Energetic aspects of oak and larch pellets obtained from sawdust waste improved by torrefaction

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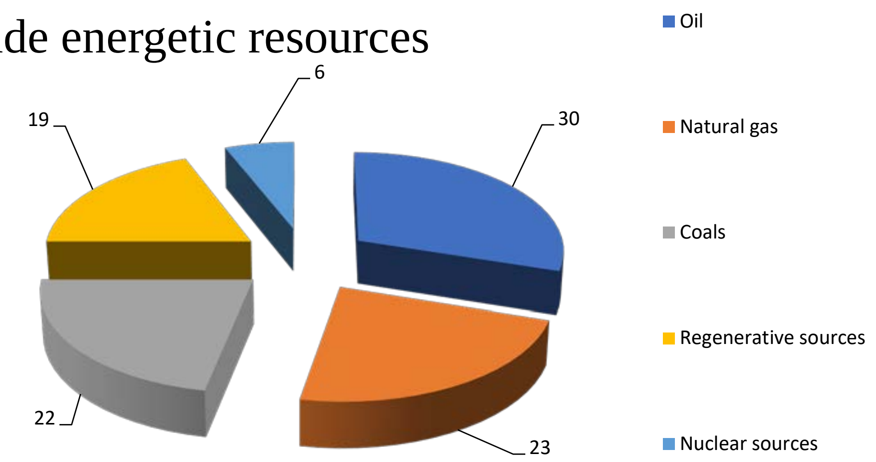
1 introduction

- Energetics of resource is a science that deals with energy types but also with combustible materials from which the energy is obtained
- The natural gases have won the consumers preferences due to a clean combustion in comparison with coals and oil, respectively due to a low pollution of the atmosphere. Also, the combustion of natural gases doesn't release sulphur dioxide or nitrates. However, the main problem is that natural gases do not regenerate so fast and the reserves will be soon finished. That's why in the present time the natural gases are just the solution of transition period to fuel regenerative resources.
- Even if nowadays the natural gas has the supremacy in the fuels used for domestic purposes for preparing food and heating the homes, the reducing of fossil fuels amount will necessarily lead to finding alternative energy sources, including biomass, which is available to all countries
- Worldwide energetic resources



Background

- Kambo and Dutta [1] studied the methodology of raw material improving by torrefaction. The density and energetic density of torrefied pellets increased from 834 kg/m^3 and 15.7 GJ/m^3 to 1036 kg/m^3 and 26.9 GJ/m^3
- Akinrinola [7] stated that the heat treatment of torrefied biomass in Nigeria (resulting from 2 woody species and two other crops) promised to improve many fuel characteristics, regardless of whether it is used for energy generation or is used in the domestic field.
- Ahn et al [10] used sawdust of two woody species *Larix kaemferi* C and *Liriodendron tulipifera* L to obtain pellets, and for the improvement of durability and calorific power it used lignin powder as an additive.
- Peng et al [11] demonstrated that the best pellets are obtained from the finest particles
- An exhaustive analysis of untreated and torrefied pellets by Kumar et al [6] identified the benefits of using pellets even in combination with coal
- The main parameters of the pelletizing and torrefaction process are analysed by Rudolfsson et al [12], focusing on the particle size, their moisture content, and the length of the pellet extrusion channel.
- The research carried out by Oh et al [13] on the pelletisation of the torrefied sawdust of two woody species revealed the Larch species (*Larix Kaempferi* C) compared with the yellow poplar species (*Liriodendron Tulipifera* L).
- Nhuchhen and Basu [14] found a method of replacing very expensive nitrogen with pressurized air for the heat treatment of torrefaction by replacing the continuous inlet nitrogen heat pipe with a poorly pressurized batch reactor
- Kudo et al [15] replaced the inert gas that produced a weak adhesion of the shale with wet saturated steam. The tensile strength of the pellets obtained by this method increased 5 times.
- Peng et al [16] recommend that the biomass might be torrefied and then compressed in order to

Objectives

- As one of the main conclusions of the researches in the field of heat treatment of sawdust or torrefaction, it is observed that although it is very efficient, nitrogen flow treatment is expensive and requires sophisticated installations and large quantities of nitrogen, which is why new and simpler methods of thermal treatment are tried, which leading to appropriate effects.
- The paper aims to increase the energetic properties of the biomass of larch and oak species by heat treatment at high temperatures without air intake during treatment. The effective density of the pellets, the calorific power, the calorific density, the energy efficiency, the rate of energy release are taken into consideration, and the influence of moisture content on the calorific value of the two wood analysed species will be studied as determinant factor.

Materials and method

- Two types of lignocellulosic biomass in the form of sawdust were used, namely sawdust of larch and oak, and their correspondingly pellets
- Lignocellulosic biomass in the form of sawdust taken from a circular saw has also undergone to a torrefaction process in an oven without air admission, with different temperatures of 200, 220, 240, 260, 280, and 300 C degrees, in order to improve its calorific value.
- The density of pellets was determined as the ratio between mass and volume $\rho = \frac{4 \cdot m}{\pi \cdot d^2 \cdot l} 10^6 \quad [kg/m^3]$
- The installation used for determining the calorific value of the wooden biomass was the explosive burning (bomb) calorimeter type XRY-1C, produced by Shanghai Changji Geological Instrument Co.

$$CV = \frac{k \cdot (t_f - t_i) - q_i}{m} 10^{-3} \quad [MJ/kg]$$

- The energetically density (ED) is determined by keeping into account the caloric power of the pellets and density $ED = CV \cdot \rho \quad [MJ/m^3]$

$$BR = \frac{CV}{t} \cdot m_0 \quad [kJ/\min]$$

- On the basis of the combustion time, calorific value and oven-dry mass, the burning rate was also determined
- The influence of moisture content on the calorific power: two different moisture contents of the samples from untreated pellets were used, respectively of 20 and 50%. From these tests the high and low calorific power were determined, thus obtaining two straight lines, in the x0y plane (CVOMc), equations that intersect the vertical axis CV at the same point, and the horizontal axis Mc at two different points. The arithmetic mean of horizontal intersections will be called Limitative Mc.

Materials and method

- To determine the ash content of the biomass, the general method of standardized determination was used (as ASTM E1755-01. According to this method, the milled and dried material (dried to 0% moisture content) is calcined at a temperature of 650° C in a laboratory calibrated oven, for a period of at least 3 hours

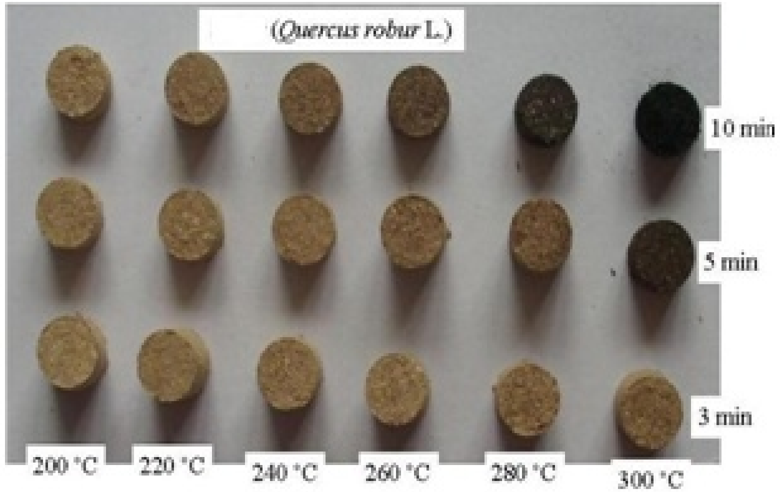
$$A_c = \frac{m_{a+c} - m_c}{m_{s+c} - m_c} \cdot 100 \quad [\%]$$

- The percent mass loss (PM) of the sawdust was calculated: $PM = \frac{m_i - m_f}{m_i} \cdot 100[\%]$, Where: mi is the initial mass of sawdust sample, before torrefaction (g), and mf is the final mass of sawdust sample after torrefaction (g).
- In the second step, the torrefied wood sawdust has been compressed in cylindrical pellets (about 10 mm diameter, 0.5-0.8 g mass, and 9-11 mm length) with the help of a handle press (Fig. 2b). At least 12 pellets were obtained from each white and thermally treated wood sawdust batch. Two different categories of pellets, made of larch (*Larix decidua*), and oak (*Quecus robur*) were analysed.
- Improving of calorific value after thermal treatment was determinate, based

on the calorific value before and after treatment, with aid of the next relation:

- $I_{CV} = \frac{CV_{at} - CV_{bt}}{CV_{bt}} \cdot 100\ [\%]$

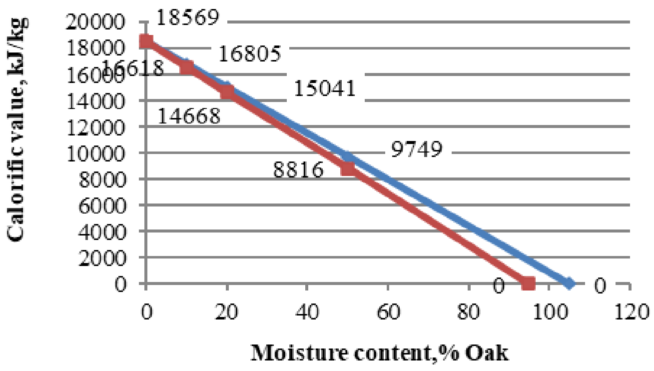
where: I_{CV}- Increasing of Calorific value (CV), in %; CV_{at}-calorific value, after torrefaction, in kJ/kg; CV_{bt} –calorific, value before torrefaction, in kJ/kg.

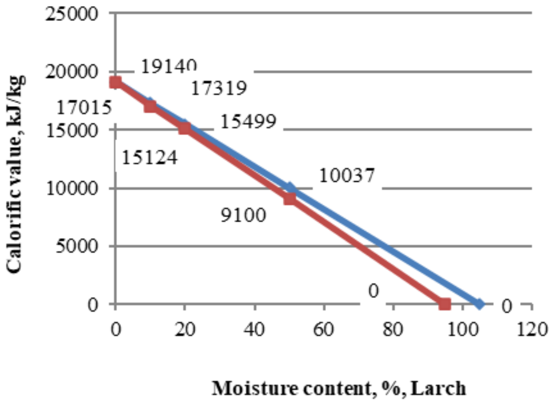


Results and discussion

- Moisture content of sawdust and pellets was 10%, being determined by method of weighing and drying, as was stipulated by EN 14774-1:2009. Density of pellets, determined as a ratio between mass and volume, was about 1010 kg/m^3 for oak specie and 1012 kg/m^3 for larch specie.
- The calorific value depends on the moisture content, and the two HCV and LCV values decrease as value with increasing in moisture content. It is observed that the HCV and LCV values are slightly different from each other; although the pellets used in the introduction into the calorimetric bomb were dried to constant mass (i.e. they had a moisture content of 0%). This is explained by the fact that about 3 ml of distilled water is introduced into the bomb, which absorbs nitrogen compounds during the combustion

Specie	Time of burning	Calorific value			Lineal equation	Limitative Mc, %	
		HCV	LCV	CV			
Oak	25	18 564	18 563	18569	HCV=18569-176.4·Mc LCV=18569-195.1·Mc	105.2 95.1	100.1
Larch	29	19 135	19 132	19140	HCV=19140-150.8·Mc LCV=19140-279.4·Mc	126.9 68.5	97.7





Results and discussion

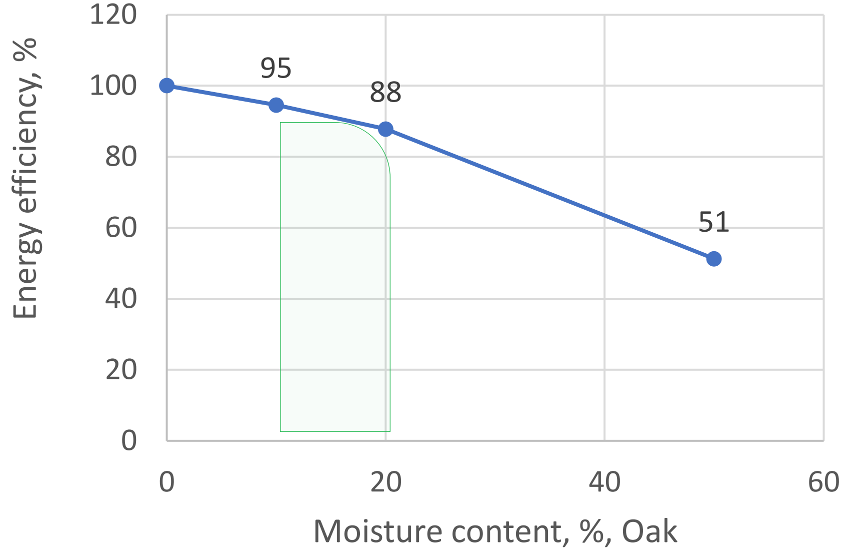
- it is observed that by increasing the moisture content, it will decrease the calorific power by consuming a higher amount of heat to dry the lignocellulosic material, such that at moisture content of about 109 ° C

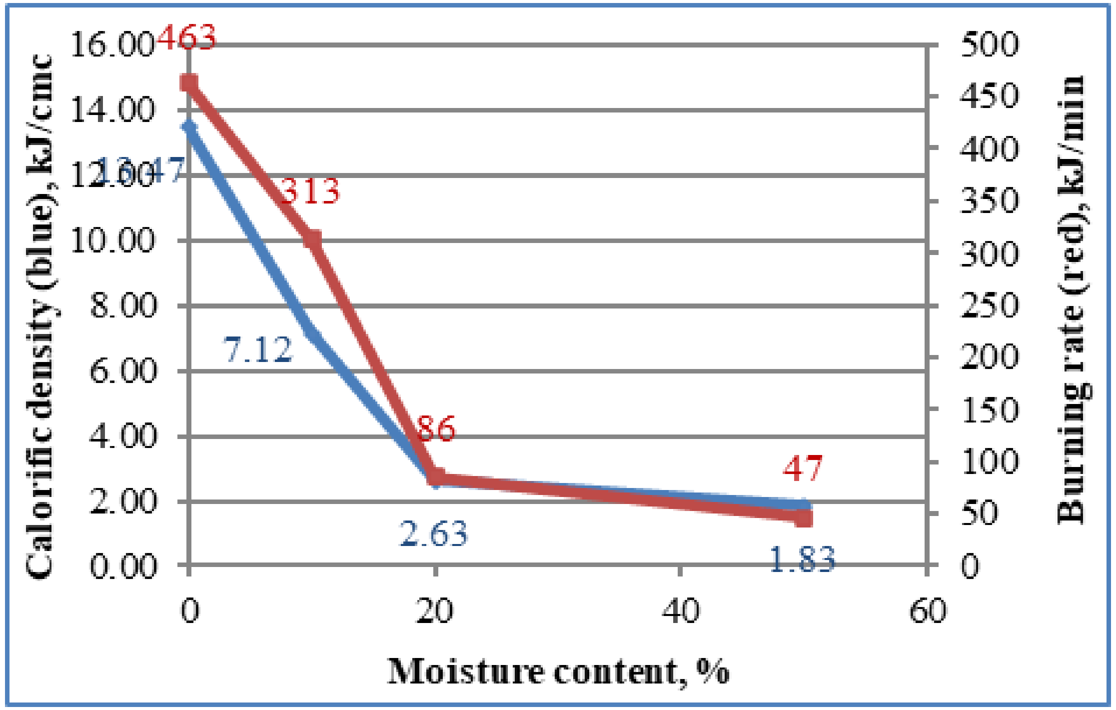
- Medium values as 100.1% and 97.7% show as a value when no energies release, because energy of wood combustion is equal with energy to consume (to dry) water from wood. At 0% moisture content, the two values of equation merge into one, obtaining a point with the calorific value CV.

Results and discussion

- the calorific efficiency decrease with increasing of moisture content of oak biomass usually value of 10% moisture content offer a good efficiency of 95%.

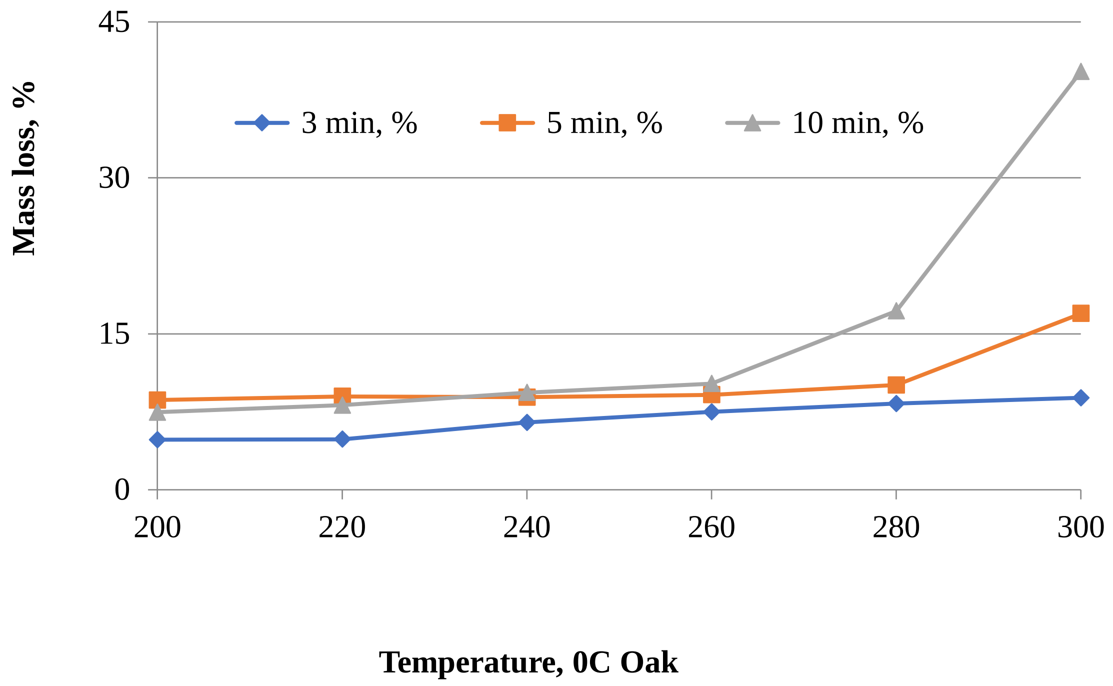
- Regarding the torrefaction activity of sawdust, it was noticeable that calorific density has extremely values 2-15 kJ/cm^3, and burning rate also decrease with increasing of moisture content





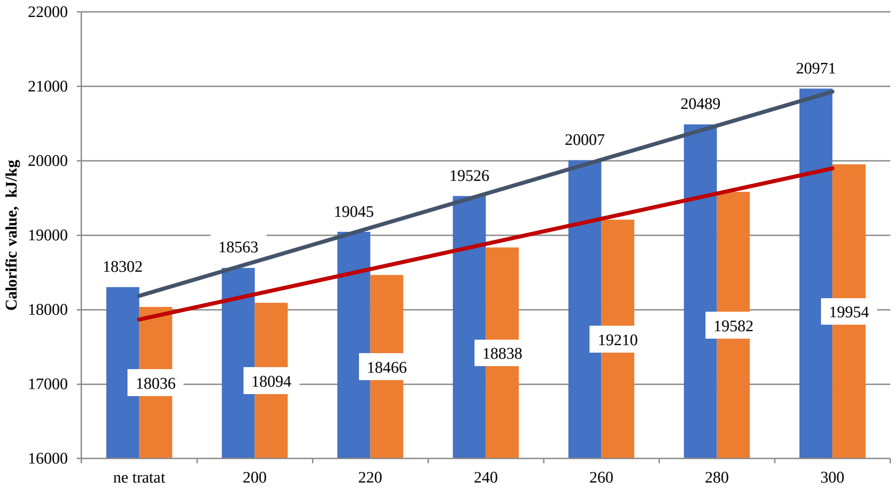
Results and discussion

- As a general rule it is observed that with the increase of degree of torrefaction (given by the temperature and time of the thermal treatment) the mass loss will increase (Fig 6). Temperatures over 260 ^{0}C increase better the mass loss [33-36], and temperature of 300 ^{0}C represents the best one in this field. Assuming that the mass loss for the white sawdust is zero, the mass loss over the total temperature range for 3 minutes is 8.84%, for 5 minutes it is 16.95%, and for 10 minutes it is 40.24%. Almost similar values were obtained in the case of the larch specie; by this it was shown that during the torrefaction treatment, the woody species have an almost similar behaviour.

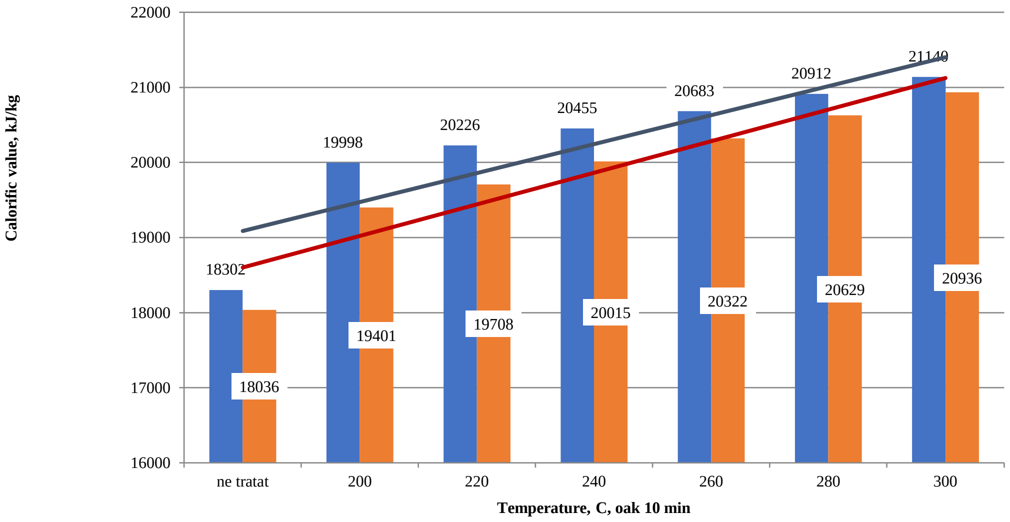


Results and discussion

- Regarding about the influence of torrefaction temperature on calorific value of oak pellets, Fig 7 shows the increasing CV for 3 min with 14.5%, and with 15.5% for 10 min, taking as starting point the un-treated pellets.

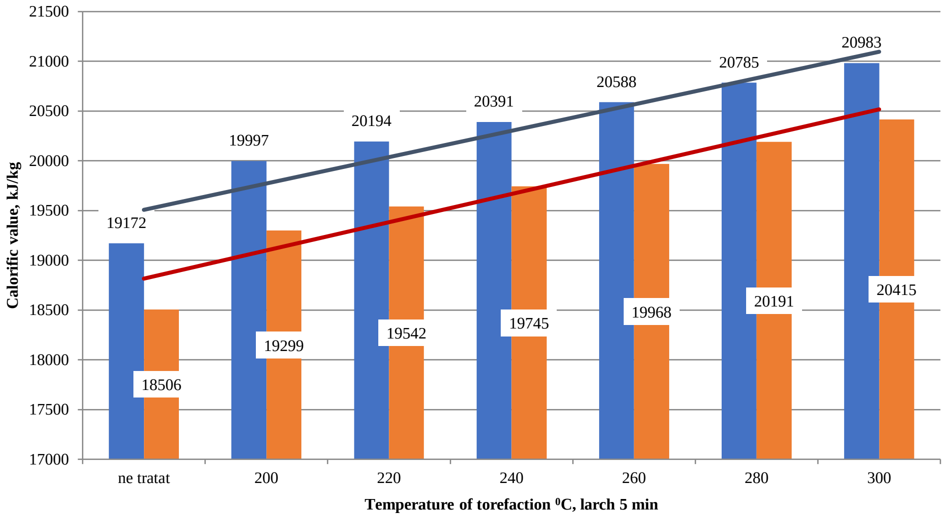


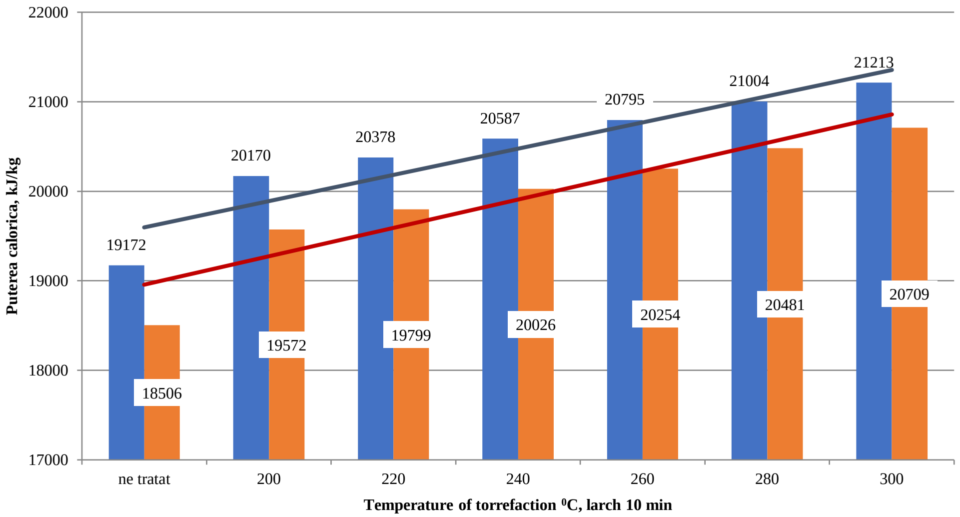
Temperature of torrefaction, ^{0} C, oak 3 min



Results and discussion

- Regarding the influence of the torrefaction temperature on the calorific value of the larch pellets, a CV increase of 9.4% for the 5-minute period and 10.6% for the 10-min period is observed. It should be noted that the 3-minute period offers an increase of less than 5% for both analysed species.





Results and discussion

- Ash content was different for native biomass, being 0.42% for larch and 0.51% for oak. The torrefied sawdust had higher ash content, corresponding to the mass losses obtained by heat treatment. Therefore, maximum values of ash content for sawdust treated at temperatures of 300 ^{0}C as 0.58% for larch and 0.71% for oak were highlighted during laboratory tests.
- If a comparative analysis is made of the properties of larch and oak biomass, it is observed that although they are two different species (softwood and hardwood) and have different densities (oak 775 kg / m^3 and larch 521 kg/m^3 at 10% moisture content), their energetic properties are quite appropriate. In this sense the densities of the pellets differ below 0.2%, the calorific powers of the white pellets differ below 3.1%, and the differences in the increase of calorific power after torrefaction are under of 3.1% in favour of larch biomass. Similar differences were found for caloric efficiency, energy release rate and calorific density.

Conclusions

- On a general way, woody biomass in the form of sawdust is environmentally friendly and gives to the world a neutral energy against the emissions of carbon dioxide. The CO_2 is sequestered inside the biomass during the growing process of trees (about 60-140 year) and forms a closed circuit, because the quantity of CO_2 which was absorbed by the plants during the growing process will be equal to which was raised during the complete burning process (in a few minutes or hours). It could say that the same quantity of CO_2 is raised when woody biomass is naturally discomposed in open spaces in few years, which is why the use of wood biomass in combustion for human needs is recommended.
- From an experimental point of view it was shown that the oak and larch pellets obtained within the research had small differences in density, but after the torrefaction treatment they both considerably increased their calorific value. There have been observed increases of up to 12% of the calorific value after torrefaction, both for oak and larch sawdust. No exceptional differences were found between the calorific properties of the two species analysed, although they are considered structurally different species.
- Considering that the two wood species (oak and larch) are valuable species with main uses in the construction of furniture and veneers, it is recommended to use only the remnants from the manufacture of these products in the manufacturing of normal or torrefied pellets.

Thank you for attention !

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