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ENERGY VALUE OF AGRICULTURAL SPELT RESIDUE (TRITICUM SPELTA L.) – FORGOTTEN CULTURES

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Original scientific paper

Spelt (Triticum spelta L.), also known as dinkel wheat, or hulled wheat is one of the oldest crops. It originates from Asia. In Europe spelt was very important cereal during the Bronze Age and the Middle Ages. After the processing grains for food, biomass lags as a by-product or waste. Rising fossil fuel prices and increasing concerns about climate change are creating a growing demand for new sources of raw material for biomass combustion for sustainable heat production. In recent years studies have shown the positive effects of the use of agricultural residues for energy production. Grains of Spelt are processed into various purposes, while the chaff, glumes and stems remain as a by-product. Therefore, it is important to carry out research in order to determine energy characteristics of chaff, glumes and stems. This paper examined the two Spelt varieties: BcVigor and Ostro. Collected and homogenized samples were analysed by the energy characteristics: high (HHV) and lower (LHV) heating values of chaff, glumes and stems were determined by standard methods. The results obtained in this research showed that, after the use of Spelt grain for food, chaff, glumes and stems are representing by-product but also it is a high-quality raw material for energy production because of its high calorific values: the upper heating value in BcVigor stem was 17.367 MJ/kg and 17.224 MJ/kg in the Ostro stem, 16.402 MJ/kg in the Ostro chaff and glumes and 16.650 MJ/kg in the BcVigor chaff and glumes.

Keywords: *biomass; energy; environmental protection; Spelt*

Energetska vrijednost poljoprivrednih ostataka pira (Triticum spelta L.) − zaboravljene kulture

Izvorni znanstveni članak

Pir, krupnik ili dinkel (Lat. Triticum spelta) jedna je od najstarijih žitarica, a potječe iz Azije. Od brončanog doba do srednjeg vijeka u Europi je bio vrlo važna žitarica. Nakon upotrebe zrna u prehrambene svrhe ostaje biomasa pira kao nusproizvod odnosno otpad. Rastuće cijene fosilnih goriva i sve veće zabrinutosti oko klimatskih promjena stvaraju sve veću potražnju za novim izvorima sirovine za održivu proizvodnju topline. U posljednjih nekoliko godina istraživanja su pokazala pozitivne učinke uporabe poljoprivrednih ostataka za proizvodnju energije. Zrno pira prerađuje se u različite svrhe, dok pljeve, pljevice te stabljika zaostaju kao nusproizvod odnosno ostatak u proizvodnji. Stoga je značajno provesti istraživanje kako bi se utvrdila energetska (goriva) svojstva pljeve i pljevice te stabljike pira. U radu su obuhvaćene dvije sorte pira BcVigor i Ostro. Nakon prikupljenih i homogeniziranih uzoraka za svaku sortu određene su gornje i donje ogrjevne vrijednosti (Hg i Hd). Rezultati dobiveni u ovom istraživanju pokazali su da su pljeve i pljevice te stabljika pira, kao ostatak nakon upotrebe zrna u prehrambene svrhe, vrlo kvalitetna sirovina za proizvodnju energije zbog svoje visoke ogrjevne vrijednosti: gornja ogrijevna vrijednost stabljike sorte BcVigor iznosi 17.367 MJ/kg, a stabljike sorte Ostro 17.224 MJ/kg dok gornja ogrijevna vrijednost pljeve i pljevice sorte Ostro iznosi16.402 MJ/kg, a sorte BcVigor 16.650 MJ/kg.

Ključne riječi: *biomasa; energija; pir; zaštita okoliša*

1 Introduction

Spelt (Triticum Spelta L.) is annual grass in the Poaceae (grass family) native to the Mediterranean region and southwest Asia. It is one of the oldest known wheat types, also known to Egyptians because the oldest findings of this wheat type were found in the Nile valley and they date from the 5000 B.C. Spelt was an important grain in Europe from the Bronze Age until medieval period, when it was largely replaced by other forms of wheat (T. aestivum and T. durum, durum wheat). By creating high-yielding common wheat this very important species almost vanished and was maintained only in gene banks worldwide. Spelt has received attention again in the past two decades along with the development of environmental awareness of the population in Switzerland, Austria and later in other developed countries of Western Europe and North America [1].

Spelt is very resistant crop suitable for organic farming. It requires less fertilizer and pesticides than other forms of wheat. By including Spelt in organic production it is possible to increase the diversity of grains in the human diet [2].

Nutritional value of spelt is similar to the nutritional value of wheat. It contains all the basic components which are necessary for human beings: proteins, unsaturated fats, vitamins (A, C, B group), minerals (calcium, cobalt, iron, phosphorus, magnesium, manganese, potassium, copper, selenium, sodium) and fibres [1]. It also retains a high antioxidant properties (selenium prevents the formation of free radicals) and therefore is especially suitable for people exposed to stress, for menopausal women and the elderly. Being rich with fibres, it is of great use in diets for weight loss (quickly spread a feeling of satiety and facilitates the work of the intestine), and because of the richness in carbohydrates, iron and calcium is recommended for athletes, anaemic persons and those suffering from osteoporosis. The unique nutritional and rheological properties of the grains tend to increase the nutritional value of bakery products [3].

Reviewing past literature we have found that previous work has only focused on nutritional spelt value. Outlining similarities with other authors' results is not possible because, as far as we know there is no paper which investigates energy value of agricultural spelt residue.

The need for energy is constantly growing and requires the use of all available technologies, because almost all human activity on earth is based on the use of some of the available forms of energy [4].

Considering the fact that the sources of oil and natural gas are not exhaustive, there is a need to develop renewable energy sources which can be a solution in case of a possible energy crisis. In addition to the security of energy supply, one of the main objectives of European energy policy focuses on the protection of the environment through reduced energy consumption and greater use of renewable energy sources. The energy sector creates a significant impact on the environment, whether it is on a local, regional or global impact. Therefore, energy and development issues must be addressed in the context of two very strongly interlinked and the key issues - energy security and climate change [5].

Climate change, global warming and greenhouse gas emissions have become a priority issue of global development. The main challenge is long-term development of the economy with reduced emissions of carbon dioxide. The goal is a more efficient use of energy, renewable energy, use of energy sources that do not produce greenhouse gases and more efficient transportation system with increased use of neutral fuel with regard to CO2 emissions. Using renewable energy sources improves the security of energy supply and gives impetus to the development of domestic production of energy equipment and services, as well as the achievement of environmental objectives [5, 6 and 7].

The economies of the Western world were faced with a series of ups and downs. The last global recession that began in 2008 in the United States and then spread throughout the world has opened up new questions about the connection between the financial crisis with the energy crisis and climate change. There are more open debates about the human relationship to nature and the environment. Energy, as an essential element driving the economy and all social activities, is one of the fundamental questions for Europe [8].

Total world resources of biomass have the theoretical potential which is ten times larger than the world's total primary energy consumption, which is about 7 billion tons of oil equivalent per year. Total biomass energy potential, which is growing in the country, estimated at 70 billion tons oil equivalent. World oil and gas reserves are estimated at 50÷70 years, while the estimate for coal about 200 years. Considering already mentioned problems with global warming, it is not acceptable to continue with the current model of using fossil fuels. It is necessary gradually replacing them with renewable energy sources [9].

The need to protect the environment while simultaneously increasing agricultural production can be found in political and research agendas worldwide [10].

The European Commission has adopted a series of regulations and directives to extensively support the consumption and production of green energy from renewable energy sources, primarily because of critical necessity to mitigate negative influence of fossil fuels on the environment [11].

Much has been achieved since the EU adopted its first package of climate and energy measures in 2008. While progressing in meeting its climate and energy targets for 2020, EU countries have agreed on a new 2030 Framework for climate and energy, including EU-wide targets and policy objectives for the period between 2020 and 2030:

- a 40 % cut in greenhouse gas emissions compared to 1990 levels
- at least a 27 % share of renewable energy consumption
- at least 27 % energy savings compared with the business-as-usual scenario (2030 framework for climate and energy policies, 2015).

Sustainable agriculture is one of the European Commission's key objectives aimed at supplying sufficient food, feed, biomass, and raw materials while safeguarding natural resources and mitigating climate change [10].

2 Agricultural biomass as feedstock for biofuels

The energy stored in biomass can be released to produce renewable electricity or heat. Biomass is the first and oldest source of energy that people used to form a variety of wood residues that are collected and used for heating, cooking and other purposes. Until the beginning of the intensive use of fossil fuels, whose use has greatly influenced the development of civilization, biomass was the primary and almost only source of energy. Even today, biomass is the only source of fuel for domestic use in many developing countries. After intensive use of fossil fuels and their negative impact on the environment, biomass is becoming a significant source of energy and interest in biomass use begins to rise again [11 and 12].

In the 1980s in Europe agricultural production shows a surplus of grains, especially wheat. In fact, due to higher yields obtained from wheat and corn, this crop "pushed out" oil seeds. It was considered that the solution is in the export of the surplus. However, all countries that produced cereals had a similar development. The prices in the world market were no longer agriculturally oriented as a result of political actions [13 and 14]. At the same time, after extensive energy research, it was obvious that sources of fossil fuels will be largely exhausted by the end of the 21st century.

It will be necessary to find new sources of energy, because the consequences of energy resources disappearance are almost unimaginable [4, 5, and 11].

Biomass is a renewable source of energy, and through a process of photosynthesis with the help of sunlight on organic matter. Biomass is defined as 'the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste. Biomass can be converted through different processes into solid (briquettes, cubes, and pellets), liquid (bioethanol, propanol, and butanol via cellulose process), and gaseous (e.g., methane via anaerobic digestion) fuels [2, 6 and 15].

The use of agricultural biomass for energy production including Spelt biomass has a number of advantages, both in the energy sector and in the sector of agriculture and environmental protection. Some of these advantages are [16]:

- reducing dependence on fossil fuels
- increasing the number of possible sources of energy
- greater security of energy supply
- competitiveness and sustainability
- reducing greenhouse gas emissions.

It should also bear in mind the socio - economic aspects since the use of biomass provides employment and the creation of new and existing jobs, increasing local and regional economic activity and additional income in agriculture, forestry and wood industry through the sale of biomass as fuel.

The main advantage of biomass compared to fossil fuel is its renewability. Impact on the atmosphere with CO_2 using biomass as fuel is negligible. Biomass utilization on a global scale could contribute to environmental protection, having in mind that biomass sources are CO_2-neutral because all the CO_2 from biomass combustion is absorbed during new biomass growing to be used for the same purpose. Most bio fuels limit greenhouse gas emissions by more than 30 % compared to fossil fuels [17].

Lately, it becomes more and more obvious that today's energy consumption is unsustainable. Biomass is not just potentially renewable but it is enough similar to fossil fuels that it can directly be a substitute [7 and 16].

Therefore, the world community in 1990s began to discuss how to mitigate the alleged damage. Limitation of the amount of fossil fuels, their increasing prices and the impact of fossil fuels on air pollution represents a strong argument in favour of the growing expansion of the use of biofuels.

According to Directive 2009/28/EC biofuels are liquid or gaseous fuels derived from biomass. Biofuels today represent one of the most valuable forms of renewable energy because of the numerous possibilities of use [11]. The various biofuel production technologies available are contributing to the solving of economic and ecological problems [18 and 19]. Biofuel production technologies have developed and today, besides first generation technologies, second generation technologies are already in use.

Due to the limited amount of sugar, starch and oil resources 2nd generation biofuels is derived from lignocellulose biomass.

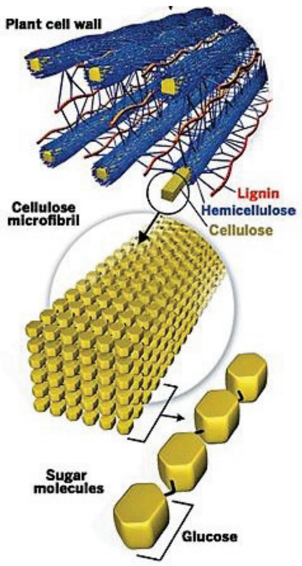

Figure 1 Lignocellulose biomass

The goal of second generation biofuel processes is to extend the amount of biofuel that can be produced sustainably by using biomass consisting of the residual non-food parts of current crops, such as stems, leaves and husks that are left behind once the food crop has been extracted, as well as other crops that are not used for food purposes (non-food crops), such as plants and trees grown for energy production (Miscanthus, Sudan grass), and biodegradable fraction of waste [13 and 20].

Since the raw material for second-generation biofuels is not suitable for human consumption, thus it means avoiding the frequent objection to the first generation to turn food into fuel. Lignocellulose refers to plant dry matter (biomass), so called lignocellulosic biomass. It is the most abundantly available raw material on the Earth for the production of biofuels. It is composed of [20]:

- lignin (15÷20 %) - a key component of the cell wall and forms a protective layer between the cellulose and hemicellulose
- hemicellulose (25÷35 %) - of short polymers of various sugar sticking together bundles of cellulose together
- cellulose (40÷50 %) - consisted of a long series of interrelated disaharidacelobioze molecules.

Technologies for energy use of agriculture residues are different so it is not so easy to use agriculture biomass for liquid, gas or solid fuel. The process and method, pretreatment of lignocellulosic biomass and also the availability of the resources are important factors for high shares of biomass to penetrate the electricity, heat or liquid fuel markets.

3 Materials and methods

Laboratory investigations were carried out at the University of Zagreb, Faculty of Agriculture, in the Department of Agricultural Technology, Storage and Transport laboratory. In this investigation, two Spelt cultivars, BcVigor and Ostro, were used. Spelt was grown in experiment station of Department of Field Crops, Forage and Grassland, Maksimir, Zagreb in 2014.

Samples were ground in a laboratory grinder (IKA Analysentechnik GmbH, Germany). Each sample was analysed at least three times to provide reproducibility of the analyses.

High heating value (HHV), one of the basic parameters of energy value of a fuel, was determined by ISO method (EN 14918:2010) using an IKA C200 oxygen bomb calorimeter (IKA Analysentechnik GmbH, Heitersheim, Germany). A total of 0.5 g of sample was weighed in a quartz crucible and put in a calorimeter for combustion. Higher heating value was obtained after combustion, by using the IKA C200 software. Heating value is reported in MJ/kg on dry basis.

Lower heating value (LHV), also called net heating value, is determined by subtracting the heat of vaporization of the water vapour from the higher heating value.

4 Results and discussion

Calorimetry is considered as the most influential analyse, since it gives the exact data about the heating value of a specific sample [21]. The calorific value of the spelt biomass samples was determined using the method described above. Table 1 shows calorific values of investigated samples.

Table 1 Calorific values of Spelt biomass

Variety	HHV (MJ/kg)	LHV (MJ/kg)
BcVigor Chaff and glumes	16.650	15.300
Ostro Chaff and glumes	16.402	15.052
BcVigor Steams	17.367	15.932
Ostro Steams	17.224	15.789

It was found that there is no difference between varieties BcVigor and Ostro considering their upper heating value as the total average higher heating value in the chaff and glumes and steam of the variety BcVigor is 17.009 MJ/kg, and the variety Ostro 16.813 MJ/kg, but the analysis of data in Table 1 shows difference between the upper caloric value of chaff and glumes compared with stems of both cultivars. The highest heating value is defined in the stem of variety BcVigor (17.367 MJ/kg). A slightly lower higher heating value determined in the steam of the variety Ostro (17.224 MJ/kg), while the lowest higher heating value was found in the chaff and glumes (HHV of chaff and glumes of the variety BcVigor is 16.650 MJ/kg, and HHV of the chaff and glumes of the variety Ostro is 16.402 MJ/kg). These values are slightly lower than those reported by Krička et al. [19] as the average higher heating value of the biomass of wheat (17.953 MJ/kg), and lower than HHV of wheat straw reported by Naik et al [22] in their research where they presented study in which were selected different origin of biomass such as agriculture residue, wild grass and forest residue. The basic objective of their study was to select the potential candidates from different type of biomass and evaluate the potential of these biomasses as feedstock for the production of biofuel based on their physical and chemical characterization. Five biomasses, including the wheat straw mentioned above, were characterized using thermo-chemical methods: wheat straw, barley straw, flax straw, timothy grass and pinewood [22].

Wheat plays a major role among the few species widely grown as food sources and likely was central to the beginning of agriculture. Approximately one-sixth of the total arable land in the world is cultivated with wheat. Wheat straw is a major agricultural by-product that has been successfully utilized as a raw material in energy sector [24]. It is observed that wheat straw, according to Naik et al., shows high calorific value (20.3 MJ / kg) compared to spelt steams, chaff and glumes conducted in this research [22].

Barley is one of the major crops in the world and barley straw is a significant raw material used in cellulose production as an energy resource and in agriculture as ruminant feed [23]. It is observed that barley straw, according to Naik et al., shows low calorific value (15.7 MJ / kg) compared to spelt steams, chaff and glumes conducted in this research [22].

Flax straw has a heating value per tonne similar to soft coal and it is cheaper than conventional fuels. It is observed that flax straw, according to Naik et al., also shows low calorific value (17.0 MJ/kg) compared to spelt steams (17.367 MJ/kg variety BcVigor and 17.224 MJ/kg variety Ostro), but HHV of flax straw is higher than HHV of chaff and glumes conducted in this research (16.650 MJ/kg variety BcVigor and 16.402 MJ/kg variety Ostro) [22].

Timothy grass is commonly grown for cattle feed and as hay for horses. It is relatively high in fibre so it makes a very high energy feed, especially for work horses. Timothy grass biomass can also be utilised for bio-fuel production [22]. It is observed that timothy grass, according to Naik et al., also shows low calorific value (16.7 MJ/kg) compared to spelt steams (17.367 MJ/kg variety BcVigor and 17.224 MJ/kg variety Ostro), and HHV of chaff and glumes conducted in this research are quite similar (16.650 MJ/kg variety BcVigor and 16.402 MJ/kg variety Ostro) to HHV of timothy grass reported by Naik et al [22].

Pinewood biomass is generated in the process of making of small pieces, which is a source of waste biomass [15]. It is observed that pinewood biomass, according to Naik et al., shows high calorific value (19.6 MJ/kg) compared to spelt steams, chaff and glumes conducted in this research [22].

Very similar differences were obtained and the calculation of lower heating value (LHV), which is also slightly higher in the stem of both cultivars (BcVigor: 15.932 MJ/kg; Ostro: 15.789 MJ/kg) than in the chaff and glumes (BcVigor: 15.300 MJ/kg; Ostro: 15.052 MJ/kg). LHV of the studied Spelt varieties is also smaller than the average lower heating value of the biomass of wheat (16.443 MJ/kg) according to Krička et al. 12] and according to Naik et. al (20.3 MJ/kg) [22].

This high calorific value especially of spelt steams compared to barley straw, flax straw and timothy grass biomass [22] shows that spelt biomass has potential for the production of bio-energy.

5 Conclusion

Spelt is an old and almost forgotten culture, which comes back to a growing number of producers and consumers because there is great potential to expand the cultivation of this crop because of its nutritional and energy value, and due to favourable climatic conditions for growing throughout Croatia.

The results obtained in this research showed that, after the use of Spelt grain for food, chaff, glumes and stems are representing by-product but also it is high-quality raw material for energy production, because of its high calorific values: the upper heating value in BcVigor stem was 17.367 MJ/kg, 16.650 MJ/kg in the BcVigor chaff and glumes, 17.224 MJ/kg in the Ostrostem and 16.402 MJ/kg in the Ostro chaff and glumes.

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