by weight of steam-exploded/heat-treated pulp and about 80-90% by weight of non-steam exploded lignin containing material, such as wood, may be used.

20

The consistency of the steam-exploded /heat-treated pulp also has an effect on the quality of the pellets/briquettes, and thus on what mixture ratios are optimal. The particle size for the raw materials/the material upon entering the reactor is decisive for whether the pulp becomes a brown powder, as when ingoing raw material is sawdust, or  
25 whether the pulp has a consistency more like dry shredded peat, with longer fibre bundles that are soft. Pellets/briquettes from the last type of pulp provide even better properties as regards a smaller quantity of fines than steam-exploded pulp from sawdust. To make this type of pulp, the ingoing raw material in the reactor must be far larger than the typical particle size for sawdust, and some types of lignin containing  
30 materials are better suited than others for producing such pulp.

In the present method, the moisture in the raw materials when they enter the reactor to be steam-exploded/heat-treated is considerably lower (about 0-30%, alternatively about 0-20% by weight) than in the prior art method (30 - 45% by weight). This means that  
35 the steam consumption in the reactor that is necessary to heat the material to the given temperature is lower, which results in lower production costs. Lower steam requirements also give a shorter filling time and pressure reduction time for steam,

which in turn gives a greater number of portions or batches per time unit. This means higher production capacity in a reactor of a given size.

In the present invention there is preferably just one optional drying step, independent of the initial moisture and the pulp does not need to be dried before it passes to pelletization. However, the mass may possibly be dried according to the present invention by using superheated (unsaturated) steam in the reactor during the heat treatment, instead of saturated steam which is common for such heat treatment.

By using unsaturated overheated steam in the reactor during heat treatment, water will be drawn out of the material and the temperature of the atmosphere in the reactor is reduced to obtain equilibrium conditions. In this manner, superheated steam may be supplied at conditions and amounts that result in the same temperature range (about 180-235 °C) in the reactor for the heat treatment that is necessary for the processing as described earlier. Such conditions may for example be unsaturated aqueous steam of about 350 °C, at about 20 bars. In real life, a reduction in moisture in the raw material is in this way obtained of typically up to 5 percent units. That is to say that material loaded into the reactor with relative moisture of about 20% might be reduced to about 15%, and likewise that if material with relative moisture of about 12% is fed to the reactor the moisture of this material might be reduced down to about 7%, by injecting superheated steam into the reactor.

Hence, the present invention makes it possible to obtain extremely dry material for pelleting or briquetting, and thereby extremely dry pellets or briquettes. Alternatively, the technique of superheated steam for reduction of water of the material in the reactor is used to reduce the temperature or the time of the drying step before the heat treatment in order to obtain the same product with the same properties as described earlier. Depending on whether more, less or the same amount of energy is supplied with the overheated steam, different results and products may be obtained.

30

It is also possible to dry the material more in the reactors, but then the reactors need to be used as driers in addition to the heat treatment, which would extent the retention time in the reactors, and thereby reduce the capacity for processing.

The advantage of only performing one drying step, and possibly obtaining further reduction of water content in the material by superheated steam in the reactor, is that two classic drying steps as in prior art are avoided, wherein saturated steam and two

35



dryers is used, which means important higher investment costs than if one drying step is used as in the present invention. When the same drying capacity is to be divided on two classic driers, the investment costs are moreover substantially higher than for one dryer which has the collected capacity alone. According to the present invention the capacity  
5 of the one dryer may possibly also be reduced if additional drying is performed in the reactor as mentioned above, or the total treatment time may be reduced.

In the present invention, the pressure reduction may alternatively be carried out so that a steam explosion is obtained, or the pressure reduction can be carried out so gradually  
10 that there is no steam explosion. The choice between these methods is made on the basis of whether the material is so finely divided beforehand that it is not necessary to defibrate it by steam explosion.

The method that is provided according to the present invention can be accommodated to  
15 existing pellet/briquette plants that are based on mechanical fine grinding and pelletization or briquetting without other investments than in reactor(s), steam production, receiving the pulp and handling the steam that is separated from the pulp, and optional mixing with mechanically finely ground lignin containing material, for example wood. If the whole feedstock is to be steam-exploded, a reactor can be put in  
20 the production line instead of fine grinding (typically with an impact mill). If a mixture is to be made, some of the raw materials may optionally be moved after the dryer to a reactor and some to mechanical fine grinding, - typically in that larger particles are taken to the reactor.

25 If the two-step drying method from the prior art is to be accommodated to existing plants, an additional dryer must be invested in for drying of the pulp after steam explosion, i.e., before the pulp is pelletized or briquetted. In practice, the same dryer could not be used for raw materials that are to be steam-exploded and the portion of the raw materials that is optionally to be finely ground mechanically, since the requirement  
30 of relative moisture content after the drying is very different in the two cases. As such, the method according to the invention is preferable to implement practically, logistically and economically in existing plants.

P a t e n t   c l a i m s .

1.

5 A method for the production of pellets or briquettes from lignin containing material in the form of processable particles, c h a r a c t e r i z e d i n that it comprises the steps of:

- 10 (a) passing the material, if it has a relative moisture content of more than about 30%, alternatively more than about 20% by weight, to a drying step and drying it to a relative moisture content of about 0-30%, alternatively about 0-20 % by weight;
- (b) passing the material, optionally via an intermediate storage step, to a heat treatment step and heating the material to about 180-235°C by injecting steam into a reactor;
- 15 (c) maintaining the material in the reactor at the temperature reached for a sufficient time to soften the material and release lignin;
- (d) reducing the pressure in the reactor in at least one step; and
- (e) pelletizing or briquetting the treated material.

2.

20 A method according to claim 1, wherein the material is chosen from the group comprising: lignocellulosic material, wood comprising material, wood, bamboo, bagasse, straw, or grass.

3.

25 A method according to any one of the preceding claims, wherein the material is in a form chosen from the group comprising: dust, saw dust, chips, splinters, coarse particles, chippings, shavings or cuttings.

4.

30 A method according to claim 3, wherein the material is in the form of coarse particles, such as cellulose chips, such as with a length of about 25 mm.

5.

35 A method according to any one of the preceding claims, wherein the steam injected into the reactor is superheated unsaturated steam, such as at about 350 °C and about 20 bar, which further reduces the moisture of the material during the heat treatment, such as in

the range of about 1-5 percent units, or about 4-5 percent units and alternatively about 5 percent units of relative moisture of the material.

6.

- 5 A method according to any one of the preceding claims, wherein the treated material in a step (d2), between the steps (d) and (e), is emptied from the reactor and received in a receiving tank or cyclone where the steam is separated from the material, so that as little condensate from the steam as possible is brought along as moisture further in the process or product.

10

7.

A method according to any one of the preceding claims, wherein the treated material is mixed with lignin containing material in a step (d3), between step (d) and (e), preferably after the optional step (d2).

15

8.

A method according to any one of the preceding claims, wherein the material is dried to a relative moisture content of about 5-15% by weight, or about 2-12% by weight before it passes to the reactor step (b).

20

9.

A method according to any one of the preceding claims, wherein the retention time in the reactor is within the range of about 10 seconds to 2 hour, about 30 seconds to 60 minutes, about 1-30 minutes, about 1-20 minutes, about 1-15 minutes and alternatively  
25 about 1-12 minutes.

25

10.

A method according to any one of the preceding claims, wherein the last pressure reduction of the reactor takes place suddenly by steam explosion so that the material is  
30 defibrated.

30

11.

A method according to any one of the claims 1-9, wherein the pressure reduction of the reactor takes place slowly without steam explosion.

12.

A method according to any one of the preceding claims, wherein the material is finely  
5 divided before the reactor step, such as in the form of dust or sawdust, such as with a  
length of less than about 3 mm.

13.

A method according to any one of the claims 7 -12, wherein the admixed material has a  
10 moisture content of less than about 18% by weight and/or a typical particle size of less  
than about 2 mm.

14.

A method according to any one of the preceding claims, wherein the method comprises  
15 an additional step of:

(f) passing the pellets or briquettes to a cooler, through which air is passed for a  
controlled cooling of the pellets or briquettes, whereby the volume of fines is  
reduced.

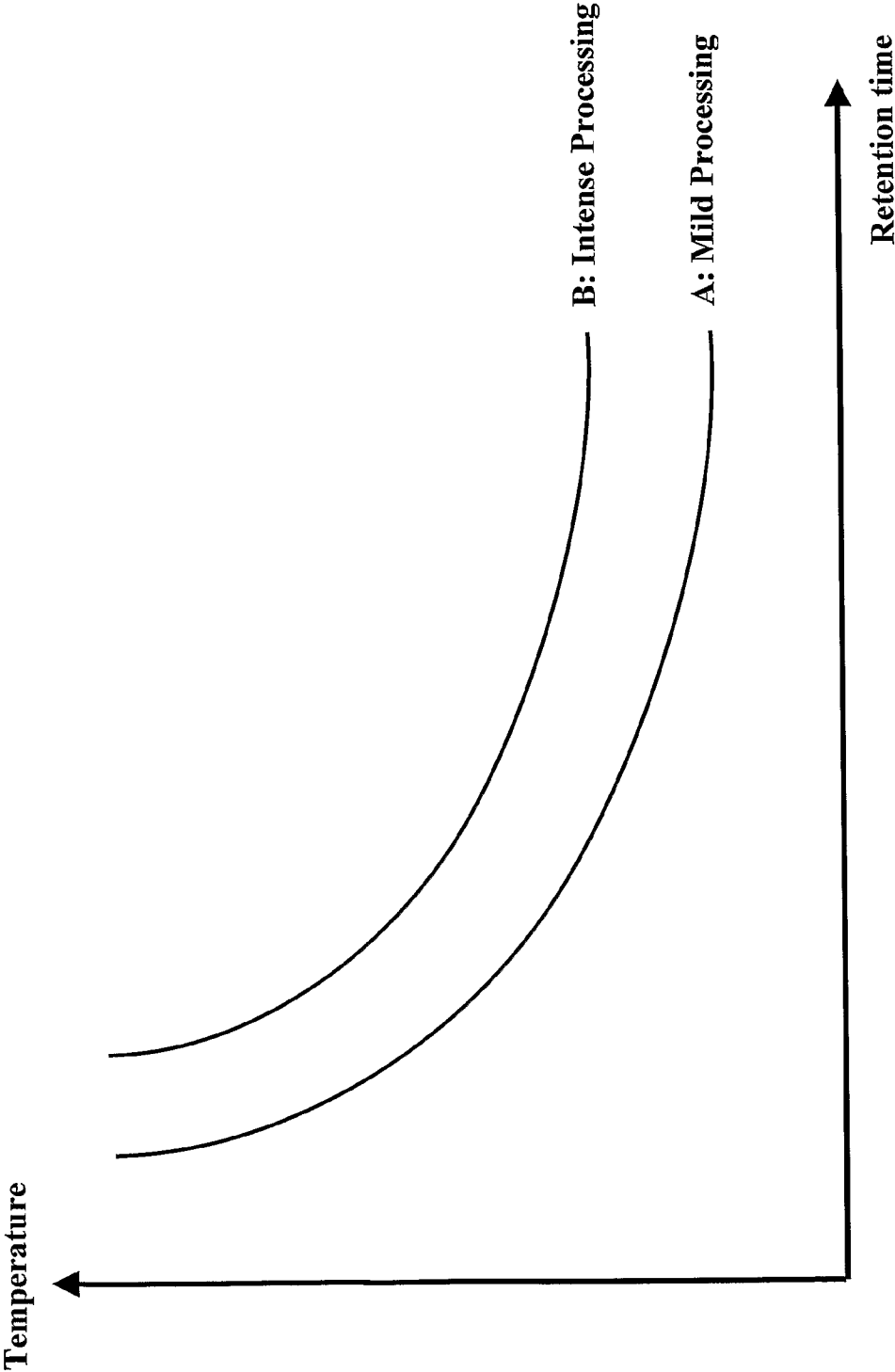
20 15.

Pellets or briquettes, c h a r a c t e r i z e d i n that they are  
produced according to any one of claims 1-14, and which may have a relative moisture  
content of about 5% by weight or less, alternatively about 2% by weight or less.

25 16.

Pellets or briquettes according to claim 15, which have an energy content of about 5.0  
MWh/tonne or more, preferably about 5.2 MWh/tonne or more.

FIG. 1



# INTERNATIONAL SEARCH REPORT

International application No  
PCT/NO2009/000346

**A. CLASSIFICATION OF SUBJECT MATTER**  
INV. C10L5/44 C10L9/08

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
C10L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, INSPEC

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2006/006863 A (NORSK PELLETS VESTMARKA AS [NO]; BRUSLETTO RUNE [NO]) 19 January 2006 (2006-01-19) claims 1,3 page 4, line 29 - page 5, line 29	1-14
X	& NO 320 971 B1 (ARBAFLAME TECHNOLOGY AS [NO]) 20 February 2006 (2006-02-20) cited in the application the whole document	1-14
X	WO 2006/122405 A (EVERGREEN BIOFUELS INC [CA]; DRISDELLE MARK [CA]; LAPOINTE CLAUDE [CA]) 23 November 2006 (2006-11-23) page 5, lines 21-28 page 7, lines 10-15 page 5, lines 15-19 page 9, line 24 - page 10, line 12 claims 1-4,11 ----- -/-	15,16

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

\* Special categories of cited documents:

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*&\* document member of the same patent family

Date of the actual completion of the international search

14 January 2010

Date of mailing of the international search report

27/01/2010

Name and mailing address of the ISA/  
European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040,  
Fax: (+31-70) 340-3016

Authorized officer

Greß, Tobias

# INTERNATIONAL SEARCH REPORT

International application No

PCT/N02009/000346

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CA 1 141 376 A1 (LONG EDWARD A DE) 15 February 1983 (1983-02-15) the whole document	1-16
A	----- CULLIS, IAN FRANK: "The effect of steam explosion pretreatment parameters on softwood delignification efficiency" THESIS - UNIVERSITY OF BRITISH COLUMBIA, [Online] 11 February 2003 (2003-02-11), XP002563067 Vancouver, Canada Retrieved from the Internet: URL:https://circle.ubc.ca/bitstream/handle /2429/13929/ubc_2003-0135.pdf?sequence=1> [retrieved on 2010-01-12] pages 64-79	1-16
A	----- US 4 828 573 A (JELKS JAMES W [US]) 9 May 1989 (1989-05-09) claims 1,6 column 2, lines 21-45 figure 1	1-16
A	----- US 2005/156347 A1 (HAAS GERNOT V [DE] ET AL VON HAAS GERNOT [DE] ET AL) 21 July 2005 (2005-07-21) claim 1 page 2, paragraph 17-22	1-16
A	----- US 4 502 227 A (JANUSCH ALOIS [AT]) 5 March 1985 (1985-03-05) cited in the application claim 1 -----	1-16

# INTERNATIONAL SEARCH REPORT

International application No

PCT/N02009/000346

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 2006006863	A	19-01-2006	AT 398164 T CA 2573046 A1 CN 101010417 A DK 1776440 T3 EP 1776440 A1 NO 320971 B1 RU 2369631 C2 US 2009223119 A1	15-07-2008 19-01-2006 01-08-2007 06-10-2008 25-04-2007 20-02-2006 10-10-2009 10-09-2009
NO 320971	B1	20-02-2006	AT 398164 T CA 2573046 A1 CN 101010417 A DK 1776440 T3 EP 1776440 A1 WO 2006006863 A1 RU 2369631 C2 US 2009223119 A1	15-07-2008 19-01-2006 01-08-2007 06-10-2008 25-04-2007 19-01-2006 10-10-2009 10-09-2009
WO 2006122405	A	23-11-2006	CA 2652303 A1 CN 101218329 A EP 1888722 A1 US 2008172933 A1	23-11-2006 09-07-2008 20-02-2008 24-07-2008
CA 1141376	A1	15-02-1983	NONE	
US 4828573	A	09-05-1989	NONE	
US 2005156347	A1	21-07-2005	CA 2467606 A1 DE 10322228 A1 EP 1479511 A2	18-11-2004 09-12-2004 24-11-2004
US 4502227	A	05-03-1985	AT 374491 B AU 557078 B2 AU 1028283 A CA 1194442 A1 DD 209473 A5 DE 3248372 A1 GB 2115003 A IN 156113 A1 JP 58171486 A PL 240169 A1 YU 9783 A1	25-04-1984 04-12-1986 28-07-1983 01-10-1985 09-05-1984 28-07-1983 01-09-1983 18-05-1985 08-10-1983 29-08-1983 31-10-1985