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ASSESSMENT OF ENERGETIC POTENTIAL OF CHERRY STONES IN POLAND

Summary

Biomass is one of the renewable energy sources that could replace conventional carbonaceous fuels. The remains of timber industry or the agro-food sector are attractive sources of biomass taking into account environmental and economic aspects. Stones of fruits such as cherries, peaches or apricots can be converted into heat in the combustion processes. They can also be converted into liquid or gas biofuels in a gasification and pyrolysis processes. The aim of the study was to determine the higher (HHV) and lower heating value (LHV) of cherry stones and to determine their energy potential in Polish market of renewable energy. Relative humidity of dried cherry stones was 5.80±0.12% and ash content was equal to 1.43±0.04%. The higher heating value of crushed cherry stones was 20.6±0.7 MJ·kg^{-1}, while the lower heating value 19.2±0.8 MJ·kg^{-1}. The theoretical share of thermal energy from combustion cherry stones in the national heat production from renewable energy sources amounted to 0.42% in 2013.
***Key words**: biomass, cherry stones, renewable energy, lower heating value, higher heating value*

OCENA POTENCJAŁU ENERGETYCZNEGO PESTEK WIŚNI W POLSCE

Streszczenie

Jednym ze źródeł energii odnawialnej, mogącym zastąpić tradycyjne paliwa węglowe, jest biomasa. Atrakcyjnym ze względu na aspekt środowiskowy i ekonomiczny źródłem biomasy są pozostałości przemysłu drzewnego lub rolno-spożywczego. Pestki owoców takich jak wiśnie, brzoskwinie lub morele mogą być przetworzone w energię w procesach bezpośredniego spalania lub współspalania. Można je również poddać procesom pirolizy lub zgazowywania i otrzymać biopaliwa ciekłe i gazowe. Celem pracy było określenie ciepła spalania i wartości opałowej pestek wiśni oraz określenie ich potencjału energetycznego w warunkach krajowych. Wilgotność względna suszonej pestki wiśni wynosiła 5,80±0,12%, a zawartość popiołu 1,43±0,04%. Średnie ciepło spalania rozdrobnionych pestek wiśni było równe 20,6±0,7 MJ·kg^{-1}, natomiast wartość opałowa 19,2±0,8 MJ·kg^{-1}. Teoretyczny udział energii cieplnej pochodzącej ze spalania pestek wiśni w krajowej produkcji ciepła z odnawialnych nośników energii wynosił 0,42% w 2013 roku.
***Słowa kluczowe**: biomasa, pestki, energia odnawialna, wartość opałowa, ciepło spalania*

1. Introduction

Progressive robotisation and automation of all industry sector and increasing quality of life associated with the development of society lead to higher energy consumption in all its forms. This enforces increased and continuous energy supply. The growing demand for energy causes its price increase, which is a key factor of competitiveness [14, 18]. Concerns about energy security, competitiveness and energy production impact on the environment have led to take actions at promoting the production and use of energy from renewable sources [12, 20]. According to UE regulations, the share of energy from renewable sources must reach 20% in all Member States till 2020 [5].

Biomass is one of the renewable energy sources that could replace conventional carbonaceous fuels. It is the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as biogases and the biodegradable fraction of industrial and municipal waste [16]. Among the many types of biomass, plant biomass is the most important. To solid plant biofuels are included inter alia: straw, wood, energy crops and grain. These are the primary energy raw materials, which beside environmental and economic benefits, provide an opportunity for development of agriculture [1, 11]. Taking into account environmental and economic aspects the remains of timber industry or the agro-food sector are attractive source of biomass. Energetic utilization of remnants from the agri-food production is directed mainly to produce biogas. However, some of them, including fruit stones cannot be treated in this way [10]. Stones of fruits such as cherries, peaches or apricots can be converted into heat in the combustion processes [9]. They can also be converted into liquid or gas biofuels in a gasification and pyrolysis processes [4, 7]. The most important in the domestic energy market may be cherry stones, because Poland is a major producer and processor of cherries in the world.

The aim of the study was to determine the higher and lower heating value of cherry stones and to determine their energy potential in Polish market of renewable energy.

2. Materials and methods

Dried cherry stones with an average diameter of 10.2 ± 1.0 mm and an weight of 0.24 ± 0.04 g, provided for testing by the BIOHEAT Company Waldemar Goździcki constituted a research material (Fig. 1). The accredited testing laboratory of the Institute of Technology and Life Sciences, Branch in Poznan, in accordance with standards PN-EN 12880: 004 and PN- EN 6540:2010, determined analytical humidity by drier method and ash content by gravimetric method in accordance with standard PN-EN 12879:2004. For this purpose analytical balance B&D HA 202M with an accuracy of 0.0001 g, heat chamber Wamed KCB 30 and muffle furnace Nabertherm B150 were used.

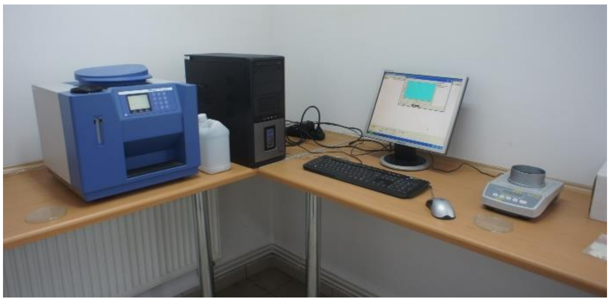
a)

b)

Source: authors' photos/ Źródło: zdjęcia autorów

Fig. 1. Dried cherry stones: whole (a) and crushed (b)
Rys. 1. Suszone pestki wiśni: w całości (a) i rozdrobnione (b)

The higher heat value (HHV) and lower heat value (LHV) of crushed cherry stones were determined using an adiabatic calorimeter IKA C200 with isoperibolic method (Fig. 2).



Source: authors' photos/ Źródło: zdjęcia autorów

Fig. 2. Test stand for determining the higher and lower heat value
Rys. 2. Stanowisko do wyznaczania ciepła spalania i wartości opałowej

The measurements were conducted in accordance with the PN-81/G-04513 and PN-ISO 1928. HHV is the amount of heat gained from complete and total combustion of solid fuel in an oxygen atmosphere. Gases in ambient temperature are the final products of the combustion. LHV is determined by subtracting the heat of vaporization of the water vapor from HHV. It was calculated using a computer program controlling operation of the calorimeter in accordance with the PN-80/G-04511 and PN-ISO 1928. Data concerning the size of cherry production and export (fresh and frozen cherries) in Poland are obtained from statistical studies of the Central Statistical Office of Poland and the Agricultural Market Agency.

3. Results and discussion

The relative humidity and ash content were determined for crushed cherry stones, because combustion of whole stones in boiler not prepared for this purpose reduces its heat efficiency. Research showed that combustion of not crushed cherry stones decreased the boiler heat efficiency to 65%. For crushed cherry stones it was 80% [9]. Determination of dry matter, relative humidity and ash content was carried out for sample which was a mixture of cherry stones taken from 10 different parts of test material. The results are shown in Table 1.

Table 1. Physical parameters of crushed cherry stones
Tab. 1. Parametry fizyczne rozdrobnionych pestek wiśni

Dry matter (%)	Relative humidity (%)	Organic dry matter (%)	Ash content (%)
94.20 ± 1.88	5.80 ± 0.12	98.57 ± 2.96	1.43 ± 0.04

Source: own research / Źródło: badania własne

The higher heat value was determined for one sample, which was also a mixture of cherry stones taken from 10 different parts of test material. Small size of vessel in calorimeter bomb did not allow the determination of studied parameter for a representative sample of the research material. For this reason the measurement was replicated ten times. The results are presented in Table 2.

Table 2. Higher heat value of crushed cherry stones
Tab. 2. Ciepło spalania rozdrobnionych pestek wiśni

Sample	Mass (g)	Temperature difference (K)	Higher heat value ($MJ \cdot kg^{-1}$)
1	1.130	2.354	20.421
2	1.053	2.349	21.868
3	1.113	2.310	20.343
4	1.198	2.623	21.474
5	1.034	2.147	20.338
6	1.242	2.651	20.940
7	1.124	2.269	19.781
8	1.046	2.160	20.233
9	1.280	2.550	19.540
10	1.266	2.709	20.993

Source: own research / Źródło: badania własne

The average HHV of crushed cherry stones was 20.6±0.7 MJ kg^{-1}. Knowing the relative humidity 5.80±0.12% and ash content 1.43±0.04%, the LHV was calculated and amounted to 19.2±0.8 MJ kg^{-1}.

The LHV of the crushed cherry stones was high comparing with other types of biomass, including pellets and briquettes produced from industry remains (Table. 3). This value was 4.5% less than the LHV of briquettes produced from rape straw (20.1 $MJ \cdot kg^{-1}$) [3]. Wheat straw pellets (18.2 $MJ \cdot kg^{-1}$), sawdust conifers pellets (18.3 MJ kg^{-1}) and briquettes from wheat-bone meal (18.5 $M \cdot kg^{-1}$) had not much lower LHV than cherry stones [3, 19]. The LHV of triticale straw briquettes (15.2 MJ·kg^{-1}) and fuels produced from excrements and remains of the agri-food industry: apple remains pellets (16.8 MJ·kg^{-1}), pellets from chicken manure (13.6 MJ·kg^{-1}) and dried chicken manure (13.5 MJ·kg^{-1}) had lower LHV than test material [2, 3, 8, 19]. Fuel produced from a mixture of solid fraction of pig manure and bark of conifers characterized the lowest LHV (5.4 MJ·kg^{-1}) [8]. The differences in LHV of analyzed biomass mainly resulted from the different relative humidity of compared biomass types. In addition to the high LHV, cherry stones were also characterized by low ash content 1.43±0.04% which was in range of ash content for biomass (0.5 to 5.5%) [22].

Table 3. Physical parameters comparison of crushed cherry stones with other types of solid biomass
Tab. 3. Porównanie parametrów fizycznych rozdrobnionej pestki wiśni z innymi rodzajami biomasy stałej

Type of biomass	Relative humidity (%)	Ash content (%)	LHV (MJ·kg^{-1})	Source
Chicken manure pellets	15	14.2	13.6	[8]
Dried chicken manure	8.5	n.d.	13.5	[2]
Mixture of solid fraction of pig manure and bark of conifers	61	10,4	5.4	[8]
Wheat straw pellets	8.3	n.d.	18.2	[3]
Sawdust conifers pellets	6.1	0.9	18.3	[19]
Apple remains pellets	11.7	2	16.8	[19]
Wheat-bone meal briquettes	3.8	n.d.	18.5	[3]
Triticale straw briquettes	15.1	n.d.	15.2	[3]
Rape straw briquettes	9.6	n.d.	20.1	[3]
Crushed cherry stones	5.8	1.4	19.2	Own research

n.d..- no data

Source: own work / Źródło: opracowanie własne

The estimation of the energy potential of crushed cherry stones in national market of renewable energy was made for 2013 year. The mass of cherries whose stones may be used for combustion was calculated on the basis of data published by the Central Statistical Office (GUS) and the Agricultural Market Agency (ARR). According to the GUS reports, Poland produced 188,000 tons of cherries in 2013 and 10,000 tons were exported as fresh fruits and 66,000 tones as frozen fruit [15, 17]. The share of stone mass in total mass of fruit was adopted from literature and was equal to 6% [13, 21]. The average relative humidity of stones before drying was 34.3%. It is assumed that 90% of cherry stones obtained during fruit processing may be used for generation.

Table 4. The theoretical share of thermal energy from combustion cherry stones in the national heat production from renewable energy in 2013
Tab. 4. Krajowy teoretyczny potencjał energetyczny pestek wiśni na cele grzewcze w 2013 r.

	Unit	Value
Cherries processing in Poland	(ton)	112,000
Share of cherry stone in total mass of fruit	(%)	6
Total mass of cherry stones in Poland	(ton)	6,720
Relative humidity of cherry stones before drying	(%)	34.3
Relative humidity of dried cherry stones	(%)	5.8
Total mass of dried cherry stones	(ton)	4,804.8
Total mass of dried cherry stones for combustion	(ton)	4,324.3
Boiler heat efficiency	(%)	80
Lower heat value	(MJ·kg^{-1})	19.2
Theoretical energy potential of cherry stones	**(TJ)**	66.4

Source: own work / Źródło: opracowanie własne

According to the report "Energy from renewable sources in 2013", heat production from renewable energy sources was 15,949 TJ in Poland and 97.6% (15,572 TJ) of it was generated during combustion of solid biofuels [6]. The theoretical share of thermal energy from combustion of cherry stones in the national heat production from renewable energy sources amounted to 0.42% in 2013. Although this value is not high, cherry stones can be used locally, near the sources of raw material, as energy source. Taking into account the market price of drying cherry stones (350 to 500 PLN per ton) it may constitute a financial alternative to other types of fuels obtained from biomass.

4. Conclusions

The higher heat value of dried, crushed cherry stones was 20.6±0.7 MJ·kg^{-1} (relative humidity 5.80±0.12%) and lower heat value was 19.2±0.8 MJ·kg^{-1}.

Crushed cherry stones were characterized by low ash content 1.43±0.04%, which was in range of ash content for biomass (0.5 to 5.5%).

The theoretical share of thermal energy from combustion cherry stones in the national heat production from renewable energy sources amounted to 0.42% in 2013.

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