RAGWEED (*AMBROSIA ARTEMISIIFOLIA* L.) BIOMASS AS A SOURCE FOR ENERGY PRODUCTION

PROFESSIONAL PAPER

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ABSTRACT:
Due to their rapid spread and reproduction, invasive plant species adversely affect agricultural production, the biodiversity of other species, as well as human health. They can be used as a potential raw material for energy production after mechanical removal to reduce their population without using herbicides. Ragweed belongs to the group of foreign invasive species, mainly as a weed, it can be found in crops, and its pollen causes allergies in humans. This paper aimed to investigate the energy properties of ragweed and the possibility of its use in thermal energy production. The results show that ragweed is a solid energy source for direct combustion, with a slightly higher proportion of ash, which negatively affects the energy properties.

KEYWORDS: invasive species, ragweed, biomass, energy potential

INTRODUCTION

Ragweed is a native species of North and South America, and it can be found in all states of the United States except Alaska. The first records of ragweed in the United States date from 1838 in Michigan. It was shipped from America to Europe in 1863. It was found in red clover seeds, alfalfa, and cereal seeds, and its spread began from European ports: from Rijeka to the rest of Croatia and the Danube Valley, from Trieste and Genoa to northern Italy and from Marseille to the Rhone Valley [1]. Croatian herbologist Kovačević was the first to mention a ragweed presence in Croatia in 1940 in Podravina, Posavina, and Slavonia. Today it is widespread in most of Croatia, and it dominates in the continental part. Along with Croatia, Hungary, Italy, and France are European countries that have the biggest problem of ragweed pollen pollution. Ragweed is found in abandoned habitats, along railroads, roads, roads, riverbanks, and streams, in neglected gardens and poorly cultivated fields [2].

Ragweed being a weed in crops can cause significant damage. It mechanically suffocates the crop, depriving the plant of the above-ground and underground space. It reduces the yield and quality of cultivated plants, reduces the amount of water and nutrients in the soil, lowers the soil temperature, and makes tillage difficult. It can be a transient host to pests and plant disease agents. Ragweed thrives well in dry habitats and has moderate nutrient requirements. But it can also grow on bright, hot, or different habitats on neutrophilic soils, regardless of soil quality. The requirements for temperature and light are high, so ragweed is a heliophilic and thermophilic plant. The optimum temperature for germination is 20 to 22°C. The vegetation period of the plant lasts from 150 to 170 days depending on ecological conditions. Ragweed pollen is one of the most potent pollen allergens and causes serious health problems for a specific part of the population. In people who are allergic to ragweed pollen, allergic rhinitis occurs during flowering in August and September. The ragweed plant has a firm spindle root that is overgrown with lateral roots. The lateral roots of the plant provide strength and excellent absorption of water and nutrients. The root is short, compact, and branched. It usually does not penetrate deep into the soil, so it can take root on shallow and compacted soils and can be easily pulled out of the soil mechanically. Ragweed has an upright, herbaceous, and branched stem that forms a bush in the upper part. The colour of the stem can be from green-gray to reddish. The height is usually between 20 and 120 cm, and in optimal conditions, it can reach a height of 2 m. The leaves are alternately placed on the stem and pinnately divided into narrow, elongated-lanceolate lobes and overgrown with small hairs. The reverse of the leaf is gray-green, and the face is dark green. The back of the leaf is lighter in colour and hairier than the epidermis of the face of the leaf. The size of the leaves is between 5 and 10 cm. The flowers of ragweed are small, unisexual, tubular, and yellow. Ragweed is a monoecious plant and develops male and female flowers on the same plant. The male flowers are small and tubular, turned downwards, and are grouped in a head-shaped inflorescence. The heads contain 10–15 tiny yellowish flowers composed of five petals with dark lines between them). The fruit of ragweed is round ovoid hornbeam or achenia, in which seed is wrapped in a tight shell. The pods contain 5 to 7 prickly growths on one side, with the central growth being the longest. The fruit's diameter is about 5 mm, the length from 1.5 to 5 mm, and the thickness from 1.0 to 1.7 mm. The plant can produce up to 3,000 pods per year that retain germination for up to 40 years. Ragweed reproduces solely by seed. Apart from "primary dormancy" ragweed seeds also have "secondary dormancy" which occurs if the seeds fail to germinate due to unfavourable conditions [3,4,5,6].

Today, ragweed is found in almost all parts of Croatia. It is most widespread between the rivers Sava and Drava. Galzina et al. [1] conducted a three-year study (2004-2006) on the prevalence of ragweed in Croatia. Of the 521 municipalities surveyed, ragweed was found in 490 municipalities. According to the results of their research, ragweed is present in the entire interior of Croatia. It is found as a weed in the fields of sunflower, corn, sugar beet, and soybeans. It is present along roads, railways, and highways, and on abandoned land. In the coastal and mountainous parts of Croatia, it is present in a much smaller presence.

Since the optimal way to destroy ragweed is its mechanical removal before flowering to prevent further spread, the question arises whether the biomass remaining after the mechanical removal of ragweed is a useful resource in energy production. Namely, one of the underused energy sources today is biomass precisely because of the limited resources in its production. Ways to get energy from biomass are different. Plants can be directly grown as biomass for energy production, or plant residue from agricultural production, organic waste, and even invasive plant species such as ragweed. The oldest way of directly converting biomass into energy is combustion. Today, various processes of converting biomass into energy or fuel have been developed. Besides being renewable, biomass and its products, are also sufficiently similar to fossil fuels, so their direct replacement is possible. Biomass can be directly converted into energy by combustion, thus producing steam for heating in industry and households, and obtaining electricity in small thermal power plants. Some plants provide oil that can be used in diesel engines. Biochemical processes (anaerobic and alcoholic fermentation, esterification) produce biogas, bioethanol, and biodiesel. Thermochemical conversions (combustion, gasification, and pyrolysis) result in direct energy production. Dry distillation (heating without the presence of air) can produce methanol, acetone, charcoal, and other products from biomass [7,8].

Biomass of invasive plant species, including ragweed, has the potential for energy production due to its rapid spread and reproduction. Due to its spread and a large amount of generated biomass, this paper examined the possibility of using its biomass through energy recovery while reducing the need for herbicide use. Therefore, this study aimed to determine the possibility of using ragweed biomass as a potential raw material for energy production, or as a raw material for direct combustion. Analysis of ragweed biomass will be carried out after its mechanical removal from nature, guided by the fact that its invasiveness and a large amount of biomass poses a threat to biodiversity, is highly allergenic, and causes considerable damage to agriculture. Its energy potential will be determined with the aim of direct combustion and heat production.

MATERIALS AND METHODS

In this paper, research was conducted on ragweed biomass. The collection of materials was carried out at five locations in the city of Zagreb, the Republic of Croatia. Materials were collected on abandoned land and along roads. The first location is the sub-Sljeme zone of the Markuševec district the second location is the Dubrava district, the third location is Maksimir Park near the Faculty of Agriculture, the fourth location is the Sava embankment, and the fifth location is near Jarun Lake.

After collecting samples, the research was conducted in the laboratory of the Department of Agricultural Technology, Storage and Transport, University of Zagreb, Faculty of Agriculture.

Samples were analysed by the following standard methods: dry matter content (HRN EN ISO 18134-2: 2017); ash content (HRN EN ISO 18122: 2015), coke (EN 15148: 2009), fixed carbon (calculated), volatile matter content (EN 15148: 2009), carbon, hydrogen, nitrogen content (HRN EN 15104: 2011), sulphur (HRN EN 15289: 2011), the content of cellulose, hemicellulose (NREL / TP-510-42623) and content of lignin (NREL / TP-510-42618) and higher and lower calorific value (EN 14918: 2010).

The analyses were preceded by the grinding of the samples in a laboratory mill (IKA Analysentechnik GmbH).

RESULTS AND DISCUSSION

The water content in biomass is a significant factor as it affects the fuel's energy value. Dry biomass has a higher calorific value because no energy is wasted on evaporation. The moisture content in biomass varies from 10 to 50% [9]. According to Ross et al. [10] (2008), the optimal water content ranges between 10 and 15%. The method of obtaining energy from biomass depends on the water content. Raw materials with low moisture content (<50%) are required for heat treatment, while raw materials with high moisture content can be used for biochemical processes [7].

Table 1. Share of water in the wet and dry samples in investigated ragweed biomass

Samples location	Wet sample (%)	Dry sample (%)
I	59.09	10.02
II	58.50	9.21
III	61.08	11.46
IV	57.33	10.81
V	67.87	12.97
Average	**60.84**	**10.93**

Table 1 shows the mean values of the water content of analysed biomass samples from different locations in Zagreb. The mean value of the water content in the dry sample is 10.93%, which is acceptable because, according to Ross et al. [10], the optimal water content is between 10% and 15%.

Table 2. Share of ash, coke, fixed carbon and volatile substances in the studied ragweed biomass

Samples location	Ash (%)	Coke (%)	Fixed carbon (%)	Volatile substances (%)
I	10.61	15.68	5.07	74.30
II	11.52	18.82	7.30	71.97
III	10.79	16.93	6.14	71.61
IV	11.34	19.09	7.75	70.10
V	12.14	17.58	5.44	69.45
Average	**11.28**	**17.62**	**6.34**	**71.49**

Ash is an inorganic part of the fuel that remains after complete combustion. The ash content can vary from 1% to 40% [11]. According to Parmer [9], wood has less than 1% ash, while crops and residues have higher ash content. According to Bilandžija et al [12], the ash content in agricultural biomass ranges from 2% to 25%. The substances that produce the ash have no calorific value, and its desirable value should be as low as possible. Table 2 shows the mean value of the ash content in the dry matter of the analysed samples of ragweed biomass, depending on the location. The average value of the ash content of the samples is 11.28%, which is a high content compared to some energy crops that are targeted for this purpose.

Coke is secondary coal formed at higher temperatures. It is the rest of the dry distillation, and by its increasing, it increases fuel quality [13]. Table 2 shows the mean values of the coke content of the analysed ragweed biomass samples. The average value of the coke content of the analysed samples is 17.62%. However, there was a significant difference in the coke content between the samples, which ranged from 15.68 to 19.09%. Yet, the obtained values of coke in ragweed biomass have favourable amounts of coke for energy production.

The fixed carbon content is, in addition to the ash, a solid residue after combustion or release of volatile substances. Increasing the fixed carbon increases the calorific value, thus improving the quality of the biomass. Table 2 shows the fixed carbon content in ragweed biomass samples at different locations which averaged 6.34%, which is significantly less compared to wheat biomass containing 21% fixed carbon, barley containing 18%, and wood biomass containing 17% fixed carbon [7]. Due to the low content of fixed carbon, the value of biomass raw material for energy production decreases.

Volatiles are components that are released at high temperatures [7]. The volatile matter content of ragweed biomass samples from different locations is also shown in Table 2. The range of volatile matter content in the samples is from 69.45 to 74.30%, and the mean value of volatile matter content in the samples is 71.49%, which is higher volatile matter content compared to wheat straw [14], but lower compared to miscanthus [15].

Biomass contains different amounts of cellulose, hemicellulose and lignin, and small amounts of other components (lipids, proteins, simple sugars, and starches). The ratio of cellulose to lignin is one of the essential factors in determining the suitability of a particular plant species for energy production [7]. It is desirable to have the lowest possible cellulose content and hemicellulose in the biomass in the combustion process. Biomass with higher lignin content is more suitable for direct combustion processes [14].

Table 3. The share of cellulose, lignin and hemicellulose in the studied ragweed biomass

Samples location	Cellulose (%)	Lignin (%)	Hemicellulose (%)
I	30.87	24.16	17.70
II	27.54	27.16	13.84
III	28.44	24.81	15.79
IV	25.28	27.46	13.15
V	25.66	28.29	16.90
Average	**27.55**	**26.38**	**15.48**

Table 3 shows the proportion of cellulose, hemicellulose, and lignin in ragweed biomass samples from different locations. The cellulose content averaged 27.55%. The average cellulose content for wheat straw is 45 to 50%, and for wood biomass 40 to 50%. The share of lignin in analysed samples averaged 26.38%, which was in wheat 15 to 20%, and 20 to 25% for woody biomass [7]. The share of hemicellulose ranged, on average, 15.48%, which is lower than the biomass of wheat, 20 to 25%, or wood biomass, which is 25 to 30%.

Table 4 shows the total carbon, nitrogen, hydrogen, oxygen, and sulphur in ragweed biomass samples.

Table 4. The share of carbon, hydrogen, nitrogen, sulphur, and oxygen in the studied ragweed biomass

Samples location	Carbon (%)	Hydrogen (%)	Nitrogen (%)	Sulphur (%)	Oxygen (%)
I	61.68	5.36	7.55	0.31	25.10
II	64.99	6.54	8.85	0.34	19.38
III	57.51	6.18	8.36	0.37	27.58
IV	61.41	6.49	7.91	0.28	23.91
V	59.00	5.42	9.47	0.30	25.81
Average	**60.92**	**6.00**	**8.43**	**0.32**	**24.36**

The fundamental element of biomass is carbon, which makes up 30 to 60% of the dry matter, depending on the ash content [16]. Higher carbon content increases the energy value of biomass. Carbon is not free in biomass, but in organic compounds with oxygen, hydrogen, nitrogen, and sulphur. During combustion, carbon binds to oxygen and gives off significant amounts of heat energy. In total combustion, if combustion takes place with enough oxygen, CO_2 is released [17]. The mean value of the carbon content in the samples is 60.92%. In the research of Bilandžija (2014) on miscanthus culture, the percentage of carbon ranged from 48.55 to 48.72%. The carbon content of wood biomass is 51.6%, and of wheat 48.5%. According to these crops, ragweed has a significantly higher carbon content and, therefore, is suitable for energy production.

Hydrogen is, in addition to carbon, the essential component of the fuel, and biomass contains, on average, 5 to 6% hydrogen. Higher hydrogen content increases the energy value. The hydrogen content of the analysed samples was around 6.00%. According to Parmer [9], miscanthus contains 5.8% hydrogen, wood biomass 6.3%, and wheat 5.5% hydrogen. The analysed ragweed samples have a slightly higher hydrogen content than miscanthus and wheat crops, but a lower content than woody biomass.

Nitrogen is a macronutrient that is important for plant growth (Jenkins et al., 1998). The nitrogen content in biomass varies from 0.2% to more than 1% [9]. During combustion, nitrogen is released in the elemental state and acts as an inert ingredient, which means that it neither burns nor gives off heat. It negatively affects the activity of the elements with which is combined and reduces the calorific value. It can create undesirable nitrogen oxides (NO_x) that pollute the environment [17]. Nitrogen in the examined ragweed samples averaged 8.43% in all samples. The nitrogen content of miscanthus is 0.5%, and 0.3% of wheat [7]. Compared to other crops, ragweed tested contains large amounts of nitrogen, which reduces its calorific value.

Most of the biomass fuels contain less than 0.2% sulphur, with a few exceptions with a higher amount of 0.5 to 0.7% [9]. Sulphur in fuel can be combustible and non-combustible. Combustible sulphur is usually bound to organic matter or is in combination with metals. Non-combustible sulphur is stably bound in the form of calcium sulphate, which remains mainly in the ash during and after combustion [17].. Sulphur oxides (SO_x) are formed during combustion and affect environmental pollution. Biomass usually has a low sulphur content, and its combustion does not significantly contribute to sulphur emissions. In the analysed samples, the average sulphur value in ragweed biomass was 0.32%, which is higher compared to miscanthus, wheat, and wood biomass, which have 0.1% sulphur or less [7].

According to Jenkins et al. [16], the oxygen content in biomass ranges from 30% to 40%. The presence of oxygen in the fuel is undesirable because the oxygen does not burn, but it participates in combustion. It is most often found in compounds with other elements. It makes them non-combustible, so it reduces the effect of combustible elements with which they are combined, resulting in a decrease in the calorific value of fuel [17]. The oxygen content in the samples averaged 24.36%. The oxygen content in miscanthus is 43%, in wheat 44.5% [9], and in wood biomass 41.5% [7]. According to these cultures, the tested samples of ragweed have significantly lower oxygen content; therefore, they are better raw material for combustion processes.

The calorific value (higher and lower heating value) of fuel represents the amount of heat generated during the complete combustion of a certain amount of fuel [17]. The higher heating value (Hg) is the amount of heat generated by the complete combustion of a certain amount of fuel. Produced gasses are cooled to a temperature of 25 ° C and moisture is eliminated from them as condensate. The lower heating value (Hd) is the amount of heat generated by the complete combustion of a certain amount of fuel. Produced gasses are cooled to a temperature of 25°C, and the moisture in them remains in a vapor state, and the condensate heat remains unused. Table 5 shows the higher and lower heating values of ragweed samples from different locations.

Table 5. Higher and lower heating value in the investigated ragweed biomass

Samples location	Higher heating value (MJ/kg)	Lower heating value (MJ/kg)
I	16.60	15.43
II	15.93	14.50
III	16.49	15.14
IV	14.83	13.41
V	16.42	15.24
Average	**16.05**	**14.74**

The average higher heating value of ragweed biomass is 16.05 MJ / kg, and the average lower value of samples is 14.74 MJ / kg. In a study conducted by Bilandžija et al. [12], miscanthus has a higher heating value of 18 MJ / kg, which is slightly higher than the tested samples of ragweed biomass. Wheat straw (24.72 MJ / kg), barley (25.35 MJ / kg), oats (25.70 MJ / kg) and triticale (24.87 MJ / kg), from the research of Grubor et al. [14] their samples also have more eminent heating values than ragweed values investigated.

CONCLUSION

Based on the analysis conducted on ragweed biomass from five different locations in the city of Zagreb, the following can be concluded:

1. Analysis of ragweed biomass from different areas does not cause excessive deviations between samples,
2. Biomass has a favourable content of water, coke, volatile substances and heating values, but too high ash content and low content of fixed carbon. The lignocellulosic composition of ragweed is beneficial because it has desirable amounts of lignin and does not have too high a cellulose content. As for the elemental composition of biomass, ragweed samples have a favourable carbon and hydrogen content, but excessively high nitrogen.
3. According to the above data, ragweed biomass is a suitable raw material for the direct combustion process with unfavourable ash content. It could be used in the energy production process.

REFERENCES

[1] Galzina N., Barić K., Šćešanović M., Goršić M., Ostojić Z. (2010). Distribution of invasive weed *Ambrosia artemisiifolia* L. in Croatia. Agriculturae Conspectus Scientificus. 75 (2): 75-81

[2] Gajnik D., Peternel R. (2009). Methods of intervention in the control of ragweed spread (*Ambrosia artemisiifolia* L.) in the area of Zagreb county and the city of Zagreb. Coll. Atropol. 33(4): 1289-1294

[3] Novak N., Kravarščan M. (2011). Invazivne strane korovne vrste u Republici Hrvatskoj. Hrvatski centar za poljoprivredu, hranu i selo, Zagreb

[4] Lehoczky, E.; Busznyak, J.; Golya, G. (2013): Study on the Spread, Biomass Production, and Nutrient Content of Ragweed with High-Precision GNSS and GIS Device System; Communications in soil science and plant analysis; 44(1-4); 535-545

[5] Solter, U.; Verschwele, A. (2016): Suppressing common ragweed biomass with integrated farming methods; Halt Ambrosia - final project report and general publication of project findings; Book Series: Julius-Kuhn-Archiv.

[6] Basky, Z.; Ladanyi, M.; Simoncic, A (2017): Efficient reduction of biomass, seed and season long pollen production of common ragweed (Ambrosia artemisiifolia L.); Urban forestry and urban greeneng 24; 134-140

[7] McKendry P. (2002). Energy production from biomass (part 1): overview of biomass. Bioresource Technology 83: 37-46

[8] Krička, T.; Matin, A.; Voća, N.; Jurišić, V.; Bilandžija N. (2015): Reuse of rapeseed by-products from biodiesel pro-

duction; Spanish Journal of Agricultural Research; Vol.13; No.1; e02-007.

[9] Parmer K. (2017). Biomass – an overiew on composition characteristics and properties. *IRA*-International Journal of Applied Sciences 7(1), 42-51

[10] Ross C.J. (2008). Biomass drying and dewatering for clean heat and power. Northwest CPH apllication center, USA

[11] Garcia R., Pizzaro C., Lavin A.G., Bueno J.L. (2012). Characterization of Spanish biomass wasters for energy use. Bioresource technology 103: 245-258

[12] Bilandžija N., Leto J., Kiš D., Jurišić V., Matin A., Kuže I. (2014). The impact of harvest timing on proporties of *Miscanthus* x *giganteus* biomass as a CO_2 neutral energy source. Collegium antropologicum. 38 (1): 85-20

[13] Mohan A., Pittman C.U., Steele P.H. (2006) Pyrolysis of wood biomass for bio-oil: a critical review. Energy & fuel 20 (3): 848-889

[14] Grubor M., Krička T., Voća N., Jurišić V., Bilandžija N. (2015). Iskoristivost slame žitarica za proizvodnju zelene energije. Krmiva 57:63-68

[15] Bilandžija N. (2014). Perspektiva i potencijal korištenja kulture *Miscanthus* x *giganteus* u Republici Hrvatskoj. Inženjerstvo okoliša 2(1): 1-87

[16] Jenkins B.M., Baxter L.L., Miles Jr. T.R., Miles T.R. (1998). Combustion properties of biomass. Fuel processing tecnology 54: 17-56

[17] Šilić Đ., Stojković V.. Mikulić D. (2012). Goriva i maziva., Veleučilište Velika Gorica, Velika Gorica