Physical-chemical characterization pellets produced from mixtures 50/50 bituminous coal/waste-wood

Caracterización físico-química de pellets producidos a partir de mezclas 50/50 carbón bituminoso/madera residual

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Abstract

Biofuels demand characterization and reliable processes to ensure proper manufacturing process for end users in order to use them safely. About 4.42 % of biofuels that are marketed globally are presented as agglomerates or pellets. Considering that Colombia is a country with high coal reserves and, as an agricultural country, produces large amounts of organic waste, our results show that the mixture of these two products has benefits in terms of energy and combustion, facilitating burning and decreasing the emissions of both particulate material and sulfur-containing gases. This article presents the results of the characterization as international pellets produced in the Laboratory for Renewable Energy of the National University of Colombia for 50/50 % mixture of wood and anthracite. The physicochemical parameters evaluation was made using the standard Austrian ONORM M7135, in order to evaluate each of the items established. Also test results and analysis of the characterization of these mixtures and their calorific value according to ASTM D5865 11a and the impact resistance according to ASTM D440-86 are shown. Additionally the advantages and disadvantages are discussed from an environmental point of view related to the use of biofuels agglomerates.

Keywords: Pellets; biomass; calorific value; characterization of biomass.

Introduction

The sources of biomass of the forest sector and the timber industry in Colombia, generate 1.9 mega tons of residues per year (UPME, 2003), that can be used for the production of energy on having been submitted to a process of compaction (to produce pellets) to increase its energetic density; thus energetic use is more efficient in such thermal processes as the direct combustion or the gasification

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(Carrazco, 2008). The residues of the natural forests and of the cultivated ones (energetic plantations), are renewable resources, which generally, are left in the area cultivated as waste, without bearing in mind that in modern processes of changeover (gasification, pelleted) it is possible to generate heat or electrical large-scale energy, focused towards the substitution of fossil fuels.

The residues of the natural forests are an important source of biomass that nowadays is little exploited. It is consider that, of every tree extracted for the timber production, only takes advantage commercial of a percentage near to 20 %. It is estimated that 40 % is left in the field in the branches and roots, in spite of the fact that the energetic potential is very much strong as 1 appears in the Table; the other 40 % remains in the process of sawmill in the shape of splinters, bark and sawdust (BUN-CA, 2002), that turned into energy would produce 268 MWh/year (UPME, 2003).

Table 1. Energetic distribution of a tree

Part of the tree	Distribution in %
Branches	6-22
Leaves	1-6
Trunk	74-86
Bark	3-16
Roots	21-33

Source: BUN-CA, 2002.

Other one of the considered residues are those of the big plantations of trees or plants cultivated with the specific end of producing wood and in some cases energy. For that purpose there are selected trees or plants of fast growth and under maintenance, which usually are cultivated in lands of low productive value. The harvest period changes between the three and ten years, the energetic potential of these residues is approximately 383 MWh/year (BUN-CA, 2002). This represents the utilization of the resources of the forest way and timber, to produce heat or electrical energy. The technology is based on thermal reactions of decomposition and of oxidation according to the quantity of oxygen contributed in the same ones (Bilbao, 2009), these are:

Combustion

Application of high temperatures with stoichiometric ratio complete or with excess of oxygen where there is liberated carbon dioxide, water, ashes and heat.

Gasification/pyrolysis

Application of high temperatures (between 500 °C and 800 °C) (Ramirez *et al.*, 2011), with quantities of oxygen lower than the necessary ones to offer a stoichiometric ratio, without allowing complete combustion, liberating in the monoxide process and carbon dioxide, hydrocarbons, hydrogen and methane.

The consumption of pellets in Europe is increasing rapidly (Weary *et al.*, 2012). As 1 is observed in the Figure, the projection of the consumption of pellets in Europe until the year 2010 increased 2.5 times, which increased the participation of the imports of 12 % of the production in the year 2006 to 34 % in 2010.

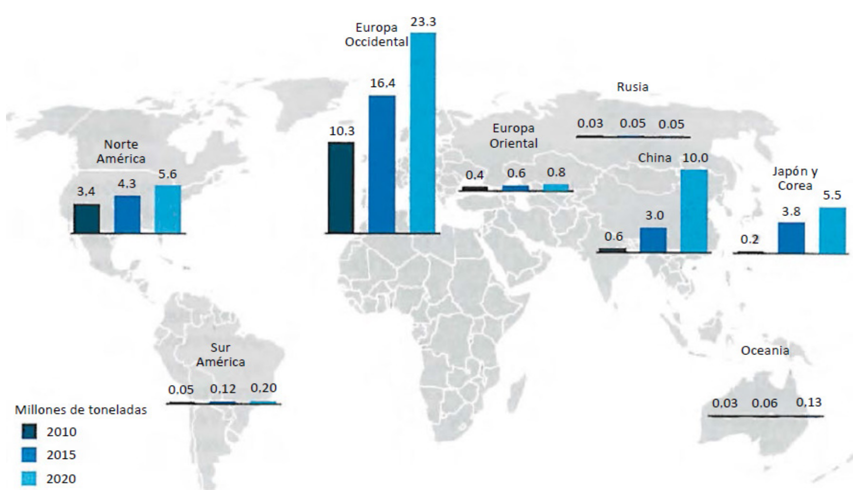

Figure 1. Projection of the world consumption of pellets.
Source: Cochi, 2011

In aim of producing pellets of mixtures coal / wood, is to take advantage the energetic properties of the coal and the properties of binders of the wood, to obtain a compressed product (pellet) with major energetic density that the pellets of 100 % wood and minor pollutant emission that if it was burning 100 % coal.

Material y Methods

Production of pellets

In this investigation of characteristics of the biomass to produce solid fuels specifically pellets of mixtures with mineral coal, the characterization of the mixture appeared 50/50 coal / wood and the study of the procedure that regulate the parameters of production, characterization and quality.

Materials

In the manufacture of the pellets of the analyzed sample there was in use sawdust of residual wood of the timber industry (carpentries of the city of Bogota) and coal anthracite of the *zone Cundiboyacence* of Colombia. To sift the coal and the sawdust, there used the sieve model Rx-29 of brand W.S.Tyler, to have a coal grading between 600 and 850 µm. In the Figure 2 the press appears pelleted of brand Amertek model 2003 used to produce the pellets. The parameters of operation of the machine were: pressure of closings 24.6 Kg/cm^2, time of closing 15 seconds, the used mold was 19mm of diameter .

Figure 2. Pelleted Press.
Source: Laboratory of Thermal Plants and Renewable Energies. Universidad Nacional de Colombia- Headquarters of Bogotá.

Methods

The methods of production of pellets more acquaintances to pressure are: flat counterfoil, counterfoil to annul, extrusion screw and hydraulic press.

In the production of the pellets a hydraulic press was in use with a counterfoil of 19 mm, and the following materials: sawdust of wood sifted and selected in minor size to 850 µm. In the selection of the coal several sieves were in use, and for the sample of the grading it took as a point of item understood between 850 µm and 600 µm, to obtain the first results, and from inferring these on the grading that gives the best conditions for the manufacture of pellets of mixtures coal / wood.

Determined the conditions of the sample were mixed in a proportion 50/50 in weight (30 grams of sawdust and 30 grams of coal). Obtained the mixture three samples took place of pellets to test for triplicate; later the corresponding analysis was done.

In the characterization of the pellets there took as a reference the Norm ONORM M7135, which established the criteria of quality evaluation as for production, transport, storage and final consumption; it is one of the most ancient, of major rigor and compline in this field.

During the characterization there decided the physical and chemical properties of the pellets (Obernberger and Thek, 2003), evaluating the following articles:

Dimensions: It was determined the dimension of the pellets of agreement to the norm ÖNORM M 7135 for measure of length and the diameter of the sample.

Bulk density: The volume and the weight of a pellet measured up to determine the bulk density, in agreement to the norm ÖNORM M7135; for the weight it was used a scale calibrated with a precision of 0,001 gram, and for the volume was used a test tube.

Water volume: The water content was calculated weighing the sample of fuel (near 100 g), before and after drying off to 105 °C in agreement with the norm ÖNORM G 1074. C.H. = ((Humid Weight - dry Weight) / Humid Weight) *100 %.

Ash content: T The content of ash measured up for the loss of ignition of one sample to 550 °C in agreement to the norm ASTM D-5142-09.

Calorific value: The heating power of the sample was calculated in a calorimetric bomb in agreement to the norm ASTM D-5865-04; this test was realized in the laboratories of the Geological Colombian Service.

Impact resistance: The samples were left to fall 4 times from an equal height to 1,85 m to a metal plate. The weight retained by the samples is considered to be the resistance of the samples of agreement to the NORM ASTM D440-86.

Resistance to water: The endurance test to the water was applied following the procedure of the American Society of Agricultural Engineers, ASAE according to the authors recount (Lindley and Vossoughi, 1989), since in the moment no normalized test exists. Every sample submerged in water to 27 ºC during 30 seconds, the value of the resistance was taken as the percentage in weight of water absorbed by the sample.

Resistance to the compression or resistance to the crushing: It is the maximum load that a pellet can support before cracking or breaking. The resistance to the compression of the densified products was decided for the test of diametrical compression. The pellets placed between two flat plates, an increase of load was applied to a constant rate of 5 N/seg until the pellet of test collapsed for cracking or breaking. The load of break is read in the curve of registered tension - deformation, which is the resistance to the compression, and is reported as the force or the maximum effort that resists the densified product; this procedure was realized applying the norm ASTM C39-96.

Instant analysis: In this set of tests it was determined the percentages of dampness, ashes, volatile matter and fixed carbon (It Saws *et al.*, 2011).

Elemental analysis: It is a technique that provides the total content of carbon, hydrogen, nitrogen and sulfur of a sample of solid or liquid materials (It Saws *et al.*, 2011). The technology was based on the complete and instantaneous oxidation of the sample by means of a combustion by pure oxygen to an approximate temperature of 1000 ºC.

Results and discussion

The pellets produced in the experiment appear in the Figure 3; although the dimensions are over those of the Austrian norm ÖNORM M7135, they were in use for evaluating other parameters of the norm.

In the Table 2 is presented the comparison between the parameters of the Austrian norm ÖNORM M7135 with the results of the tests of the pellets.

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It is analyzed and discuss the results obtained of the tests applied to the pellets of agreement to the methods before mentioned:

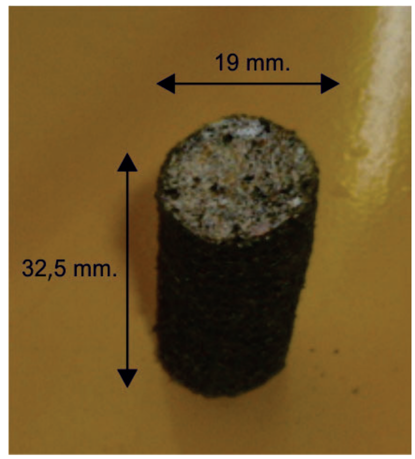

Figure 3. Pellet of mixture coal / wood.
Source: The authors.

Dimensions: Comparing the results obtained with the criteria evaluated in the Austrian norm ÖNORM M7135, is immediately evident that as for the dimensions of the pellets it is not fulfilled by this norm, since these should be between 6 and 10 mm, but when these parameters compare with the European norm CEN/TS 14961 specifications and properties for the pellets (CEN/TS IN 14961-2, 2012), the Swedish norm SS 18 71 20 specification of three classes of pellets depending on the size and the quantity of ashes that they generate and the Italian norm CTI R04/05 that establishes the quality parameters of the pellets of biomass with energetic ends, steadies itself that the pellets objects of this investigation expire with the parameter of dimensions which must be minor or equal to 25 mm (Duca *et al.*, 2014); other parameters of these procedure are very similar, for this reason the norm is taken as a reference ÖNORM M7135 to produce and to evaluate the behavior of the pellets.

Bulk density: As for the bulk density of the pellets it is fulfilled with exposed in the norm, since the obtained value was of 933.33 kg/m3; this indicated that with the mixture of wood - coal it was fulfilled by the values of the norm.

A low density has a negative effect on the density of energy and therefore in the costs of transport and the capacity of storage so much for the producer and the final user of pellets. The results are shown in the Table 2.

Water content: In the dampness obtained in the test (10.28) it appeared lightly over the value of exposed in the norm (<10), this depended basically on the quality of the wood and on the used coal. The water content had a negative influence on the clear heating power, the efficiency of the combustion and the temperature of the combustion.

Table 2. Comparability of parameters of the Austrian norm ÖNORM

Test	Unit	Ö-Norm M7135	Results of the tests
Diameter	mm	4-10	19
Length	mm	<5*d	32.5
Weight	g	-	8.6
Heating Power	MJ/kg	18	24.2
Resistance to the graze	%	<2.3	-
Density	Kg/m^3	>600	933.3
Content of ash	%	<0.5	2.9
Content of water	%	<10	10.28
Content of sulfur	%	<0.04	0.4
Content of fixed carbon	%	-	48.12
Content of chlorine	%	<0.02	-
Content of nitrogen	%	<0.03	1.12
Content of Hydrogen	%	-	5.1
Binder	%	<2	0
Resistance to the impact	%	-	38.4
Resistance to the water	%	-	85.0
Resistance to the compression	N	-	4896

M7135 against results of the tests to the pellets of mixtures wood / coal. **Source:** The Authors.

Content of ash: The content of ash of the sample of the mixture was of 2.90 in percentage of mass, well above the value of the norms (<0.5); this value meets increased by the content of coal ash that according to the study of the coal (Rock, 2011), is high for the different existing types of mineral coal in the nature; all the analyzed samples presented contents of ash over 4.5 %. It must be born in mind that between major it is the quantity of ash in the coal or solid, minor fuel will be the heat obtained, increasing the problems of managing and disposition of the big quantities of ash produced (Uribe, 1986).

Heating power: The heating power obtained of the sample was 24.2 MJ/Kg, superior to values obtained of samples of wood without being mixed by another material. This is important for the final use of biofuel since it allows to obtain great quantity of energy in few quantities of fuel (density of energy).

Resistance to the impact: The average initial weight of the pellets was of 8.6 g; after the fourth fall the registered weight was of 3.3 g. The loss of weight after the falls is evident, with this it is shown that the material is not the sufficiently compact to resist the operations of transport, storage and final use without disintegrating or reducing to smaller sizes, which would be inconvenient for industrial uses for the managing of thin or material particulate product of the des-agglomeration of the pellets (Kruggel et al., 2012).

Resistance to the water: The average percentage in weight of water absorbed by the samples was 15 %, then the resistance to the water of the sample is 85 %; this value is in the low admissible limit (Lindley and Vossoughi, 1989), since on having been exposed to the dampness these would absorb water of environment and would lose great part of the physical properties that characterize them. In addition the dampness affects negatively the process of combustion making it slower, with loss of the efficiency and causing premature hurts in the systems of supply.

Resistance to the compression: The endurance test to the compression simulates the effort of compression due to the weight of the pellets of above on them of below during the storage in containers or silos, and the crushing of the pellets in a carrier of screw in supply of automatic systems of heating or boilers. The results of the test gave maximum supported effort of 4896 N, a maximum effort of 14.06 N/mm2 with a maximum displacement of 3,62 mm. e 3,62 mm.

Instant analysis: The content of the fixed carbon of the sample was of 48.12 in percentage of mass; although there is no parameter of comparison in the norm, this one is obtained of the content of ashes reduces to the total of the carbon the volatile material and the dampness in percentage of mass. The higher it is this value, the more solid material will be had to be burnt; it is important to calculate the efficiency in equipments of combustion (Severs *et al.,* 2007).

Elemental analysis: The content of sulfur of the analyzed sample was 0.40 % of mass; this value is superior enough to the regulated one for the norm of agglomerated fuels that must be 0.04 % in percentage of mass; this value is affected by the mixture of the wood by the coal. If it is observed, in the mixture with the coal the total content of sulfur diminishes in the fuel, if 100 % is compared with the use of the mineral coal. This improves the conditions of the combustion from the environmental point of view on having reduced SOx's emission. The content of nitrogen of the sample was of 1.12 in percentage of mass, compared with the value of reference of the Austrian norm (<0.03); it is top for the high place contained of nitrogen of the coal. The results of the analysis are affected by the contents of the same compounds of the coal (Jiancheng et al., 2014), since it is known that the wood contains under content of pollutants. A high place contained of nitrogen is harmful since NOx emissions would take place, of great worry for the environmental measures that are taking in the evaluation of new fuels.

Conclusions

The analyzed sample corresponded a proportion 50/50 coal anthracite / wood, with a coal grading between 600 and 850 µm; referring that the test of impact and other were done by triplicate, the results show low resistance to the compression (38.4 %), which can be associated with the size of grain of the coal.

The mixture of coal / wood for the formation of an agglomerated fuel, has advantages as for the increase of the heating power as volumetric unit and the bulk density. The fact of using coals with high place contained of sulfur, ashes and nitrogen increases the admissible value of agreement to the norm done for biomasses; nevertheless it reduces the content of sulfur, ash and nitrogen with regard to if alone coal was used. The control of these parameters performs great importance for the environmental impact and for the managing of the products of the combustion.

According to the parameters evaluated in the norm the following ones were fulfilled: length (32.5 mm), weigh (8.6 gm), heating power (24.2 MJ/Kg), bulk density (933.3 Kg/m3) and resistance to the water (85 %), with values moderately superior to the norm, this indicates that the production of pellets of mixtures coal/wood is possible.

The use of mixtures of lignocellulosic biomasses since they are the residues of poor wood and coals, these are coals with high place contained of sulfur and ash, allow to combine the positive properties of both materials; using the good capacity of agglomeration and under content of sulfur of the biomasses and good heating power of the coal. These mixtures can promote the industrial use of coals that nowadays are not commercialized in Colombia due to high places contained of sulfur and ash.

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