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CALORIFIC VALUES FROM GREEK SPRUCE RESIDUES & BIOENERGY POTENTIALS VIA PELLET PRODUCTION

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Abstract:
This paper presents the results of an experimental research performed with Greek Spruce residues (Picea Abies), originating from Pindos mountain. A bomb calorimeter was used to determine the calorific value from the Spruce's leaves (needles), branches and bark. This was to identify the potential to use waste by-products for pellet production. The outputs of the readings of these three residues, taking under consideration the moisture content as well as the ash content after burning the samples are promising showing that biomass waste can be transformed into an alternative mean of heating fuel.

Key words: *biomass; bomb calorimeter; calorific values; waste to energy.*

INTRODUCTION

Fossil fuels are the foremost contributors to carbon emissions. The last two decades, efforts to divert the origin of fuels have shifted the fuel chain, amongst other renewables, to biomass using wood and agricultural residues. Biomass is a promising, sustainable, and eco-friendly supplier of heat energy, improving also the carbon footprint (Demirbas 2006). Currently, wood residues offer the means for modern energy plants (Hoogwijk et al. 2003) providing heat as well as generating electricity.

In the Greek energy market, particularly the last decade, the demand for alternative and cheaper heat energy way-outs have been increased dramatically. 25,4% of the Greek land is covered by forests (Greek Land Registry 2019) which makes the country reach enough to address a viable, resource wise, fuel substitute. The most significant forest products in Greece are Spruce and Pine, thus this study was focus on one of them. Biomass is estimated to lead the energy supply in general, especially due to the positive carbon footprint. This is the main reason where efforts to exploit as more as possible of the forest's resources are undergoing. Currently, during the tree harvesting period, apart from the main products there is no strategy or utilisation of the left overs. These by-products (branches, leaves, bark etc.) are left in the forest, causing often major issues (risk of fire) especially during the hot summer period.

A number of efforts have been undertaken to use such forest byproducts giving them added value often as new market products. One of those was the construction of insulation boards (Ninikas et al. 2019). Focusing on this research into identifying the capacity to utilise the wood residues as a heat energy source, is another option to upscale waste forest products.

The use of pellet as a heating mean, is growing rapidly all over Northern Europe and the Southern European countries are following this trend. The biomass burner's technology for domestic use has been simplified especially due to the automated feeding system and the supply of controlled air to the burner. The cost for such an installation deliver a competitive heating solution. The advantages of the pellets are such to surmount other fuels, especially wood. The transportation and the storage are easy due to the product uniformity size wise maintaining the storage cost predicted and low. The energy output, compared to wood, is stable and higher, the ash is at predefined levels. A major setback often is the market demand which has to be covered, as more as possible, from local resources in order to maintain in low levels the overall cost. This is why identifying ways to use local waste forest products is expected to increase the available pellet volume.

OBJECTIVE

The key objective of this experimental research was to identify ways to exploit in which extend wood byproducts may be alternatively used as a high capacity heat energy source, rather than being discharged with an additional cost. The Spruce's leftovers calorific value analysis is the principal task which was undertaken to identify if those can be transformed into high valued alternative heat fuel.

This is estimated to reduce the wasted resources, keeping safe and clean the forests following the harvesting period and also providing a simultaneous additional financial benefit to the local economy. This process is expected to play a key role further in the transition from fossil fuels to renewable biomass from wood residues.

MATERIAL, METHOD, EQUIPMENT

At the Greek mountain Pindos during the harvesting period in Summer 2018, leftovers from Spruce were collected and studied to identify their calorific values and heat capacity. The samples were collected from the ground at an elevation height of 1180m. Three different batches were compiled: leaves (needles), small branches, and bark (Fig. 1).

Fig. 1.
Spruce residues. From left to right. A: Leaves (needls), B: Branches, C: Bark.

The samples were set agreeing to the general analysis test sample (CEN/TS 14780, 2005). For the moisture content determination, a technical specification was applied (CEN/TS 14774-3, 2004). The moisture content was initially measured for the samples A, B and C at 18,4%, 19,1% and 18,8% respectively. Following an oven-dried at 105^{o}C, where the samples reached an average moisture content of 8%, a hammer mill (Fig. 2) was used (Wiley mill, Culatti type MFC, 110-160W, Mot KG 80-60) for grinding the three samples (Fig. 3).

Fig. 2.
Wiley mill used for grinding the residues.

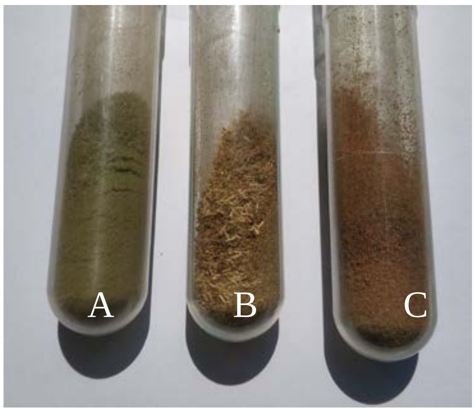

Fig. 3.
Spruce's residues after grinding.
From left to right. A: Leaves, B: Branches, C: Bark.

The ash content of the three samples was determined according to the ASTM D 3174-97 (1998). Two measurements per sample (six in total) were undertaken to acquire the mean value of each sample. One gram of each sample's powder after weighted, placed into a porcelain crucible (Fig. 4) and then into the furnace. The temperature was set to 580^{o}C (Fig. 5) and the samples remained at that temperature for four hours.

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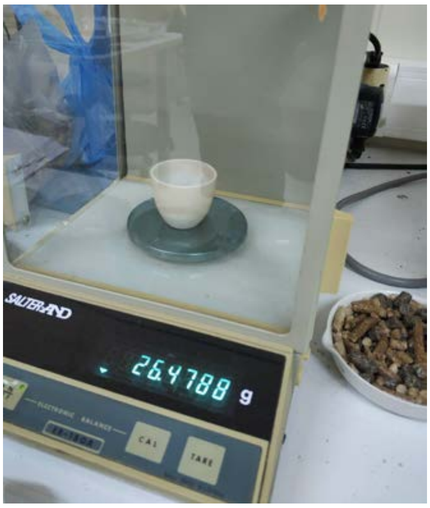

Fig. 4.
The samples positioned into the furnace.

Fig. 5.
The samples positioned into the furnace.

An oxygen bomb calorimeter (Sundy, Model SDC 311) was used to measure the carofic values of all three samples following the CEN/TS 14918:2005 method in an atmosphere of O_2 that affirms the complete sample's combustion.

Fig. 4.
Having compacted the powdered sample into the capsule and attached the ignition thread.

Fig. 5.
Preparing the bomb head.

Fig. 5.
Filling the bomb with oxygen.

Fig. 6.
Final step, inserting the bomb into the apparatus.

All six samples with a weight of 1.0g (± 0.1g) were prepared acoordingly to the Standard (Figs. 3,4,5,6) and incinerated at 30 bar under pure oxygen conditions. During the inceneration, the emitted heat was transferred to the calorimeter's fluid, where the heat capacity (*C*) is specified. From the temperature difference between the initial condition and the calorimeter's fluid temperature (*Δt*) after incineration the energy which is released from the sample and the gross-heat of combustion *(PCS)* can be derived, according to Equation (1):

$$PCS = (C * \Delta t - b) / m \tag{1}$$

where: *b* is the correction factor. The sum of the released energy through incineration of the tread and the ignition wire (Q_z), plus the energy release that happens via the formation of nitrid acid (Q_n) and sulphur acid (Q_s), Equation 2.

$$b = Qz + Qn + Qs \tag{2}$$

Two values have to be taken into account. The first one is the Gross Calorific Value (GCV) which is the energy amount released after a complete combustion of a mass unit of sample (at a constant volume in an oxygen atmosphere). This is determined with the use of a bomb calorimeter according to ASTM D2015-96 (1998). The second value is the Net Calorific Value (NCV) knowing that the water in the product exists as a vapor. The relationship between the two values for a dry sample is, according to Equation (3):

$$NCV = GCV - (H2O * 24{,}41) \tag{3}$$

where: 24,41 kj kg^{-1} is the heat of water vaporization according to Nunez-Regueira et al. (2001).

RESULTS AND DISCUSSION

Having stated the moisture content for the samples in the previous chapter (moisture content of: A, B and C at 18,4%, 19,1% and 18,8% respectively) and the final moisture content of 8% for all three samples, following an oven-dried at 105°C, the results for the ash content are presented in Table 1.

Table 1

Ash content

Sample's numbering & description	Crucible's weight	Sample's weight	Sample's weight (dry with 8% humidity)	Gross weight (crucible + sample)	Ash's weight	Ash's value (%)	Ash's mean value (%)
A1 Leaves (Needles)	27,5575	1,0860	0,9991	27,6345	0,0770	7,7068	**8,1635**
A2 Leaves (Needles)	26,4786	1,0844	0,9976	26,5646	0,0860	8,6203	
B1 Branches	28,6118	1,0220	0,9402	28,6410	0,0292	3,1056	**3,1603**
B2 Branches	27,6021	1,0075	0,9269	27,6319	0,0298	3,2150	
C1 Bark	41,6318	1,0193	0,9378	41,6549	0,0231	2,4633	**9,5050**
C2 Bark	27,8115	1,0563	0,9718	27,9723	0,1608	16,5467	

Two test samples per category were measured to obtain the ash's mean value. The ash values for the leaves present a higher valued compared to the natural wood due to the high existence of inorganic substances such as magnesium and potassium. The branches have a lower percentage of ash due the size (branch diameter). The bigger the diameter is, the smaller the ash content (closer to natural wood's ash content which is around 1%). The branches which were used in our case had a mean diameter of 0,5mm which justifies the mean value of 3,1%.

In order to ascertain that these wood residues are ideal to be used for pellet production, a comparison with natural wood has to be undertaken. The calorific value of wood is approximately 20 Mj/kg for ovendry softwood according to Bajpai* (2018).

The results analysis for the three samples following the procedure decribed above are displayed in Table 2.

Table 2

Results analysis of the three samples

Sample's numbering	Sample's description	Moisture content before (%)	Moisture content after (%)	Ash content (Mean) (%)	Net Calorific Value (Mean) (NCV) (Mj/Kg)	Calorific Value (mean) (cal/g)
A	Leaves (Needles)	18,4	8,00	8,1635	18,69	4464
B	Branches	19,1	8,00	3,1603	19,03	4546
C	Bark	18,8	8,00	9,5050	18,74	4475
*	*Wood (softwood)*			*1,0000*	20,00	*4780*

The obtained results show that the calorific values of the residues are very close to those of natural wood. The moisture content when the samples were received from the forest is still not so high. (Table 2 “moisture content before”). Due to the experimental procedure, the moisture content went down to 8% via an oven. In normal circumstances, this moisture reduction could be achieved if the residues would be left for a short period of time (a few weeks) to an open natural ventilated space protected only by the rain. This would eliminate the cost of reducing the residue’s humidity as well as the overall pellet production cost.

The influence of the moisture content with regard to the calorific value plays a substancial role, not only increasing the value but when the samples are dry, the calorific value can be doubled (Haberl et al. 2000).

CONCLUSIONS

The results obtained within the present research demonstrated the calorific values of three different Spruce’s residues together with their ash content with a specific moisture value (8%). The variances between leaves, branches and bark are not significantly dissimilar having values between 18,7 and 19Mj/Kg. This demonstrates the possibility of using those residues for pellet production either individually or as a mixed residue’s product. The ash content which is crucial to the combustion process was for all three test samples at lower acceptable levels (3% to 9%).

These values have demonstrated that forestry waste products may be utilised as heat energy fuel minimising the carbon footprint due to the nature of these residues.

The three critical elements which determine the quality of the pellet production’s output (moisture, ash content and calorific value) are capable to perform efficiently at pellet stoves and pellet burners.

In the context of this preliminary study and these first results, more experimental research is likely to follow by undertaking readings from other wood residues to identify their performance. This is expected to diversify the existing path of wood waste into an alternative natural fuel.

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REFERENCES

Demirbas A (2006) Energy priorities and new energy strategies. Energy Edu Sci Technol 16:53-109.

Hoogwijk M, Faaij A, van den Broek R, Berndes G, Gielen D, Turkenburg W (2003) Exploration of the ranges of the global potentials of biomass for energy. Biomass Bioenergy 25:119-33.

Greek Land Registry. https://gis.ktimanet.gr/wms/forestsuspension/default.aspx [Assessed 23/06/2019].

Ninikas K, Ntalos G, Hytiris N, Skarvelis M (2019) Thermal properties of insulation boards made of tree bark & hemp residues. Journal of Sustainable Architecture and Civil Engineering. DOI 10.5755/j01.sace.24.1.22125

CEN/TS 14780 (2005) Solid fuels – Methods for sample preperation.

CEN/TS 14774-3 (2004) Solid fuels – Methods for the determination of moisture content – oven dry method – part 3: moisture foe general analysis samples.

Mani S, Tabil LG, Sokhansanj S (2003) An overview of compaction of biomass grinds. Powder Handling and Processing 15(3):160-168.

ASTM STANDARD D2015-96 (1998) Standard test method for gross calorific value for coal and coke by the adiabatic bomb calorimeter.

Nunez-Regueira L, Rodrigues-Anon J, Proupin-Castineiras J, Romero-Garcia A (2001) Energetic study of residual forest biomass using calorimetry and thermal analysis. Journal of Thermal Analysis and Calorimetry 66:281-292.

Bajpai P (2018) Biermann's Handbook of Pulp and Paper: Volume 1: Raw Material and Pulp Making, Third Edition, 19-74.

Haberl H, Geissler S (2000) Cascade utilization of biomass: Strategies for a more efficient use of a scarce resource. Ecol Eng.16:S111-21.