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Eucalyptus Wood from Congo's Industrial Plantations is a Promising Raw Material for the Production of Paper Pulp

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Abstract

Scientific Novelty and Innovation: the chemical composition, physical properties and structure by analogy of the wood of the core and duramen (heart or central wood) and the wood as a whole are determined at three (3) levels, depending on the height of the trunk of *Eucalyptus* at the age of 6 years, grown in plantations in the Republic of Congo, have revealed and demonstrated.

Practical Value: It has been shown that for the production of cellulose from soda ash (NaOH), wood can be used along the entire trunk of Eucalyptus at the age of 6 years. The technological regimes of baking with soda have been refined and developed. This wood, impregnated in the aqueous medium and in the system of isobutyl alcohol – water, including in the presence of anthraquinone. A reliable and economically feasible ecological principle for the production of cellulose soda from Eucalyptus wood in the isobutyl alcohol – water system has been proposed. The possibility of anthraquinone regeneration (up to 60%) when using the Water - Isobutyl Alcohol system for soda cooking has been established.

Purpose and Objectives of the Study: The objective of the study is to study the characteristics of the delignification of young plantation wood by various soda-based cooking modifications and the development of scientific and environmentally sound technology for cellulose production.

In line with this, the objectives of the research included:

- The study of the anatomical structure, physical properties and chemical composition of *Eucalyptus* wood seedlings.
- Clarification (choice of diet or mode) of the method of cooking soda the soda of the young *Eucalyptus* wood.
- Development (research and development of the soda cooking regime) of the cooking method of soda in the iso butyl alcohol-water system.
- Establishment (implementation) of the delignification process of *Eucalyptus* wood during the use of various soda firing modifications.
- Explore the possibility of reusing isobutylic alcohol and anthraquinone in the soda cooking of *Eucalyptus* wood.
- Characteristics of the properties and components composing and forming the paper pulp derived from Eucalyptus wood from baking soda.
- Development of a technological master scheme for the production of cellulose to soda from *Eucalyptus* wood in the isobutyl alcohol - Water system.
- Technical and economic evaluation of the method of producing cellulose from *Eucalyptus* wood cooked or treated in the isobutyl alcohol - Water system.

This work is presented and illustrated on 3 figures, 2 tables and 22 literature references.

Keywords: Delignification, Wood, Anthraquinone, Yield, Black Liquor, Regim

1. Introduction

The Republic of Congo is a state of Equatorial Africa with developed forestry. In the tropical steppes of Congo, in the Pointe-Noire region, a modern plantation of clonal plantations of 2 hybrids of *Eucalyptus* wood, with an area of about 25,000 hectares, with the prospect of an extension of 100,000 hectares. In Congo, there is a project to build a plant for the production of cellulose from wood waste by the alkaline method.

Nature conservation and market competition require new approaches to the use of plantation timber for pulp production. The cooking of *Eucalyptus* by or based on NaOH - Anthraquinone is favorable and used by one of the promising alkaline methods, which increases yield while eliminating the formation of foul-smelling sulfur compounds inherent in the sulfate method… Delignification of *Eucalyptus* wood by the soda and anthraquinone method in a dismiscible liquid system can further increase the speed and selectivity of the delignification process, simplify the chemical regeneration system and significantly reduce the energy intensity of the process.

The development of science-based technology for cooking modified soda wood from a tree used for plantation cultivation will help to solve important national economic tasks of the Republic of Congo, namely the current problems of climate change and carbon sequestration, and to improve the simplify the chemical regeneration system and significantly reduce, namely the current problems of climate change and carbon sequestration, and to further improve pulp production.

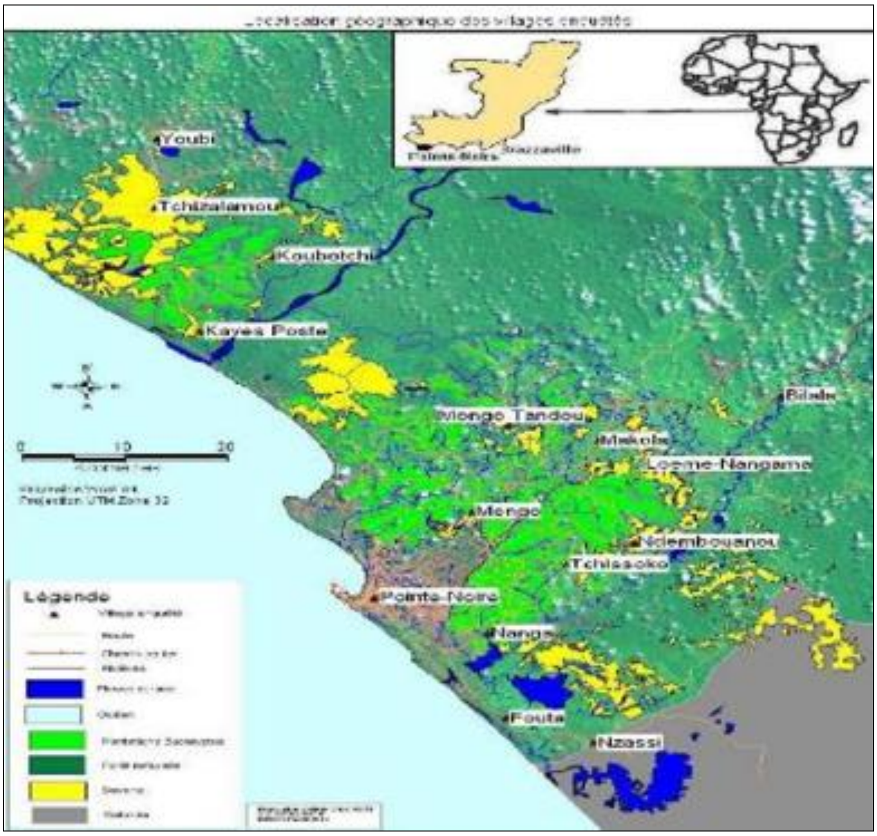

Fig 1: Map of location of *Eucalyptus* woods in the Department of Pointe Noire and Kouilou

Fig 2: Saint-Pétersbourg State Forest Technical University

2. Methodologies (Materials and Methods)

2.1 Methodology

This work was carried out at the Department of Cellulose and Pulp and Paper Production of the St. Petersburg State Technical and Forestry Academy (Russian Federation).

In the Methodological Part, the methods of analysis of cellulose wood, cooking and used (used) solutions after baking with soda in an aqueous medium and in the Isobutyl Alcohol – Water System are described, cooking methods, as well as methods for the qualitative and quantitative determination of anthraquinone content in solutions (thin-layer chromatography and UV spectroscopy).

To conduct our study well, it was essential to have the following suitable equipment: - the equipment for transforming *Eucalyptus* slices into chips or chips; washing machines, chemicals and appropriate reagents, NaOH; isobutanol and anthraquinone as well as small boiler appliances; the wood is loaded into the autoclave and/or washing machine.

3. Results

The results of the study are presented in the following experimental parts:

***-In the first part*,** the results of the study of the anatomical structure, physical properties and chemical composition of Eucalyptus wood (6 years old, hybrid of clone PF 1 obtained following the crossing of plantations E. Alba x (E. Urophylla x E. Grandis) in Congo. The wood was delivered in the form of washers with a thickness of 20 to 25 mm, selected at the rate of 3 pieces every 2 m along the height of the trunk. The washers taken according to their belonging to the base of the barrel (stump) (10 m high), the middle (24 m) and the top (7 m) of the trunk. To carry out the analyses, a sector of 20 to 25 ° was cut in each washer, divided into bran and sapwood. As a result, 3 sapwood samples and 3 heartwood samples were obtained at trunk height.

In general, the trunk contained 68% sapwood (33% end-to-end wood, 21% of half and 14% of the top of the tree(s)) and 32% of heartwood (21% end-to-end, 8% of the core and 3% of the tops of the trees).

A study of the composition and properties of wood at different levels of trunk height showed that the most important differences were involved heartwood and sapwood and that, to a lesser extent, the height of the *Eucalyptu*s stem of these applicants varied (see Table 1).

In general, it was found that in Congo, at the age of 6 years, the wood (of) young (s) of *Eucalyptus* plantations had a relatively low density (0.53 g / cm²), a sufficient length of fibers (1.9 mm) and, ranged from 13% to 17% (despite differences in core and heartwood, the chemical composition of wood at trunk height varies slightly).

-***In the Second Part***, studies were conducted to clarify the cooking method of Eucalyptus wood seedlings from Congolese plantations. The cooking was carried out in a 0.4 l battery of autoclaves heated in a glycerin bath. The consumption of sodium hydroxide Na2O units) to the wood mass of a liquid module of 4.5: 1. As a result, it was found that to obtain cellulose with a degree of delignification of 21, a yield of 45.5% and a low incomplete penetration content (0.5%), the consumption of NaOH for baking with soda of *Eucalyptus* wood would have to be 17% (in Na_2O units) to the mass of wood with a liquid modulus of 4.5: 1. consequently, it was found that to obtain cellulose with a degree of delignification of 21, a yield of 45.5% and a low incomplete penetration content (0.5%), the consumption of NaOH for baking with soda of Eucalyptus wood should be 17% (in Na2O units) for a total duration of 3 and 45 minutes (temperature rise to 170 ° C - 2 hours, cooking at 170 °C - 1 h45 minutes). The addition of up to 20% used liquor to the cooking solution has a positive influence on the delignification process of *Eucalyptus* wood and pulp production. Such an operation will reduce heat consumption for evaporation and boiling of black liquor and use a facility for the regeneration of chemicals of lower productivity. The addition of up to 20% spent (purified) liquor to the cooking liquor affects and favorably influences the delignification process of Eucalyptus wood and cellulose pulp. Such an operation will reduce the heat consumption for the evaporation of the black liquor, and for cooking as well as the use of the plant for the regeneration of chemicals of lower productivity.

-***In the third part***, she presents the results of research on the development of the *Eucalyptus* wood cooking regime in the isobutyl alcohol – water system. The cooking was carried out in a 2.5-liter autoclave with electric heating. Once the wood was loaded into the autoclave, it was treated with saturated steam at a temperature of 100 ° C for 15 minutes. Why the autoclave was filled with a solution of NaOH and the chips were soaked with this solution for 30 minutes at a temperature of 50 ° C and an overpressure of 1 MPa overpressure; Cooking at this temperature continued to the required degree of delignification. Research has revealed that cooking soda wood with eucalyptus is practically isobutyl alcohol – water having about the same total cooking time, with the boiling point of soda being in an aqueous medium, it occurs at a lower temperature (14°C lower) and reduced NaOH consumption (1.3 times less). And, with a degree of delignification (33 units), increases the overall yield of cellulose by 2.1% and the yield of sorted cellulose by 7.7% by weight of wood. This is explained by the complexity of the measures set forth in the developed firing method, and above all by the uniform impregnation of the wood with a solution of sodium hydroxide before increasing the temperature, as well as by the presence of isobutyl alcohol, which, by dissolving the extractive substances of the wood, increases its capillary system while maintaining a high concentration of sodium hydroxide.

Table 1: Characteristics of young Eucalyptus wood along the height of the trunk or barrel

Indicators	Part of the base or abutment			Central part of the barrel or middle			Upper part of the barrel or top		
	Core (Kernel)	Heartwood and Sapwood	Core + heartwood and Sapwood as a whole	Core (Kernel)	Heart wood and Sapwood	Core + wood heart and Sapwood as a whole	Core (Kermel)	Heart wood and Sapwood	Core + heart wood and Sapwood as a whole
Density, g/cm^3	-	-	0.54	-	-	0.53	-	-	0.49
Fiber length, mm	-	-	1.11	-	-	1.09	-	-	0.99
Pulp or Cellulose by Kürschner-									
Hoffer,%;	42.0	44.8	43.0	43.0	43.5	43.2	41.4	42.9	42.0
Lignin,%	30.0	26.6	27.9	32.2	29.3	30.3	31.2	28.9	29.5
Pentosanes,%	20.0	15.9	17.5	19.4	19.2	19.0	19.0	17.1	18.0
Extractive substances, %									
-Hot water	3.4	2.7	3.05	2.6	2.7	2.65	2.5	3.2	2.75
- Solution of NaOH at 1%	14.1	11.1	12.8	14.1	10.1	12.1	10.7	15.2	12.9
- Acétone	0.39	0.61	0.50	0.46	0.40	0.43	0.51	0.40	0.45
Ashes	0.23	0.37	0.30	0.18	0.35	0.26	0.25	0.28	0.26

The introduction of anthraquinone in the natural cooking of *Eucalyptus* wood in the isobutyl alcohol – water system had a positive effect on the speed and selectivity of the delignification process and, in general, further increased the advantages of this method.

-***In Part IV***, the peculiarities of the delignification process of *Eucalyptus* wood were studied using various modifications of soda cooking. As a result of the research, it was found that the process of delignification of soda in the aquatic environment can be divided into 3 stages: - The first is the rise in temperature up to 120 ° C - accompanied by intensive absorption of sodium hydroxide by wood with a slight transition of lignin in your solution - The second temperature increase from 120 ° C to 170 ° C and 60 minutes of exposure to this temperature is characterized by the transfer of most of the lignin (80%), and pentosans (67%) to the cooking liquor with a low consumption of sodium hydroxide; - Third stage - exposure to temperature from 170 ° C from 60 minutes to 120 minutes - the remaining lignin in cellulose dissolves slowly…

The yield of sorted cellulose has increased, the amount of incomplete penetration and acid-soluble lignin has decreased. At the same time, the process has retained a distinct character in three stages. In the isobutyl alcohol system, the delignification process takes place in two stages: rapid delignification begins at the same time as the final temperature (150 ° C) and lasts 30-45 minutes at this temperature and slows down after 45 minutes…In the case of anthraquinone addition, the yield of sorted cellulose increased, the amount of incomplete penetration and acid-soluble lignin decreased. At the same time, the process has retained a distinct character in three stages. In the isobutyl alcohol system, the delignification process takes place in two stages: rapid delignification begins at the same time as the final temperature (150 ° C) and lasts 30 to 45 minutes at the final temperature. The presence of anthraquinone during natural cooking in the isobutyl alcohol – water system accelerates delignification, but does not change the character of the process. As can be seen in Fig 3 despite a low final temperature 156 ° C, against 170 ° C) and a lower consumption of sodium hydroxide for cooking (14% against 17% of Na_2O by weight of wood), delignification of *Eucalyptus* wood in the isobutyl alcohol system – water with a solution. The same amount of lignin has a significantly shorter duration than when soda is boiling in an aqueous medium. The delignification process, both in the aqueous medium and in the isobutyl alcohol – water system, moreover, in the presence of anthraquinone, the delignification process of *Eucalyptus* wood occurs more deeply, that is, at a lower content of lignin in cellulose.

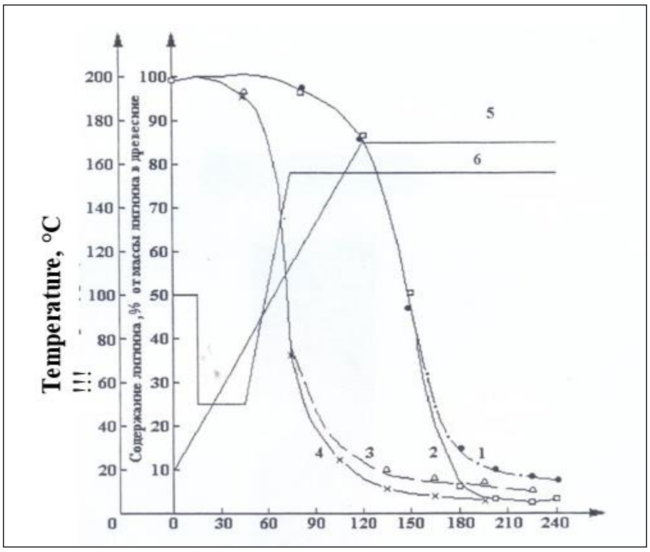

Fig 3: Evolution of soda melting process (1); cooking with soda and anthraquinone (2); cooking soda in the isobutyl alcohol system - water (3); and boiling soda in the isobutyl alcohol-water system in the presence of anthraquinone (4); Diet at 5 temperatures of boiling soda in an aqueous medium; 6 - temperature mode of boiling soda in isobutyl

Cooking time, min alcohol-water system.

As shown in Fig 4, the lowest selectivity of the delignification process occurs when baking soda in an aqueous medium (curve 1) and the highest - when using anthraquinone - corresponds When cooking *Eucalyptus* wood soda in an aqueous medium, cellulose fibers begin to separate from the chips with a lower degree of delignification than in the case of cooking in the isobutylwater alcohol system. The presence of anthraquinone contributes to the early appearance of cellulose fibers. This indicates or testifies that the process of delignification into eucalyptus wood soda in an aqueous medium is more developed on the surface of the chips, and gradually moves into the sheep, while under the conditions of cooking in the isobutyl alcohol - water system, it occurs more evenly along the thickness of the chips, This provides a high yield of sorted cellulose. As shown in Fig 4, when the first 15% of lignin is removed in an aqueous medium, almost 40% of the pentosans contained in *Eucalyptus* wood pass into the cooking solution, while under the conditions of the isobutyl alcohol – water system, about 15% of the pentosans dissolve during the same period. As the delignification deepens during habitual cooking of soda, the amount of pentosans transferred to the solution increases rapidly, and when 85% of the lignin is removed, reaches 74%. At the end of cooking, there is an increase in the content of pentosans in cellulose due to the reverse sorption of their cooking solution.

In the presence of anthraquinone for soda cooking, it offers the best preservation of pentosans in wood residues (see curves 1 and 2). However, the process of reverse sorption of the pentosans of the cooking solution is in this case less developed.

In the case of cooking in the isobutyl alcohol – water system, the pentosan content of wood residues is preserved throughout the delignification process according to a much larger equation than during cooking in an aqueous medium, but the phenomenon of cellular sorption of pentosans by cellulose fibers has not been observed. The difference in paste yields for the studied modifications of soda cooking is mainly due to differences in pentosans content.

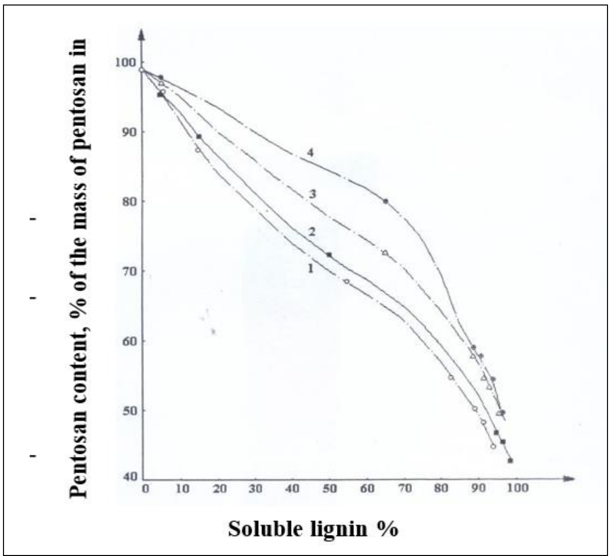

Fig 4: Evolution of total wood residue production as a function of the amount of lignin dissolved during baking with soda ash and anthraquinone (2); cooking soda in the isobutyl alcohol system-water (3); and boiling soda in the isobutyl alcohol-water system in the presence of anthraquinone (4)

-***In the fifth part***, the possibility of repeated use of alcohol - isobutyl during baking soda is studied. In this regard, a series of 9 firings was carried out in the same mode, in which the isobutyl alcohol used or spent was used in a closed cooking cycle. For the first cooking, fresh alcohol was used. For further cooking, a mixture of isobutyl alcohol, selected with purges (48%), separated from the cooking liquid (36%) and fresh alcohol (16% by volume) was used. It has been established that the reuse of spent isobutyl alcohol without distillation and purification accelerates the delignification of *Eucalyptus* wood, contributes to its uniform discoloration with little change in the production of sorted cellulose.

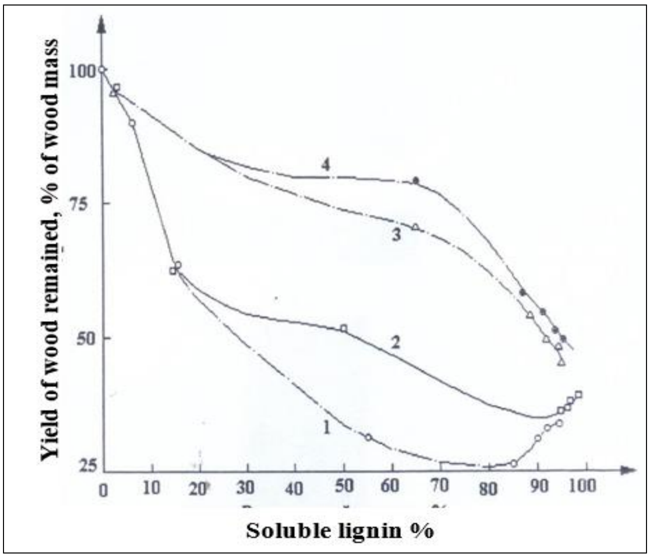

Fig 5: Modification of the wood residue content of pentosans as a function of the amount of dissolved lignin from Eucalyptus wood used during baking with soda ash (1), cooking of anthraquinone soda (2); cooking soda in the isobutyl alcohol system - water (3); and boiling soda in the Isobutyl alcohol-water - System in the presence of anthraquinone (4)

The dry substance content in the alcohol layer of the spent liquid gradually increased, but was overall low and reached 8.3 g / l at the 9th cooking. The use of spent isobutyl alcohol in a closed cycle allows us to naturally simplify the system of its regeneration.

In Part Six, the possibility of reusing anthraquinone under soda cooking conditions in the isobutyl alcohol-water system was studied. As a result of the studies carried out by TLX method, it was found that isobutyl alcohol, separated from the blowing liquid of the purge, and thus the isobutyl alcohol, selected and collected in the cooking liquid, contains anthraquinone. These experiments confirmed not only anthraquinone's ability to dissolve in isobutyl alcohol, but also its ability to be distilled (sublimated) with isobutanol vapors during purging.

In a series of cooking eucalyptus wood with soda – anthraquinone in the isobutyl alcohol system – water, it was found that reusing spent (exhausted) isobutyl alcohol for cooking without distillation or cleaning ensures a return to cooking greater than half of the previous anthraquinone cooking. With the introduction of the missing amount of anthraquinone and the use of Isobutyl Alcohol in closed cycle, very favorable conditions are created for wood degeneration and cellulose production with high quality indicators. Thus, another important advantage of baking wood with soda in the Isobutyl Alcohol System and Water gives the possibility of anthraquinone regeneration.

In the seventh part, the paper-forming properties of Eucalyptus cellulose soda were studied. As a result of the studies carried out, it was found that at equal lignin content, cellulose samples obtained by making soda leather in the isobutyl alcohol – water system were ground faster up to a standard grinding degree (60 ° SR), namely. It has higher breaking lengths and burst strength, but a lower tensile strength than soda paste obtained in an aqueous medium.

Table 2: Mechanical strength indicators for cellulose samples

Type of cooking	Baking with soda	Baking soda-anthraquinone	Baking soda in the alcohol system isobutyl-water	Baking soda in the Alcohol system isobutyl-water and anthraquinone
Grinding time, min.	45	40	27	19
Fracture length, m Resistance to:	6150	6750	6750	6900
▪ Pressure, KPa	240	270	255	275
▪ Tear, mN	650	790	640	700
▪ Breakage, in units of folding	675	1050	380	490

As delignification deepens (a decrease in lignin content of 8-2%), all indicators of mechanical strength in soda pulp samples decrease regardless of the curing change. Table 2 shows the mechanical strength indicators for cellulose samples from various soda firings (lignin content of 3.6-3.8%).

4. Conclusion and Recommendations

1. *Eucalyptus* wood, 6 years old and grown in plantations in Congo, has a relatively low density (0.53 g / cm3), sufficient fiber length (1.09 mm) and, despite slight differences in the composition of heartwood and sapwood. The composition of the wood as a whole along the height of the trunk changes only slightly. This allows us to recommend the use of the entire keg for cooking.
2. Designed or developed cooking regimes for young *Eucalyptus* wood in the aqueous medium and in the isobutyl alcohol - water system have been developed. The introduction into baking of up to 20% used black liquor accelerates the delignification process of the wood and increases the yield.
3. Intrinsic cooking regimes of young *Eucalyptus* wood in aqueous media and in the isobutyl alcohol – water system have been developed. The introduction of boiling soda up to 20% used black liquor accelerates the wood delignification process and increases the pulp yield. The presence of anthraquinone during cooking based on *Eucalyptus* wood soda, both in the aqueous medium and in the isobutyl alcohol – water system has a positive effect on the speed and selectivity of the delignification process of this wood.
4. The main regularities of delignification of young *Eucalyptus* wood under conditions of developed soda cooking regimes have been identified. In the aqueous medium, the delignification of wood is carried out in three stages: slow - during ascent up to 170 ° C; rapid – – for 1 h of exposure to a temperature of 170 ° C and much with a continuation of exposure to 170 ° C. In the isobutyl alcohol – water system, the delignification process has a two-stage character: the rapid phase begins simultaneously with the rise in final temperature (156 ° C), and the very slow phase after 45 minutes of cooking to the final temperature. The presence of anthraquinone in both cases accelerates delignification, but does not change the character of the process.
5. It has been established that the selectivity of the delignification process of *Eucalyptus* wood increases with the transition from baking soda in an aqueous medium to the same cooking in the presence of anthraquinone, then cooking in the isobutyl alcohol – water system and that the greatest selectivity is manifested when cooking soda in the isobutyl alcohol – water system with the introduction of anthraquinone.
6. It has been established that sodium cellulose from *Eucalyptus* wood obtained using the isobutyl alcohol system – water is easier to grind, and has higher indicators of breaking length and burst strength, but a lower tensile strength than sodium cellulose obtained in an aqueous medium, in the system Isobutyl alcohol – Water, facilitates grinding and increases its mechanical strength.
7. A diet has been developed for baking with soda of *Eucalyptus* young woods in the isobutyl alcohol system - water using isobutyl alcohol and anthraquinone, from cooking to cooking, according to the maximum closed cycle. There is evidence that anthraquinone can be sublimated and consumed after cooking with isobutyl alcohol from the condensate from the final purge (discharge) at the end of cooking, as well as subsequent cooking with isobutyl alcohol separated from the residual liquid.
8. It has been established that the soda baking pulp of *Eucalyptus* wood obtained using the isobutyl alcohol – water system is easier to grind and has a longer breaking length and burst strength, but a lower tensile strength than baking soda obtained in an aqueous medium and, In the alcohol – isobutyl alcohol system, facilitates the grinding of cellulose and improves its mechanical strength.
9. The feasibility study showed that the production of pulp from young *Eucalyptus* wood by this method is economically more advantageous than soda ash production. This allows us to fight climate change as well as greenhouse gases (GHGs).
   Nature conservation and market competition require new approaches to the use of plantation timber for pulp and other products. Cooking *Eucalyptus* by or based on NaOH - Anthraquinone is favorable and used by one of the promising alkaline methods, which increases yield while eliminating the formation of foul-smelling sulfur compounds inherent in the sulphate method. This allows us to fight climate change and reduce greenhouse gases (GHGs). In addition, this cooking method can also increase the speed and selectivity of the delignification process, simplify the chemical regeneration system and significantly reduce the energy intensity of the process.
   The development of science-based technology for baking soda wood (NaOH) through various modifications from a plantation tree will help solve important national economic tasks of the Republic of

Congo and improve pulp production.

5. References

1. Pazukhina G, Ewossaka A. Plantation growing of *Eucalyptus* wood perspective raw material for pulp production- 11th International Symp. On cellulose Chemistry and Technology. Iassy - Romania, September. 1995; 12-14:67.
2. Ewossaka A, Pazukhina GA. Le Bois d'*Eucalyptus* est une matière première prometteuse pour la production de pâte à papier. -Résumés des rapports. 2e réunion "Chimie forestière et Synthèse organique", Syktyvkar, 1996, p77.
3. Пазухина ГА. Ступенчатые методы производства целлюлозы. - М. :Лесная промышленность, 1990, 216С.
4. Непенин ЮН, Мялицина ЛО, Жалина ВА. Варка целлюлозы с различными органическими растворителями /Обзор. информ., ВНИПИЭИ Леспром. – М. 1988; 8:С40.
5. Салах ЭХХ, Маршак АБ, Чудаков МИ. Исследование некоторых видов эвкалипта для производства целлюлозы // Химия древ. 1980; 2:С25-27.
6. Дейнеко ИП, Никандров АВВ. лияние температуры на скорость делигнификации древесины в присутствии антрахинона // Лесной журнал. 1988; 1:С84-87.
7. Sierra-Alvares R, Tjeerdsma B. Organosoly pulping of juvenile poplar wood. 8th Int. Symp. Wood and Pulp. Chem., Helsinki, June 6-9, 1995, Proc.,2.Jyväskylä, 1995, 207-211.
8. Shukla C, Guha SRD, Nedi JS. Studies on carbohydrates from eucalyptus grandis. Constitution of main non cellulosic – polysaccharide. – Indian Pulp and Paper. 1973; 27(2a):20-23.
9. Sigh MM. Pulping of eucalyptus grandis with nitric acid. Indian Pulp and Paper. 1973; 28(6):3-5.
10. Stewart ChM. Complexes of glucuronoxylan, uronic acid and lignin in in eucaliptus woods - Cellul. Chem. and Technol. 1973; 7(6):691-701.
11. Nikitin VM, Obolenskaya AV, Schegolev VP. Chimie du bois et de la cellulose. - M. : Industrie forestière, 1978, 368C.
12. Obolenskaya AV, Yelnitskva ZP, Leonovich AA. Travaux de laboratoire sur la chimie du bois - M. : Écologie, 1991, 320p.
13. Pazukhina GA. Procédés pas à pas pour la production de cellulose. – M. : Industrie forestière, 1990, 216p.
14. Pazukhina GA. Teploukhova MV, Khakimova FKh. Délignification de la cellulose organo-solvant par l'acide pyrétique ou pérétique et le peroxyde d'hydrogène dans les premiers stades du blanchiment / Edition des Universités ou inter-universitaires. Journal forestier. 1994; 5-6:p36.
15. Nepenin YN. Technologie de la cellulose. T. 2. -M: Foresterie, 1990, p224.
16. Nepenin YN, Myalitsina LO, Zhalina VA. Pâte à papier avec divers solvants organiques / Revue d'inform. Pâte à papier, papier - M. 1984; 8C:29.
17. Nepenin YN, Myalitsina LO, Zhalina VA. Cuisson de la cellulose avec divers solvants organiques / Revue. Information., VNIPIEI Lesprom. - M. 1988; 8:p40.
18. Debesay SKH. Obtention de cellulose à partir de bois d'*Eucalyptus* par la méthode de la Potasse - cuisson au sulfite. La Thèse de doctorat en sciences techniques. - L, 1986, 155p.
19. Deineko IP, Nikandrov AV. Effet de la température sur le taux de délignification du bois en présence d'anthraquinone // Forest Journal. 1988; 1C:84 -87.
20. Deineko IP, Nikandrov AB, Shevchenko SM. Activité catholique dans la cuisson alcaline des produits de l'interaction de l'anthraquinone avec des composants du bois // Chimie du bois. 1984; 2:113-114.
21. République du Congo. Comité national de lutte contre la pauvreté. Document de Stratégie et de réduction de la pauvreté (DSRP). Projet DSRP final, Janvier 2007, Forêts.
22. Ministère de l'Economie Forestière et de l'Environnement (MEFE), Normes Nationale d'Inventaire et d'Aménagement des Ressources forestières en République du Congo, Brazzaville, Décembre 2005, 71P.