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Determination of Energy Parameters and Their Variability between Varieties of Fodder and Turf Grasses

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Abstract: Due to the need to diversify energy sources and transform the energy system and its decarbonization, new paths for obtaining raw materials are being sought. One of the potential options is to increase the use of grasses' share in bioenergy production, which has a significant area potential. However, the diversified chemical composition of grasses and their anatomical heterogeneity mean that, between the various cultivars and species, the parameters determining their energetic usefulness may differ significantly, hence the key is to know the appropriate parameters at the variety level of a given species in order to effectively carry out the combustion process. In this experiment, a total of 23 varieties of seven grass species (Kentucky bluegrass (*Poa pratensis* L.), Red Fescue (*Festuca rubra* L.), Perennial Ryegrass (*Lolium perenne* L.), Meadow Fescue (*Festuca pratensis* Huds.), Timothy (*Phleum pratense* L.), Common Bent (*Agrostis capillaris* L.), Sheep Fescue (*Festuca ovina* L.), which had not yet been evaluated in terms of energy utilization, were tested. Proximate analysis showed the average ash content was in the range of 5.73–8.31%, the content of volatile matter in the range of 70.99–82.29% and the content of fixed carbon in the range of 5.96–17.19%. Higher heating value and lower heating value of grasses ranged from 16,548–18,616 kJ·kg^{-1}, 15,428–17,453 kJ·kg^{-1}, respectively. The Sheep Fescue turned out to be the most useful species for combustion. It has been shown that there may be statistically significant differences in the parameters determining their combustion suitability between the various varieties of a given species of grass. Therefore the major finding of this work shows that it is necessary to need to know theparameters of a given variety is necessary to optimize the combustion process and maintain the full energy efficiency of the system (especially lower heating value).

Keywords: fodder grasses; turf grasses; proximate analysis; higher heating value; lower heating value; bioenergy potential

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1. Introduction

Increasing the use of biomass in the production of electricity and heat is one of the key elements in meeting the global goals related to the transformation of the energy system and its decarbonization. Bioenergy is defined as one of the key environmental factors, as it provides sustainable energy from renewable biomass. Additionally, by being efficiently converted into energy, it can enable the production of other materials such as chemicals, fertilizers and plastics [1,2]. In 2019, bioenergy accounted for approximately 55% of renewable energy in the European Union (EU), the vast majority (75%) of which was the result of using wood biomass [3]. The nearest forecasts related to energy and climate policies and strategies estimate further increases in the level of biomass use and its demand, dictated by factors such as political priorities, principles of accounting for greenhouse gases and subsidies for biomass [4]. Unfortunately, the further increase in the use of forest biomass in the production of electricity and heat raises concerns about sustainability. They mainly concern environmental issues, related to, inter alia, reduction of biodiversity, deforestation, loss of soil productivity, soil erosion and acidification, moisture retention and reduction of soil C resources. The social issue is also important, related to the fear of losing visual aesthetics, recreational function and cultural, historical and archaeological sites [5]. In addition, according to the Institute for European Environmental Policy, the fact that the current average amount of forest biomass, aimed at meeting existing needs, is 12% higher for 2030 and 17% higher for 2050 than the average amount of available "sustainable 'biomass" may indicate that biomass is sourced too intensively from these ecosystems and needs to be reduced [4].

Therefore, it is necessary to search for alternative directions and sources in using biomass for the production of electricity and heat. One potential option is to increase the use of grasses for bioenergy production. The studies conducted so far have confirmed that both perennial and annual grasses can play a key role in the implementation of lignocellulosic biomass for various energy purposes [6]. An analysis by Wicke et al. [7] showed that the sustainable intensification of temporary grasslands can provide a total of 853 kha of surplus area for energy production in the European Union. Such action would allow the production of 3.7 to 11 million tonnes of dry mass of biomass, depending on the degree of use of conventional grass species and grassy energy crops, which could be tantamount to obtaining additional energy potential in the amount of 67–213 PJ·year^{-1} [7]. The importance of grassy biomass and its potential was also confirmed in the Biomass Policies project [8].

The use of grassy biomass is also associated with several advantages, which include increased control of greenhouse gas emissions, economic competitiveness in relation to fossil fuels, ensuring local energy security through the use and processing of local raw materials, energy conversion efficiency (grass pelleting ratio was estimated at 14:1), soil protection, rural development, or integration with existing agricultural systems [9]. The key issue is that the use of biomass as a renewable energy source can be one of the main drivers of sustainable development and of reducing or cutting energy dependence on fossil fuels [10]. Building or modernizing biomass power plants is very beneficial from the social perspective—it creates additional jobs, helps local economic development and prevents soil erosion [10]. On the other hand, it is worth emphasizing that the use of grasses in small-scale combustion devices often causes significant operational problems related to bottom ash slag, deposit formation and increased gas and particulate emissions [11], but some of these problems can be reduced by various solutions [12–16].

With regard to increasing bioenergy production from grasses, it is most often mentioned that the ideal varieties of feedstock for the circular economy are miscanthus (*Miscanthus* × *giganteus* Greef et Deuter), reed canary grass (*Phalaris arundinacea* L.), bulbous canary grass (*Phalaris aquatica* L.), switchgrass (*Panicum virgatum* L.) and giant reed (*Arundo donax* L.) [17,18]. These species are indeed valued for their high biomass yield and other environmental benefits. Nevertheless, it is important to diversify the sources of biomass, without the need to transform the land or the cultivation system. Therefore, the use of fodder and turf grasses may be an interesting option for the bioenergy industry. They are mentioned much less frequently in the context of increasing the share of biomass production, but their species diversity is favorable for cultivation in various climatic conditions. The conducted research proved that their intensive cultivation may play a significant role in the production of biomass [19] and the decisive element opening the possibilities of using forage grasses as a renewable energy source was the reduction of the demand for silage, hay and pasture fodder from permanent grassland [20]. This is partly related to the decline in the profitability of animal husbandry and changes in feeding habits [20]. It is estimated that in the European Union in 2020 there was an approx. 9% decrease in the number of bovine animals, approx. 11% decrease in the number of goats and approx. 16% decrease in the number of sheep compared to 2001 [21]. In this case, the surplus of biomass from unmown or mowed but not harvested meadows, pastures and lawns can be used for energy purposes and to a measurable extent replace conventional fuels in households and local energy centers, thus also preventing the degradation of these areas resulting from their abandonment [20,22]. In addition, the use of fodder and turf grasses would not require changing the cultivation system, which would occur in the event of the need to convert to the above-mentioned energy plants.

Some of the research work carried out earlier has provided information on the energy parameters of fodder and turf grasses [23–26]. These parameters are necessary for the assessment of biomass energy recovery potential [27]. Unfortunately, a high proportion of grass species has still not been analyzed for energy use, so there is a large scientific gap that needs to be filled. In addition, most of the research work undertaken to study the potential of energy use of grasses focuses on the species, without giving details about the variety of grass. In the context of the energy use of fodder and turf grasses, knowledge of the variety of a particular species is particularly important, as individual varieties may significantly differ in the dynamics of growth, development and chemical composition, which is reflected in the energy value. Stolarski et al. [28], while examining the yield and yield energy value of 26 genotypes of perennial plants (including grasses) in three annual harvest cycles, found statistically significant differences in the yield energy value between genotypes, which may significantly determine the economic efficiency of using a given type of biomass for energy purposes. Fijałkowska and Styszko [29], who confirmed that the plant variety is one of the important factors determining energy usefulness, also found differences in heating value between different willow clones. In addition, with the potential use of only surplus biomass for energy purposes, the legitimacy of knowing a given variety of a particular type of grass is necessary, because farmers, depending on the final use of the crop (greenfeed, silage, swath grazing), choose varieties which are significantly different in terms of yields and their quality [30]. Therefore, when assessing energy suitability, it is necessary to evaluate numerous varieties of a given type of biomass, which will allow for more accurate analyzes in the field of energy potential estimation and avoid errors related to inefficient operation of the installation.

Taking into account the above arguments, this study aims to: (i) determine the most important energy parameters for suitability for combustion (based on proximate analysis) of the previously undervalued species and varieties of forage and turf grasses; (ii) check the variability of energy parameters between different varieties of a given species and between species.

2. Materials and Methods

2.1. Species and Varieties of Grasses

Seven species of grasses were analyzed—Kentucky Bluegrass (*P. pratensis* L.), Red Fescue (*F. rubra*), Perennial Ryegrass (*L. perenne* L.), Meadow Fescue (*F. pratensis* Huds.), Timothy (*P. pratense* L.), Common Bent (*A. capillaris* L.), Sheep Fescue (*F. ovina* L.). A total of 23 varieties were tested. Table 1 presents the tested varieties of the given species.

Table 1. Species and varieties of grasses analyzed.

Species	Varieties
Kentucky Bluegrass (*P. pratensis* L.)	Tecza
	Alicja
	MHR-NT-1419

Table 1. *Cont.*

Species	Varieties
Kentucky Bluegrass (*P. pratensis* L.)	Morfa
	MHR-NT-1318
	Struga
	Harfa
Red Fescue (*F. rubra* L.)	Nimba
	Oaza
	Leo-pol
	Adio
	Nawojka
Perennial Ryegrass (*L. perenne* L.)	Pinia
	Info
	Nira
	Gazon
Meadow Fescue (*F. pratensis* Huds.)	Kaskada
	Fantazja
	Skiba
Timothy (*Ph. pratense* L.)	Egida
	Skald
Common Bent (*A. capillaris* L.)	Liryka
Sheep Fescue (*F. ovina* L.)	Noni

2.2. Experiment Field

Field experiments were carried out at the Plant Breeding Station in Polanowice (50°20′ N, 20°08′ E) and Nieznanice (50°91′ N, 19°31′ E). The soil conditions are presented in Table 2. The experiment was set up using the randomized block method in three replications.

Table 2. Soil Properties at Plant Breeding Stations.

Description	Nieznanice	Polanowice
Soil Type	brown	Degraded chernozem delivered from loess
Complex agricultural suitability	rye, good	wheat, very good
Class of soil valuation	IIIb	I
Soil pH in KCl	6.0	7.2

In the years of full use, the following fertilization was applied: for the first cut, 80 kg N·ha^{-1}, after the second and third cut, 60 kg N·ha^{-1}, each in the form of ammonium sulphate and phosphorus, once in the fall of the year preceding harvest in an amount of 120 kg P_2O_5·ha^{-1}, in the form of triple superphosphate and potassium in a dose of 60 kg K_2O·ha^{-1} as 57% in the form of potassium salt.

The area of the experimental plots was 10 m^2. Plants were mowed with a bar mower to a height of 6–7 cm at the beginning of the heading phase and the next mowing was performed 7 weeks later. The size of the sample taken for further chemical analysis was 500–600 g of dry mass.

2.3. Energy Properties Determination

Physicochemical parameters of the analyzed grasses in the context of their energy utilization were determined using the following methods:

- Moisture Content (MC) in Drying Chamber KBC-65 W (WAMED, Warsaw, Poland) using PN EN ISO 18134-2:2017-03E [31];
- Volatile Matter Content (VMC) in Muffle Furnace SNOL 8.2/1100 (RADWAG, Radom, Poland) using PN EN ISO 18123:2016-01 [32];
- Ash Content (AC) in Muffle Furnace SNOL 8.2/1100 (RADWAG, Radom, Poland) using PN EN ISO 18122:2015 [33];
- Fixed Carbon Content (FCC) using appropriate formula according to ASTM-D-3172-73 [34];
- Higher Heating Value (HHV) in calorimetric bomb IKA C200 (IKA, Lucknow, India) according to PN-EN ISO 18125:2017-07 [35];
- Lower Heating Value (LHV) using the appropriate formula on the basis of the previously determined HHV and MC in the analytical dry state according to FAO [36].

2.4. Statistical Analysis

In order to show statistically significant differences between the varieties and species of grasses, a one-way analysis of variance (ANOVA) was performed with the Tukey HSD post hoc test. Statistical analysis was performed in the Statistica 13.0 (StatSoft—DELL Software, TX, USA) program at the significance level of $p = 0.05$.

3. Results

Figure 1 shows the ash content among the analyzed varieties of given grass species. The value of this parameter, among all 23 varieties, ranged from 5.73% ± 0.19% (Kentucky Bluegrass var. Struga) to 8.31% ± 1.06% (Red Fescue var. Leo-Pol). The highest average values of ash were obtained for the Timothy varieties (7.48% ± 0.50%) and red fescue varieties (7.25% ± 0.90%), while the lowest for the cultivars of meadow fescue varieties (6.69% ± 0.78%), Kentucky Bluegrass varieties (6.56% ± 0.58%) and perennial ryegrass varieties (6.53% ± 0.66%). Species in which only one variety was tested had an ash content of 7.47% ± 0.75% (Common Bent var. Liryka) and 7.94% ± 0.64% (Sheep Fescue var. Noni). It should be noted that, in the case of most species and varieties, the ash content was at a similar level, hence no large amount of statistically significant differences between the substrates was noted. About the varieties of one species, statistically, significant differences were observed between the varieties of Red Fescue—var. Leo-Pol and var. Nimba.

Figure 2 shows the content of volatile matter of the analyzed varieties of given grass species. The level of this parameter was much more diversified compared to the ash content and ranged from 70.99% ± 0.66% (Kentucky Bluegrass var. Harfa) to 82.29% ± 0.75% (Perennial Ryegrass var. Gazon). Among the species in which at least two cultivars were tested, the average content of volatile substances was in the Timothy—77.96% ± 0.28%—and the lowest in the Kentucky Bluegrass—74.19% ± 2.77%. It is also worth emphasizing that Sheep Fescue var. Noni was characterized by a high content of volatile substances—79.68% ± 0.30%. The performed statistical analysis showed a high variability of the parameter in relation to the varieties of the same species—in the case of Kentucky Bluegrass, the content of volatile matter in the Tęcza variety was statistically significantly different from the Alicja, MHR-NT-1419, MHR-NT-1318, Morfa and Harfa varieties. In the case of this species of grass, statistical differences also applied to the Struga variety—the mean content of volatile matter was statistically higher than in the Harfa and Morfa varieties. In the case of the Perennial Ryegrass and Red Fescue varieties, it was observed that the varieties with the highest amount of volatile matter (Perennial Ryegrass var. Gazon and Red Fescue var. Nimba) differ statistically from the other varieties of these species. The varieties of Meadow Fescue and Timothy did not differ statistically in terms of the content of volatile matter. Detailed results of the statistical analysis are included in the Appendix A (Tables A1–A5).

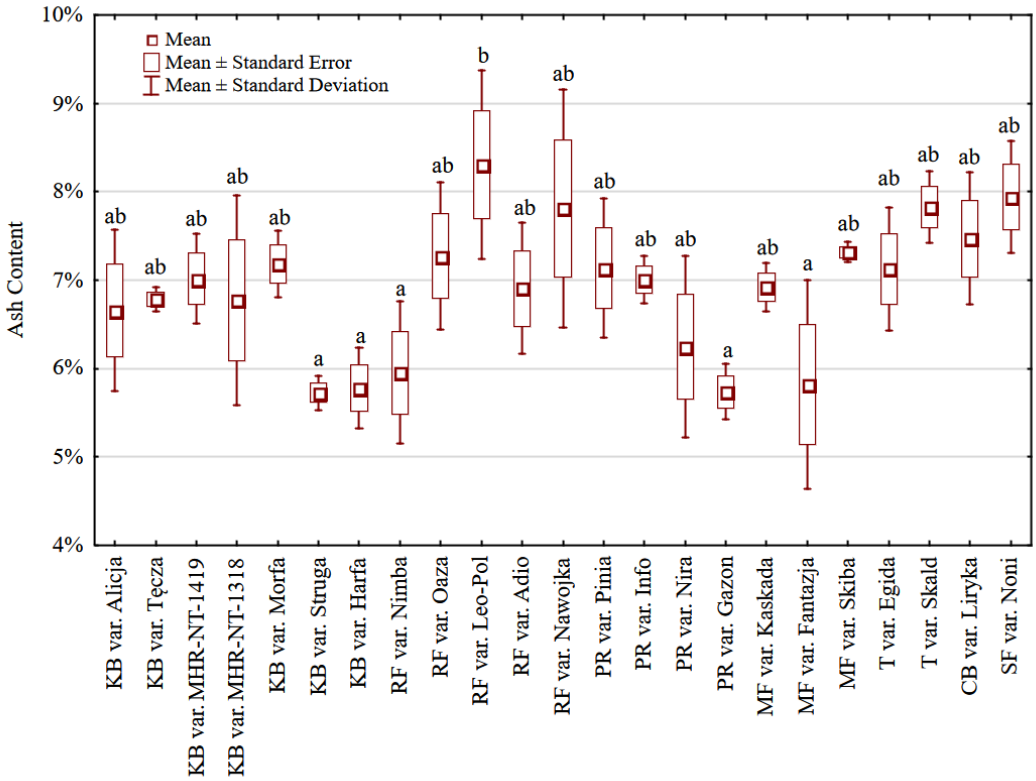

Figure 1. Ash content in the analyzed varieties of grasses; the same markings (a, b, c . . .) indicate no statistically significant differences between the means according to the Tukey HSD test at the significance level $p < 0.05$.

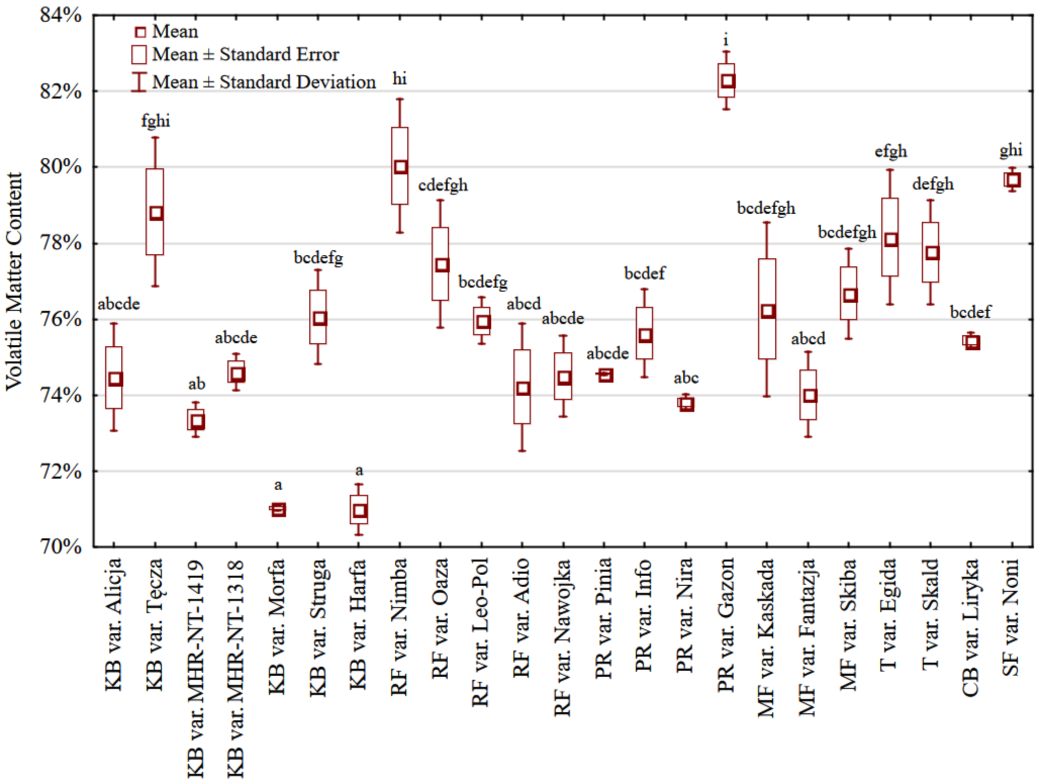

Figure 2. Volatile matter content in the analyzed varieties of grasses; the same markings (a, b, c . . .) indicate no statistically significant differences between the means according to the Tukey HSD test at the significance level $p < 0.05$.

Figure 3 shows the content of fixed carbon of the analyzed varieties of a given species of grass. This parameter informs of the content of flammable solids that are available in the test substance. It acts as the main source of heat during burning biomass and its high content indicates that the biomass will require a long combustion time [37]. Among all 23 analyzed varieties, as in the case of volatile matter, Kentucky Bluegrass var. Harfa was characterized by the highest parameter content—17.19% ± 0.47%—and the lowest was Perennial Ryegrass var. Gazon—5.96% ± 0.53%. This is due to the fact that thermally or thermochemically unprocessed biomass contains a large proportion of volatile compounds and the fixed carbon parameter is the remainder of the material after subtracting volatile matter, ash and moisture. Hence, the mean value of the parameter was 11.22% ± 2.91%. Among the species where at least two varieties were analyzed (Kentucky Bluegrass, Red Fescue, Perennial Ryegrass, Meadow Fescue, Timothy), the most fixed carbon was present in Kentucky Bluegrass—13.41% ± 2.70%. The smallest value, in turn, was in Timothy—8.57% ± 0.29% (average species value). It is also worth noting that Sheep Fescue var. Noni contained 6.86% ± 0.57% fixed carbon content.

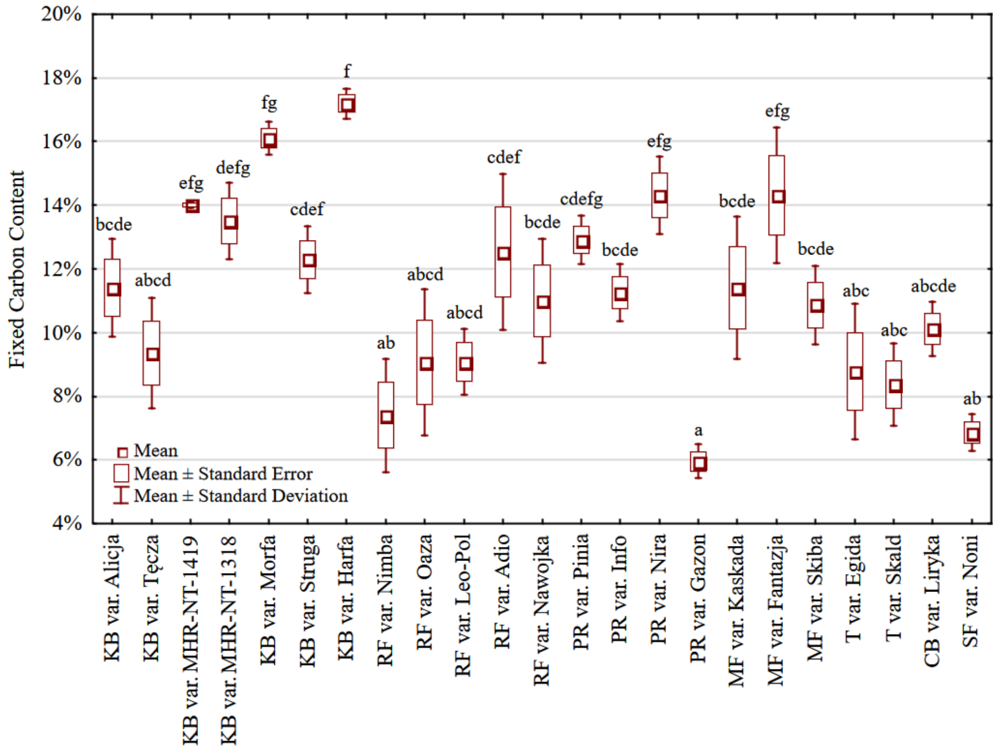

Figure 3. Fixed carbon content in the analyzed varieties of grasses; the same markings (a, b, c . . .) indicate no statistically significant differences between the means according to the Tukey HSD test at the significance level $p < 0.05$.

The performed statistical analysis confirmed that there are statistically significant differences in the content of fixed carbon between the varieties of the given species. The most commonly observed differences were noted in the case of Kentucky Bluegrass varieties. Timothy was the only species where no statistically significant differences in the content of fixed carbon were observed in the varieties tested. It is worth emphasizing, however, that only 2 varieties of Timothy grass were analyzed; therefore, to confirm the validity of this claim, it would be necessary to analyze more varieties in the future.

The distribution of the proximate analysis components is shown in the ternary diagram (Figure 4). This tool is a barycentric plot of three variables in an equilateral triangle that sum up to a constant value [38]. The points have a typical spread for unprocessed plant biomass. The close value of the proximate content and a similar position on the chart characterize most of the studied varieties and species of grasses. It is true that, based on statistical analysis, it is possible to group species according to proximate content, but it should be noted that only three varieties stand out from the rest—these are characterized by especially high (Perennial Ryegrass var. Gazon) and low (Kentucky Bluegrass var. Morfa and var. Harfa) volatile matter content. Additionally, for comparative purposes on the ternary chart, other types of fuels were included, collected from [39], to visualize the composition of proximate components in other types of fuels. Component dispersion was compared to conventional fuels—Spanish Alcorisa lignite [40], Polish bituminous coal [41], Australian bituminous coal [42], Chilean sub-bituminous coal [40]; biomass fuels—waste wood [43], sawdust [43], pinewood [44]; and waste fuels—mixed food waste [45], solid recovered fuel [46] and mixed plastic waste [47].

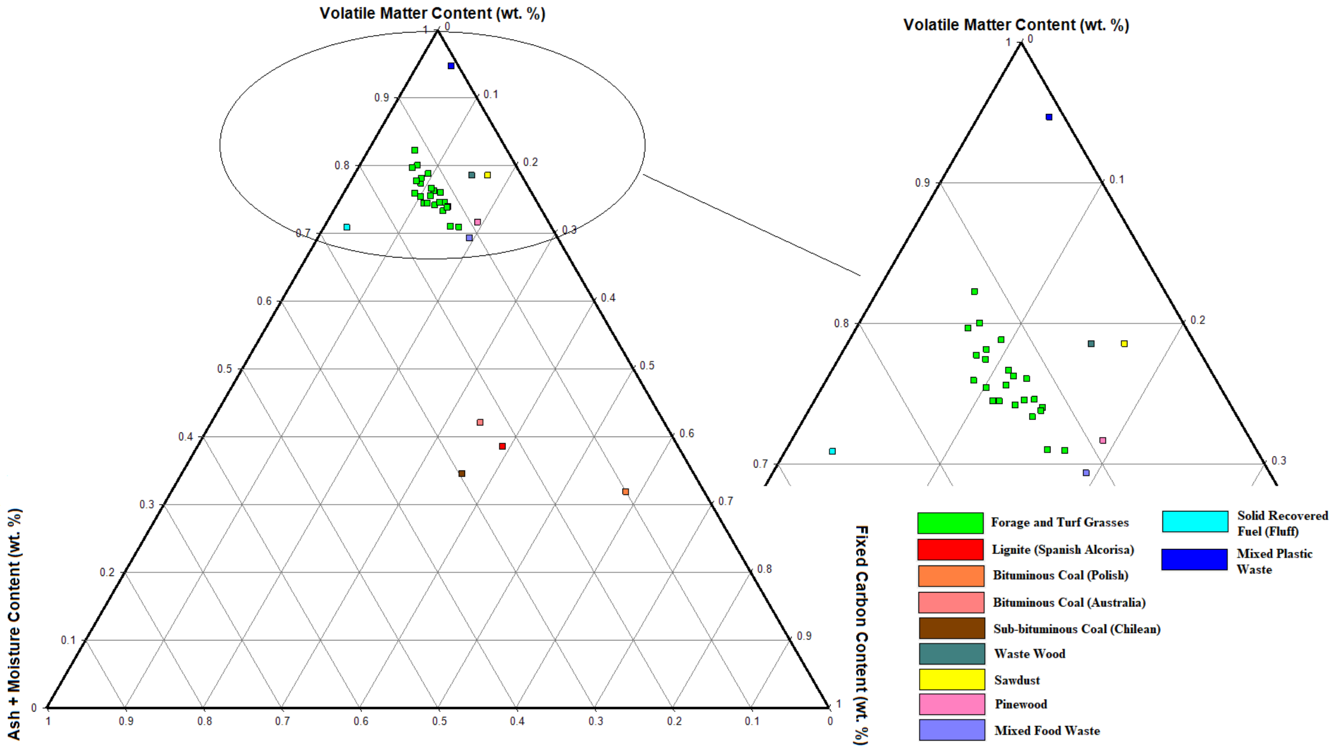

Figure 4. Ternary diagram for components of proximate analysis parameters for the analyzed varieties and species of grasses and other solid fuels (based on [39–47]).

Table 3 shows the moisture content, higher heating value and lower heating value of the analyzed varieties of the given grass species. The moisture content in the dry analytical state for all varieties was relatively similar and ranged from 5.10% ± 0.02 (for Kentucky Bluegrass var. MHR-NT-1318) to 7.34% ± 0.03 (for Kentucky Bluegrass var. Alicja). The average moisture content was 5.97%.

The conducted experiments allowed for the determination of the higher heating value and lower heating value for the tested varieties of given species of fodder and turf grasses. In the case of the higher heating value, significant variability of the parameter was obtained. A difference of 2068 kJ·kg^{-1} was noted between the most caloric species (Sheep Fescue var. Noni) and the least caloric (Meadow Fescue var. Kaskada). The average higher heating value of the analyzed samples was 17,363 kJ·kg^{-1} ± 521 kJ·kg^{-1}, with the average values for the Kentucky Bluegrass species being 17,186 kJ·kg^{-1} ± 421 kJ·kg^{-1}, for Red Fescue 17,094 kJ·kg^{-1} ± 408 kJ·kg^{-1}, for Timothy 17,832 kJ·kg^{-1} ± 42 kJ·kg^{-1}, for Perennial Ryegrass 17,707 kJ·kg^{-1} ± 132 kJ·kg^{-1} and for Meadow Fescue 16,877 kJ·kg^{-1} ± 312 kJ·kg^{-1}. The performed statistical analysis showed statistically significant differences between the higher heating value for Kentucky Bluegrass, Red Fescue and Meadow Fescue varieties. There were no significant statistical differences in the case of the Timothy and Perennial Ryegrass varieties.

Table 3. Moisture content, higher heating value and lower heating value in the analyzed varieties of grasses.

Species	Varieties	Moisture Content, %	Higher Heating Value, kJ·kg^{-1}	Lower Heating Value, kJ·kg^{-1}
Kentucky Bluegrass (*P. pratensis* L.)	Tecza	5.17 ± 0.08	17,057 ± 219 ^{bcde}	16,050 ± 200 ^{bcd}
	Alicja	7.34 ± 0.03	17,556 ± 57 ^{fgh}	16,089 ± 59 ^{bcd}
	MHR-NT-1419	5.62 ± 0.12	17,484 ± 59 ^{efgh}	16,365 ± 47 ^{de}
	Morfa	5.68 ± 0.18	16,762 ± 105 ^{abc}	15,672 ± 66 ^{ab}
	MHR-NT-1318	5.10 ± 0.02	17,778 ± 63 ^{gh}	16,746 ± 55 ^{ef}
	Struga	5.92 ± 0.05	16,975 ± 54 ^{abcd}	15,826 ± 59 ^{abc}
	Harfa	6.04 ± 0.01	16,689 ± 64 ^{ab}	15,534 ± 58 ^{a}
Red Fescue (*F. rubra* L.)	Nimba	6.61 ± 0.03	17,688 ± 101 ^{gh}	16,357 ± 91 ^{de}
	Oaza	6.20 ± 0.14	17,339 ± 133 ^{defg}	16,113 ± 97 ^{cd}
	Leo-pol	6.65 ± 0.17	16,891 ± 81 ^{abcd}	15,605 ± 77 ^{a}
	Adio	6.36 ± 0.06	16,842 ± 355 ^{abc}	15,616 ± 321 ^{a}
	Nawojka	6.69 ± 0.03	16,708 ± 266 ^{ab}	15,428 ± 252 ^{a}
Perennial Ryegrass (*L. perenne* L.)	Pinia	5.39 ± 0.01	17,892 ± 318 ^{h}	16,797 ± 299 ^{f}
	Info	6.11 ± 0.17	17,701 ± 32 ^{gh}	16,471 ± 43 ^{def}
	Nira	5.64 ± 0.05	17,591 ± 156 ^{fgh}	16,462 ± 147 ^{def}
	Gazon	6.01 ± 0.03	17,642 ± 115 ^{gh}	16,435 ± 108 ^{def}
Meadow Fescue (*F. pratensis* Huds.)	Kaskada	5.41 ± 0.01	16,548 ± 18 ^{a}	15,522 ± 16 ^{a}
	Fantazja	5.85 ± 0.15	16,912 ± 76 ^{abcd}	15,779 ± 59 ^{abc}
	Skiba	5.14 ± 0.13	17,170 ± 35 ^{cdef}	16,162 ± 43 ^{cd}
Timothy (*Ph. pratense* L.)	Egida	5.94 ± 0.25	17,802 ± 172 ^{h}	16,600 ± 178 ^{ef}
	Skald	6.04 ± 0.14	17,861 ± 34 ^{h}	16,636 ± 40 ^{ef}
Common Bent (*A. capillaris* L.)	Liryka	6.97 ± 0.07	17,842 ± 40 ^{h}	16,428 ± 47 ^{def}
Sheep Fescue (*F. ovina* L.)	Noni	5.52 ± 0.15	18,616 ± 58 ^{i}	17,453 ± 85 ^{g}

The same markings (a, b, c ...) indicate that no statistically significant differences between the means according to the Tukey HSD test at the significance level $p < 0.05$.

In the case of the lower heating value, the average value of the parameter among the analyzed varieties was 16,180 kJ·kg^{-1} ± 509 kJ·kg^{-1}. As in the case of the higher heating value, Sheep Fescue var. Noni was characterized by the highest value of the parameter (17,453 kJ·kg^{-1} ± 85 kJ·kg^{-1}). The smallest value was obtained for Red Fescue var. Nawojka (15,428 kJ·kg^{-1} ± 252 kJ·kg^{-1}). As in the case of the higher heating value, the statistical analysis also showed that there are statistically significant differences between the lower heating value between the Kentucky Bluegrass, Red Fescue and Meadow Fescue varieties, while these do not exist for the Timothy and Perennial Ryegrass varieties.

4. Discussion

In the context of the suitability of biomass for energy utilization, the proximate analysis and determination of the higher heating value are the most important parameters for determining its potential and applications [48,49]. In the case of grasses, it is particularly important because the plant material should meet several key quality parameters in order to achieve full energy efficiency and adjust individual parameters to the production of energy from direct combustion [50]. The rich diversity of species and varieties of grasses, especially rarely evaluated turf and fodder grasses, makes the knowledge of their physicochemical parameters a valuable indicator for the control of combustion processes.

The values of ash content obtained in the experiment should be considered as consistent with the literature. This parameter shows the proportion of non-flammable minerals left over from the combustion process. The phenomenon of ash content in grasses is an important factor determining whether the feedstock can be burned in a specific biomass boiler, but it is quite often omitted at the breeding stages. Selection for increasing the yield of grasses has been going on for decades, but there is basically no breeding of grasses in terms of changes in composition ash to improve combustion efficiency [51]. This is also confirmed by the lack of a clear downward or upward trend in this experiment. As reported by Bakker and Elbersen [52], the quantity and quality of ash in herbaceous biomass depends mainly on factors such as plant type, plant fraction, growth condition, fertilization, selection of the harvest date, harvesting technique and conversion system. Due to the fact that most of the above-mentioned aspects were similar or identical, similar values of the parameter were observed between all the varieties. The obtained average of 23 varieties (6.56%) is very close to 6%, which Undersander [53] gives as the average value of ash content in grasses, especially forage grasses. A similar value is given by Biedermann and Obernberger [54], who claim that grass, in general, contains 7% ash. Platače and Adamoviès [55], who tested the ash content in terms of energy use for Festololium, Timothy and Meadow Fescue, also obtained similar values, which were, respectively, 6.57–7.78%, 5.40–7.02%, 6.32–6.77%. These authors also state that the increased ash content may cause problems with the combustion automatics and cause other operational problems—related to corroding or failing of machines [55]. Duke obtained a slightly higher, but still similar, value of ash content (8.1%) for perennial ryegrass hay [56]. Nevertheless, the values of ash content obtained in the experiment did not show a large amount of statistically significant difference between the various varieties and species of grasses. This may mean that the value of this parameter is relatively similar for a larger subgroup of species and is stabilized, which will lead to better control of utilization processes. It is true that unprocessed fodder and turf grasses still contain much more ash than most biomass briquettes and pellets [57,58] or charcoal [59], but it is worth mentioning that biomass ash can be a value-added product that can be used as fertilizer [60]. Grasses also contain less ash than coal and lignite, which have an average ash content of 3.6–22.4% (depending on the origin of the raw material) [39–42]. Additionally, according to the opinion of other researchers, the level of ash generated during the combustion of pure biomass may reach 12.5% [61], whereas in the case of wooden biomass it is 0.3–7.4% and in cereal straw 4.3–10.4% [62]. Therefore, the ash level recorded in the experiment for the tested fodder and turf grasses is within the desired range; however, in order to fully avoid the aforementioned operational problems of the boiler and to determine the fertilization suitability, further research is necessary, describing the ash composition in detail.

Another parameter evaluated was the volatile matter content (VMC), whose presence in the biomass influences the reactivity of the fuel [38]. Volatile substances can be characterized as fuel components that burn easily in the presence of oxygen–usually mixtures of aromatic, short- and long-chain hydrocarbons and sulfur [63]. The conducted experiment showed a large variation of this parameter in the tested varieties and species of grasses–results were obtained in the range of 70.99–82.29%, with the average content of volatile substances at the level of 75.90%. The obtained results may suggest that there may be significant differences in the kinetics of the combustion process between individual varieties and species of grass. The different level of this parameter among the grasses is due to the different composition of condensable vapor and solid gases, except for water vapor [64]. Iordanidis et al. [65] noted that a higher content of volatile matter may lower the ignition temperature of fuel combustion. Therefore, the optimization of the combustion process based on the content of volatile substances should be adapted to the type of biomass grass fuel, due to the possibility of large differences in this parameter. However, it is worth confirming that the obtained results are similar to those found in the literature. Corsaro et al. [66], by examining the suitability of hybrid and non-hybrid perennial grasses (Mountain brome—Tacit, Red Clover, Tall Fescue, Tall Oatgrass, Redtop, Reed Canarygrass, Festulolium Becva, Festulolium Lofa, Festulolium Perun) in the context of energy use, obtained a mean level of volatile matter 77.19–83.51%. In determining the sustainable bio-energy potential of perennial energy grasses from reclaimed coalmine spoil, Kumar and Gosh [67] stated that *Cenchrus ciliaris* (L.) characterizes 81.2% and *Pennisetum pedicellatum* (Tan.) 80.5% of volatile matter. The results for fodder and turf grasses are therefore much higher than the content of volatile matter in hard coal (32.7%) or vegetal coal (26.2%), but not when compared to other types of plant biomass—in particular wood (82.0%), elephant grass (74.0%), switchgrass (83.2%), miscanthus (72.4%), wheat straw pellet (74.8) and napier grass (79.06–85.17%) [68–73]. It is also worth emphasizing that some grass species with high VMC and HHV (in particular Sheep Fescue var. Noni and Red Fescue var. Nimba) can be classified as a substrate suitable for thermochemical processing by pyrolysis and torrefaction. This biomass, during thermal treatment, would readily release volatile compounds, which results in a valuable carbonized product with a higher LHV [38].

Fixed carbon (FC) characterizes the solid carbon in biomass that remains after devolatilization [74]. In general, the fixed carbon content in the biomass is relatively low, which is dictated by the high proportion of volatile matter. With classic types of biomass used for energy purposes, the fixed carbon content usually does not exceed 20% [38]. In the case of coal and lignite, the content of fixed carbon is much higher, usually in the range 34.4–70.6% [39–42]. In this experiment, the average fixed carbon content was at the level of 11.22% ± 2.91%. This result is close to the value obtained by Guo et al. [75], who, when testing the usefulness of hydrothermal carbonization of lawn grass, showed that it contains 13.11% fixed carbon content and 79.89% volatile matter content. A similar range of values was also obtained by the authors in [66], where, by examining nine perennial grasses, they obtained 10.23–13.51% fixed carbon content. However, in this research a large number of statistically significant differences was obtained, both between grass species and varieties of a given species. The diverse chemical composition of the substrates in terms of their energetic use may cause unforeseen operational problems and the recognition of differences at the level of individual varieties and species can effectively counter them. It is worth noting that, in most of the found studies on the energetic utilization of grassy biomass, the fixed carbon content was stabilized between the different varieties of a given species. More often, differences show up between different species. Lalak et al. [71] by performing proximate analysis of four Tall Wheatgrass varieties (33 1f, 35 5f, 35 8f and Bamar) obtained 18.5%, 18.5%, 18.6% and 18.4% of fixed carbon content, respectively. Oginni et al. [76], when examining the content of fixed carbon in energy grasses (Miscanthus and Switchgrass), also did not observe statistically significant differences between the clonal varieties of both species. On the other hand, the values obtained by the authors for Switchgrass (17.03–18.22%) are significantly higher than in [73], where the value of 11.04% of fixed carbon was obtained. This may also result from the fact that plant biomass is characterized by heterogeneity of its anatomical structure and heterogeneity of chemical composition within the same species, which may be influenced by the location, age of the plant, or plant parts [77]. In terms of grasses, an interesting phenomenon was also noticed by Mohammed et al. [68], who, when examining the proximate analysis of the stems and leaves of Napier Grass, noted similar values of fixed carbon at 16.74% and 16.94%, while, with the mixed content of stems and leaves, this was only 8.49%.

The higher heating value of fodder and turf grasses determined in the experiment was 16,548–18,616 kJ·kg^{-1}. This parameter is one of the most important factors related to the design and operation of biomass-fired energy systems because it characterizes how much energy can be maximally recovered from the raw material [78–80]. The statistically significant differences in the higher heating value obtained in the experiment between individual varieties of a given species suggest that the knowledge of the higher heating value of a given variety may be crucial in designing the energy system so that the system/device efficiency is not underestimated or overestimated. In addition, the misinterpretation of the higher heating value may be associated with additional costs related to the need to purchase additional biomass, if the amount of energy is not sufficient to cover current needs. Nevertheless, it should be emphasized that such a situation can only take place in the case of a very precise determination of system performance. In the case of bioenergy production from grasses, it is common practice to use a range of values (adequate protection of the system efficiency by accumulating more biomass) that is consistent with the literature. The obtained result is close to the range of HHV values obtained by Waliszewska et al. [77], who studied the chemical composition of selected grass species from Polish meadows—17,500–18,800 kJ·kg^{-1}. Similar values were also noted in [60], where the higher heating value of biomass perennial grasses in the dry-ash-free state was at the level of 17,191–18,174 kJ·kg^{-1}. Slightly larger ranges of values were obtained by Amaleviciute-Volunge et al. [81], who tested the usefulness of six species of perennial grasses—lucerne (*Medicago sativa* L.), reed canary grass (*Phalaris arundinacea* L.), tall fescue (*Festuca arundinacea* Schreb.), Cocksfoot (*Dactylis glomerata* L.), switchgrass (*Panicum virgatum* L.) and ryegrass (*Lolium perenne* L.), for combustion—17.70–19.02 MJ·kg^{-1}. These results also depended on the growth phase of a given plant. Similar ranges of values were also observed by Danielewicz et al. [25], obtaining the heat of combustion 17.47–18.56 MJ·kg^{-1} for such species as Tall Wheatgrass, Tall Fescue, Tall Oatgrass and Miscanthus. It should therefore be noted that the species and particular varieties of grasses in this experiment that are characterized by approving higher heating value (in particular Sheep Fescue, Timothy and Common Bent) may be useful for bioenergy purposes.

Lower heating value (LHV) is a similar parameter that can describe the energy properties of biomass—unlike HHV, it does not take into account the heat needed to evaporate the moisture present [82]. Due to the fact that, in most laboratory tests, the grasses are additionally dried in dryers/climatic chambers, the moisture content is at a similar, low level. Larger differences are noticeable in the cases of natural grass drying. The values of the lower heating value obtained in this experiment ranged from 15,428–17,453 kJ·kg^{-1}. As in the case of HHV, the LHV range of the evaluated grass varieties and species was found to be in line with the literature. This result is similar to some other types of biomass (e.g., sawdust, waste wood, wheat straw), but still significantly lower than coal, which is most often characterized by LHV of 24.9–27.5 MJ·kg^{-1} [39]. Waliszewska et al. [77] showed that the moisture content of selected grasses found on Polish meadows after drying was 6.2–6.7% and the calorific value from 16,029 kJ·kg^{-1} to 18,037 kJ·kg^{-1}. Murawski et al. [83], while examining the energy value of grasses from extensively used meadows (*Phalaris arundinacea*, *Phragmites australis*, *Festuca arundinacea*, *Calamagrostis epigejos*), noticed that the value of the LHV parameter is characterized by a high discrepancy depending on the species and may range from 16.1 MJ·kg^{-1} to 18.2 MJ·kg^{-1}. It is also worth noting that in the literature there are studies in which lower heating values were obtained for grasses. Kumar and Gosh [67], by studying the bioenergetic potential of perennial grasses—*Cenchrus ciliaris* (L.) and *Pennisetum pedicellatum* (Tan.)—obtained calorific values of level 14.8 MJ·kg^{-1} and 14.3 MJ·kg^{-1}. This is confirmed by our reports on the need for a precise evaluation of the energy parameters of a given species and variety of grasses to optimize the combustion system.

5. Conclusions

Perennial and annual grasses can play a key role in the implementation of biomass for energy purposes. The large variation in the chemical composition between individual species, and even varieties of grasses of the same species, makes it necessary to evaluate a wide number of varieties to optimally adjust the parameters of the combustion process to a given type of biomass.

In this experiment, a total of 23 varieties of fodder and turf grasses, such as Kentucky Bluegrass (*Poa pratensis* L.), Red Fescue (*Festuca rubra*), Perennial Ryegrass (*Lolium perenne* L.), Meadow Fescue (*Festuca pratensis* Huds.), Timothy (*Phleum pratense* L.), Common Bent (*Agrostis capillaris* L.), Sheep Fescue (*Festuca ovina* L.). It was shown that the average ash content was in the range of 5.73–8.31%, the content of volatile matter in the range of 70.99–82.29% and the content of fixed carbon content in the range of 5.96–17.19%. Higher heating value and lower heating value of grasses ranged from 16,548–18,616 kJ·kg^{-1}, 15,428–17,453 kJ·kg^{-1}, with the highest contents obtained for Sheep Fescue var. Noni. The observed results may indicate that most of the evaluated varieties of grasses can be successfully used in the production of bioenergy.

However, the statistically significant differences in individual parameters between the varieties and species of grass obtained during the experiment suggest that, before starting the combustion processes, it is necessary to determine the energy parameters of the planned varieties in order to ensure adequate combustion efficiency and process control (especially lower heating value). Due to the fact that factors such as fertilization, harvesting technique, conversion system and harvesting date were similar, it should be expected that the type of plant significantly determines its suitability for energy utilization.

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Appendix A

Table A1. Statistically significant differences according to Tukey's test between particular grass varieties in ash content (p = 0.05).

Grass	{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}	{9}	{10}	{11}	{12}	{13}	{14}	{15}	{16}	{17}	{18}	{19}	{20}	{21}	{22}	{23}
PR var. Pinia		1.000000	0.996974	0.773455	1.000000	1.000000	0.763103	0.810083	0.933415	1.000000	0.943572	1.000000	0.999955	1.000000	1.000000	1.000000	1.000000	0.847683	1.000000	1.000000	0.999928	1.000000	0.999336
PR var. Info	1.000000		0.999668	0.884507	1.000000	1.000000	0.877154	0.909395	0.978261	1.000000	0.865650	1.000000	0.999322	1.000000	1.000000	1.000000	1.000000	0.933024	1.000000	1.000000	0.999033	1.000000	0.994932
PR var. Nira	0.996974	0.999668		1.000000	0.999999	0.994665	0.999999	1.000000	1.000000	0.984312	0.145525	0.999967	0.597720	0.999624	0.999999	1.000000	0.999950	1.000000	0.975557	0.997509	0.574153	0.914029	0.449881
PR var. Gazon	0.773455	0.884507	1.000000		0.982023	0.731354	1.000000	1.000000	1.000000	0.630663	**0.016994**	0.943236	0.139016	0.879933	0.980032	0.995639	0.935850	1.000000	0.580394	0.786339	0.128878	0.406100	0.084343
KB var. MHR-NT-1318	1.000000	1.000000	0.999999	0.982023		1.000000	0.980012	0.988155	0.998976	1.000000	0.635898	1.000000	0.982935	1.000000	1.000000	1.000000	1.000000	0.992939	0.999999	1.000000	0.978980	0.999919	0.944818
KB var. Morfa	1.000000	1.000000	0.994665	0.731354	1.000000		0.720323	0.770844	0.911271	1.000000	0.959549	1.000000	0.999984	1.000000	1.000000	0.999999	1.000000	0.812232	1.000000	1.000000	0.999973	1.000000	0.999692
KB var. Struga	0.763103	0.877154	0.999999	1.000000	0.980012	0.720323		1.000000	1.000000	0.618758	**0.016188**	0.938575	0.133779	0.872422	0.977844	0.994985	0.930789	1.000000	0.568399	0.776236	0.123957	0.395220	0.080895
KB var. Harfa	0.810083	0.909395	1.000000	1.000000	0.988155	0.770844	1.000000		1.000000	0.674281	**0.020329**	0.958368	0.159883	0.905453	0.986716	0.997476	0.952409	1.000000	0.624791	0.821940	0.148545	0.447582	0.098325
RF var. Nimba	0.933415	0.978261	1.000000	1.000000	0.998976	0.911271	1.000000	1.000000		0.847286	**0.044634**	0.993226	0.285870	0.976825	0.998775	0.999898	0.991724	1.000000	0.809523	0.939638	0.268507	0.647492	0.187593
RF var. Oaza	1.000000	1.000000	0.984312	0.630663	1.000000	1.000000	0.618758	0.674281	0.847286		0.982859	1.000000	0.999999	1.000000	1.000000	0.999989	1.000000	0.721906	1.000000	1.000000	0.999998	1.000000	0.999958
RF var. Leo-Pol	0.943572	0.865650	0.145525	**0.016994**	0.635898	0.959549	**0.016188**	**0.020329**	**0.044634**	0.982859		0.774218	1.000000	0.870528	0.647607	0.499311	0.789957	**0.024845**	0.989397	0.937625	1.000000	0.998777	1.000000
RF var. Adio	1.000000	1.000000	0.999967	0.943236	1.000000	1.000000	0.938575	0.958368	0.993226	1.000000	0.774218		0.996427	1.000000	1.000000	1.000000	1.000000	0.971689	1.000000	1.000000	0.995274	0.999997	0.982694
RF var. Nawojka	0.999955	0.999322	0.597720	0.139016	0.982935	0.999984	0.133779	0.159883	0.285870	0.999999	1.000000	0.996427		0.999396	0.984705	0.949317	0.997164	0.186320	1.000000	0.999939	1.000000	1.000000	1.000000
KB var. MHR-NT-1419	1.000000	1.000000	0.999624	0.879933	1.000000	1.000000	0.872422	0.905453	0.976825	1.000000	0.870528	1.000000	0.999396		1.000000	1.000000	1.000000	0.929795	1.000000	1.000000	0.999134	1.000000	0.995360
KB var. Tęcza	1.000000	1.000000	0.999999	0.980032	1.000000	1.000000	0.977844	0.986716	0.998775	1.000000	0.647607	1.000000	0.984705	1.000000		1.000000	1.000000	0.991986	0.999999	1.000000	0.981053	0.999936	0.949097
KB var. Alicja	1.000000	1.000000	1.000000	0.995639	1.000000	0.999999	0.994985	0.997476	0.999898	0.999989	0.499311	1.000000	0.949317	1.000000	1.000000		1.000000	0.998723	0.999966	1.000000	0.940613	0.999144	0.876673
MF var. Kaskada	1.000000	1.000000	0.999950	0.935850	1.000000	1.000000	0.930789	0.952409	0.991724	1.000000	0.789957	1.000000	0.997164	1.000000	1.000000	1.000000		0.967174	1.000000	1.000000	0.996212	0.999998	0.985440
MF var. Fantazja	0.847683	0.933024	1.000000	1.000000	0.992939	0.812232	1.000000	1.000000	1.000000	0.721906	**0.024845**	0.971689	0.186320	0.929795	0.991986	0.998723	0.967174		0.674140	0.858227	0.173541	0.496342	0.116311
MFvar. Skiba	1.000000	1.000000	0.975557	0.580394	0.999999	1.000000	0.568399	0.624791	0.809523	1.000000	0.989397	1.000000	1.000000	1.000000	0.999999	0.999966	1.000000	0.674140		1.000000	1.000000	1.000000	0.999986
T var. Egida	1.000000	1.000000	0.997509	0.786339	1.000000	1.000000	0.776236	0.821940	0.939638	1.000000	0.937625	1.000000	0.999939	1.000000	1.000000	1.000000	1.000000	0.858227	1.000000		0.999903	1.000000	0.999162
T var. Skald	0.999928	0.999033	0.574153	0.128878	0.978980	0.999973	0.123957	0.148545	0.268507	0.999998	1.000000	0.995274	1.000000	0.999134	0.981053	0.940613	0.996212	0.173541	1.000000	0.999903		1.000000	1.000000
CB var. Liryka	1.000000	1.000000	0.914029	0.406100	0.999919	1.000000	0.395220	0.447582	0.647492	1.000000	0.998777	0.999997	1.000000	1.000000	0.999936	0.999144	0.999998	0.496342	1.000000	1.000000	1.000000		1.000000
SF var. Noni	0.999336	0.994932	0.449881	0.084343	0.944818	0.999692	0.080895	0.098325	0.187593	0.999958	1.000000	0.982694	1.000000	0.995360	0.949097	0.876673	0.985440	0.116311	0.999986	0.999162	1.000000	1.000000	

Bold font indicates statistically significant differences, numbers {1}–{23} varieties of grass according to the order in the first column.

Table A2. Statistically significant differences according to Tukey's test between particular grass varieties in volatile matter content (p = 0.05).

Grass	{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}	{9}	{10}	{11}	{12}	{13}	{14}	{15}	{16}	{17}	{18}	{19}	{20}	{21}	{22}	{23}
KB var. Alicja		**0.009998**	0.999934	1.000000	0.119888	0.990772	0.107631	**0.000369**	0.302794	0.995790	1.000000	1.000000	1.000000	0.999880	1.000000	**0.000185**	0.966559	1.000000	0.812093	0.063724	0.165564	0.999993	**0.000824**
KB var. Tęcza	**0.009998**		**0.000437**	**0.015133**	**0.000185**	0.440161	**0.000185**	0.999780	0.998641	0.375471	**0.004599**	**0.010745**	**0.013033**	0.201458	**0.001384**	0.111785	0.581692	**0.002558**	0.848731	1.000000	0.999968	0.133609	0.999999
KB var. MHR-NT-1419	0.999934	**0.000437**		0.999592	0.749870	0.481765	0.720249	**0.000187**	**0.020786**	0.551719	0.999999	0.999908	0.999780	0.776489	1.000000	**0.000185**	0.349599	1.000000	0.152020	**0.002591**	**0.008674**	0.875794	**0.000195**
KB var. MHR-NT-1318	1.000000	**0.015133**	0.999592		0.085399	0.997060	0.076211	**0.000486**	0.387043	0.998876	1.000000	1.000000	1.000000	0.999985	1.000000	**0.000185**	0.985833	1.000000	0.882284	0.090737	0.223021	1.000000	**0.001219**
KB var. Morfa	0.119888	**0.000185**	0.749870	0.085399		**0.001373**	1.000000	**0.000185**	**0.000191**	**0.001831**	0.211715	0.113222	0.096791	**0.004945**	0.438309	**0.000185**	**0.000779**	0.308490	**0.000323**	**0.000185**	**0.000187**	**0.008700**	**0.000185**
KB var. Struga	0.990772	0.440161	0.481765	0.997060	**0.001373**		**0.001208**	**0.030125**	0.998155	1.000000	0.955028	0.992309	0.995442	1.000000	0.788723	**0.000199**	1.000000	0.893853	1.000000	0.869420	0.980728	1.000000	0.076873
KB var. Harfa	0.107631	**0.000185**	0.720249	0.076211	1.000000	**0.001208**		**0.000185**	**0.000190**	**0.001602**	0.192455	0.101541	0.086497	**0.004305**	0.408021	**0.000185**	**0.000690**	0.283449	**0.000297**	**0.000185**	**0.000186**	**0.007587**	**0.000185**
RF var. Nimba	**0.000369**	0.999780	**0.000187**	**0.000486**	**0.000185**	**0.030125**	**0.000185**		0.574798	**0.022806**	**0.000254**	**0.000385**	**0.000437**	**0.008708**	**0.000199**	0.786980	0.052005	**0.000218**	0.144989	0.949729	0.777278	**0.004949**	1.000000
RF var. Oaza	0.302794	0.998641	**0.020786**	0.387043	**0.000191**	0.998155	**0.000190**	0.574798		0.995490	0.180974	0.316514	0.355332	0.959237	0.070202	**0.002412**	0.999805	0.117060	1.000000	1.000000	1.000000	0.903993	0.809521
RF var. Leo-Pol	0.995790	0.375471	0.551719	0.998876	**0.001831**	1.000000	**0.001602**	**0.022806**	0.995490		0.973867	0.996582	0.998133	1.000000	0.843547	**0.000194**	1.000000	0.929578	1.000000	0.819150	0.965485	1.000000	0.059677
RF var. Adio	1.000000	**0.004599**	0.999999	1.000000	0.211715	0.955028	0.192455	**0.000254**	0.180974	0.973867		1.000000	1.000000	0.997786	1.000000	**0.000185**	0.890468	1.000000	0.646272	**0.032035**	0.090911	0.999702	**0.000443**
RF var. Nawojka	1.000000	**0.010745**	0.999908	1.000000	0.113222	0.992309	0.101541	**0.000385**	0.316514	0.996582	1.000000		1.000000	0.999914	1.000000	**0.000185**	0.970824	1.000000	0.825490	0.067828	0.174584	0.999996	**0.000887**
PR var. Pinia	1.000000	**0.013033**	0.999780	1.000000	0.096791	0.995442	0.086497	**0.000437**	0.355332	0.998133	1.000000	1.000000		0.999967	1.000000	**0.000185**	0.980282	1.000000	0.858994	0.080015	0.200823	0.999999	**0.001060**
PR var. Info	0.999880	0.201458	0.776489	0.999985	**0.004945**	1.000000	**0.004305**	**0.008708**	0.959237	1.000000	0.997786	0.999914	0.999967		0.960844	**0.000187**	1.000000	0.989168	0.999974	0.604262	0.855255	1.000000	**0.024408**
PR var. Nira	1.000000	**0.001384**	1.000000	1.000000	0.438309	0.788723	0.408021	**0.000199**	0.070202	0.843547	1.000000	1.000000	1.000000	0.960844		**0.000185**	0.657004	1.000000	0.369069	**0.010071**	**0.031759**	0.987386	**0.000242**
PR var. Gazon	**0.000185**	0.111785	**0.000185**	**0.000185**	**0.000185**	**0.000199**	**0.000185**	0.786980	**0.002412**	**0.000194**	**0.000185**	**0.000185**	**0.000185**	**0.000187**	**0.000185**		**0.000216**	**0.000185**	**0.000343**	**0.019416**	**0.005959**	**0.000186**	0.547047
MF var. Kaskada	0.966559	0.581692	0.349599	0.985833	**0.000779**	1.000000	**0.000690**	0.052005	0.999805	1.000000	0.890468	0.970824	0.980282	1.000000	0.657004	**0.000216**		0.792824	1.000000	0.943062	0.995582	1.000000	0.125265
MF var. Fantazja	1.000000	**0.002558**	1.000000	1.000000	0.308490	0.893853	0.283449	**0.000218**	0.117060	0.929578	1.000000	1.000000	1.000000	0.989168	1.000000	**0.000185**	0.792824		0.508818	**0.018553**	0.055684	0.997646	**0.000316**
MF var. Skiba	0.812093	0.848731	0.152020	0.882284	**0.000323**	1.000000	**0.000297**	0.144989	1.000000	1.000000	0.646272	0.825490	0.858994	0.999974	0.369069	**0.000343**	1.000000	0.508818		0.996220	0.999963	0.999657	0.300256
T var. Egida	0.063724	1.000000	**0.002591**	0.090737	**0.000185**	0.869420	**0.000185**	0.949729	1.000000	0.819150	**0.032035**	0.067828	0.080015	0.604262	**0.010071**	**0.019416**	0.943062	**0.018553**	0.996220		1.000000	0.472070	0.994793
T var. Skald	0.165564	0.999968	**0.008674**	0.223021	**0.000187**	0.980728	**0.000186**	0.777278	1.000000	0.965485	0.090911	0.174584	0.200823	0.855255	**0.031759**	**0.005959**	0.995582	0.055684	0.999963	1.000000		0.749238	0.937573
CB var. Liryka	0.999993	0.133609	0.875794	1.000000	**0.008700**	1.000000	**0.007587**	**0.004949**	0.903993	1.000000	0.999702	0.999996	0.999999	1.000000	0.987386	**0.000186**	1.000000	0.997646	0.999657	0.472070	0.749238		**0.014251**
SF var. Noni	**0.000824**	0.999999	**0.000195**	**0.001219**	**0.000185**	0.076873	**0.000185**	1.000000	0.809521	0.059677	**0.000443**	**0.000887**	**0.001060**	**0.024408**	**0.000242**	0.547047	0.125265	**0.000316**	0.300256	0.994793	0.937573	**0.014251**	

Bold font indicates statistically significant differences, numbers {1}–{23} varieties of grass according to the order in the first column.

Table A3. Statistically significant differences according to Tukey's test between particular grass varieties in fixed carbon content ($p = 0.05$).

Grass	{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}	{9}	{10}	{11}	{12}	{13}	{14}	{15}	{16}	{17}	{18}	{19}	{20}	{21}	{22}	{23}
KB var. Alicja		0.980680	0.843664	0.975708	**0.038515**	1.000000	**0.002791**	0.159848	0.934199	0.936268	0.999997	1.000000	0.999645	1.000000	0.695312	**0.006538**	1.000000	0.695908	1.000000	0.833792	0.622329	0.999968	0.053721
KB var. Tęcza	0.980680		**0.041634**	0.118754	**0.000357**	0.673147	**0.000190**	0.989671	1.000000	1.000000	0.537820	0.998580	0.328390	0.991804	**0.021034**	0.418187	0.980426	**0.021087**	0.999626	1.000000	1.000000	1.000000	0.888345
KB var. MHR-NT-1419	0.843664	**0.041634**		1.000000	0.976919	0.997745	0.536407	**0.000449**	**0.022126**	**0.022570**	0.999710	0.639691	0.999998	0.773599	1.000000	**0.000187**	0.844722	1.000000	0.552883	**0.010923**	**0.004025**	0.191566	**0.000234**
KB var. MHR-NT-1318	0.975708	0.118754	1.000000		0.847979	0.999988	0.273428	**0.001299**	0.067871	0.069092	1.000000	0.885179	1.000000	0.951979	1.000000	**0.000199**	0.976008	1.000000	0.826061	**0.035732**	**0.013940**	0.414702	**0.000419**
KB var. Morfa	**0.038515**	**0.000357**	0.976919	0.847979		0.222759	0.999998	**0.000185**	**0.000256**	**0.000258**	0.321388	**0.015363**	0.529242	**0.027311**	0.996095	**0.000185**	**0.038733**	0.996066	**0.010732**	**0.000213**	**0.000192**	**0.001693**	**0.000185**
KB var. Struga	1.000000	0.673147	0.997745	0.999988	0.222759		**0.024431**	**0.025001**	0.511621	0.516558	1.000000	0.999971	1.000000	0.999999	0.984322	**0.000765**	1.000000	0.984413	0.999833	0.350688	0.184255	0.965022	**0.006713**
KB var. Harfa	**0.002791**	**0.000190**	0.536407	0.273428	0.999998	**0.024431**		**0.000185**	**0.000187**	**0.000187**	**0.041412**	**0.001082**	0.093629	**0.001923**	0.708916	**0.000185**	**0.002809**	0.708327	**0.000768**	**0.000185**	**0.000185**	**0.000247**	**0.000185**
RF var. Nimba	0.159848	0.989671	**0.000449**	**0.001299**	**0.000185**	**0.025001**	**0.000185**		0.998513	0.998407	**0.014433**	0.309142	**0.005601**	0.208849	**0.000291**	0.999811	0.159114	**0.000291**	0.382374	0.999916	1.000000	0.798021	1.000000
RF var. Oaza	0.934199	1.000000	**0.022126**	0.067871	**0.000256**	0.511621	**0.000187**	0.998513		1.000000	0.382636	0.990014	0.211672	0.964600	**0.010827**	0.576988	0.933576	**0.010855**	0.996194	1.000000	1.000000	0.999999	0.959715
RF var. Leo-Pol	0.936268	1.000000	**0.022570**	0.069092	**0.000258**	0.516558	**0.000187**	0.998407	1.000000		0.387086	0.990508	0.214744	0.965931	**0.011054**	0.571989	0.935658	**0.011082**	0.996417	1.000000	1.000000	0.999999	0.958208
RF var. Adio	0.999997	0.537820	0.999710	1.000000	0.321388	1.000000	**0.041412**	**0.014433**	0.382636	0.387086		0.999607	1.000000	0.999975	0.996311	**0.000482**	0.999997	0.996339	0.998519	0.246042	0.120067	0.913076	**0.003757**
RF var. Nawojka	1.000000	0.998580	0.639691	0.885179	**0.015363**	0.999971	**0.001082**	0.309142	0.990014	0.990508	0.999607		0.991919	1.000000	0.465874	**0.017171**	1.000000	0.466479	1.000000	0.955962	0.830873	1.000000	0.120847
PR var. Pinia	0.999645	0.328390	0.999998	1.000000	0.529242	1.000000	0.093629	**0.005601**	0.211672	0.214744	1.000000	0.991919		0.998606	0.999885	**0.000277**	0.999654	0.999886	0.981212	0.124120	0.054564	0.752965	**0.001459**
PR var. Info	1.000000	0.991804	0.773599	0.951979	**0.027311**	0.999999	**0.001923**	0.208849	0.964600	0.965931	0.999975	1.000000	0.998606		0.608280	**0.009506**	1.000000	0.608905	1.000000	0.892361	0.708647	0.999996	0.074036
PR var. Nira	0.695312	**0.021034**	1.000000	1.000000	0.996095	0.984322	0.708916	**0.000291**	**0.010827**	**0.011054**	0.996311	0.465874	0.999885	0.608280		**0.000186**	0.696723	1.000000	0.384951	**0.005221**	**0.001920**	0.110236	**0.000204**
PR var. Gazon	**0.006538**	0.418187	**0.000187**	**0.000199**	**0.000185**	**0.000765**	**0.000185**	0.999811	0.576988	0.571989	**0.000482**	**0.017171**	**0.000277**	**0.009506**	**0.000186**		**0.006497**	**0.000186**	**0.024345**	0.744286	0.913290	0.120234	1.000000
MF var. Kaskada	1.000000	0.980426	0.844722	0.976008	**0.038733**	1.000000	**0.002809**	0.159114	0.933576	0.935658	0.999997	1.000000	0.999654	1.000000	0.696723	**0.006497**		0.697318	1.000000	0.832694	0.620854	0.999966	0.053429
MF var. Fantazja	0.695908	**0.021087**	1.000000	1.000000	0.996066	0.984413	0.708327	**0.000291**	**0.010855**	**0.011082**	0.996339	0.466479	0.999886	0.608905	1.000000	**0.000186**	0.697318		0.385510	**0.005235**	**0.001925**	0.110466	**0.000204**
MF var. Skiba	1.000000	0.999626	0.552883	0.826061	**0.010732**	0.999833	**0.000768**	0.382374	0.996194	0.996417	0.998519	1.000000	0.981212	1.000000	0.384951	**0.024345**	1.000000	0.385510		0.977739	0.888980	1.000000	0.159502
T var. Egida	0.833792	1.000000	**0.010923**	**0.035732**	**0.000213**	0.350688	**0.000185**	0.999916	1.000000	1.000000	0.246042	0.955962	0.124120	0.892361	**0.005221**	0.744286	0.832694	**0.005235**	0.977739		1.000000	0.999943	0.991194
T var. Skald	0.622329	1.000000	**0.004025**	**0.013940**	**0.000192**	0.184255	**0.000185**	1.000000	1.000000	1.000000	0.120067	0.830873	0.054564	0.708647	**0.001920**	0.913290	0.620854	**0.001925**	0.888980	1.000000		0.997327	0.999619
CB var. Liryka	0.999968	1.000000	0.191566	0.414702	**0.001693**	0.965022	**0.000247**	0.798021	0.999999	0.999999	0.913076	1.000000	0.752965	0.999996	0.110236	0.120234	0.999966	0.110466	1.000000	0.999943	0.997327		0.493102
SF var. Noni	0.053721	0.888345	**0.000234**	**0.000419**	**0.000185**	**0.006713**	**0.000185**	1.000000	0.959715	0.958208	**0.003757**	0.120847	**0.001459**	0.074036	**0.000204**	1.000000	0.053429	**0.000204**	0.159502	0.991194	0.999619	0.493102	

Bold font indicates statistically significant differences, numbers {1}–{23} varieties of grass according to the order in the first column.

Table A4. Statistically significant differences according to Tukey's test between particular grass varieties in higher heating value ($p = 0.05$).

Grass	{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}	{9}	{10}	{11}	{12}	{13}	{14}	{15}	{16}	{17}	{18}	{19}	{20}	{21}	{22}	{23}
KB var. Alicja		**0.019657**	1.000000	0.959694	**0.000189**	**0.002649**	**0.000185**	0.999958	0.966220	**0.000420**	**0.000236**	**0.000185**	0.434327	0.999808	1.000000	1.000000	**0.000185**	**0.000606**	0.203162	0.900860	0.613203	0.721009	**0.000185**
KB var. Tęcza	**0.019657**		0.096556	**0.000227**	0.672831	1.000000	0.275834	**0.000820**	0.742414	0.998630	0.969170	0.367061	**0.000186**	**0.000614**	**0.008528**	**0.002380**	**0.015759**	0.999794	0.999997	**0.000204**	**0.000187**	**0.000190**	**0.000185**
KB var. MHR-NT-1419	1.000000	0.096556		0.676609	**0.000226**	**0.015884**	**0.000188**	0.982391	0.999808	**0.002005**	**0.000639**	**0.000192**	0.136780	0.966220	0.999999	0.999254	**0.000185**	**0.003312**	0.560481	0.537081	0.236268	0.317907	**0.000185**
KB var. MHR-NT-1318	0.959694	**0.000227**	0.676609		**0.000185**	**0.000188**	**0.000185**	1.000000	0.075630	**0.000185**	**0.000185**	**0.000185**	0.999996	1.000000	0.993607	0.999932	**0.000185**	**0.000185**	**0.001378**	1.000000	1.000000	1.000000	**0.000186**
KB var. Morfa	**0.000189**	0.672831	**0.000226**	**0.000185**		0.972363	1.000000	**0.000185**	**0.002949**	0.999969	1.000000	1.000000	**0.000185**	**0.000185**	**0.000186**	**0.000185**	0.971026	0.999690	0.140233	**0.000185**	**0.000185**	**0.000185**	**0.000185**
KB var. Struga	**0.002649**	1.000000	**0.015884**	**0.000188**	0.972363		0.719199	**0.000239**	0.294904	1.000000	0.999944	0.816410	**0.000185**	**0.000221**	**0.001155**	**0.000407**	0.095858	1.000000	0.989738	**0.000186**	**0.000185**	**0.000185**	**0.000185**
KB var. Harfa	**0.000185**	0.275834	**0.000188**	**0.000185**	1.000000	0.719199		**0.000185**	**0.000546**	0.983898	0.999571	1.000000	**0.000185**	**0.000185**	**0.000185**	**0.000185**	0.999875	0.957324	**0.030309**	**0.000185**	**0.000185**	**0.000185**	**0.000185**
RF var. Nimba	0.999958	**0.000820**	0.982391	1.000000	**0.000185**	**0.000239**	**0.000185**		0.367061	**0.000188**	**0.000185**	**0.000185**	0.981764	1.000000	1.000000	1.000000	**0.000185**	**0.000192**	**0.012587**	0.999996	0.997423	0.999482	**0.000185**
RF var. Oaza	0.966220	0.742414	0.999808	0.075630	**0.002949**	0.294904	**0.000546**	0.367061		0.062652	**0.020602**	**0.000820**	**0.005276**	0.302454	0.878018	0.622921	**0.000189**	0.095222	0.998161	**0.045347**	**0.011334**	**0.017887**	**0.000185**
RF var. Leo-Pol	**0.000420**	0.998630	**0.002005**	**0.000185**	0.999969	1.000000	0.983898	**0.000188**	0.062652		1.000000	0.994994	**0.000185**	**0.000187**	**0.000266**	**0.000201**	0.396508	1.000000	0.761478	**0.000185**	**0.000185**	**0.000185**	**0.000185**
RF var. Adio	**0.000236**	0.969170	**0.000639**	**0.000185**	1.000000	0.999944	0.999571	**0.000185**	**0.020602**	1.000000		0.999946	**0.000185**	**0.000185**	**0.000202**	**0.000188**	0.680377	1.000000	0.479364	**0.000185**	**0.000185**	**0.000185**	**0.000185**
RF var. Nawojka	**0.000185**	0.367061	**0.000192**	**0.000185**	1.000000	0.816410	1.000000	**0.000185**	**0.000820**	0.994994	0.999946		**0.000185**	**0.000185**	**0.000185**	**0.000185**	0.999161	0.983002	**0.046690**	**0.000185**	**0.000185**	**0.000185**	**0.000185**
PR var. Pinia	0.434327	**0.000186**	0.136780	0.999996	**0.000185**	**0.000185**	**0.000185**	0.981764	**0.005276**	**0.000185**	**0.000185**	**0.000185**		0.991431	0.634547	0.885180	**0.000185**	**0.000185**	**0.000224**	1.000000	1.000000	1.000000	**0.000223**
PR var. Info	0.999808	**0.000614**	0.966220	1.000000	**0.000185**	**0.000221**	**0.000185**	1.000000	0.302454	**0.000187**	**0.000185**	**0.000185**	0.991431		0.999998	1.000000	**0.000185**	**0.000189**	**0.009103**	1.000000	0.999136	0.999866	**0.000185**
PR var. Nira	1.000000	**0.008528**	0.999999	0.993607	**0.000186**	**0.001155**	**0.000185**	1.000000	0.878018	**0.000266**	**0.000202**	**0.000185**	0.634547	0.999998		1.000000	**0.000185**	**0.000341**	0.107285	0.975298	0.800936	0.880431	**0.000185**
PR var. Gazon	1.000000	**0.002380**	0.999254	0.999932	**0.000185**	**0.000407**	**0.000185**	1.000000	0.622921	**0.000201**	**0.000188**	**0.000185**	0.885180	1.000000	1.000000		**0.000185**	**0.000215**	**0.036333**	0.999208	0.963598	0.985819	**0.000185**
MF var. Kaskada	**0.000185**	**0.015759**	**0.000185**	**0.000185**	0.971026	0.095858	0.999875	**0.000185**	**0.000189**	0.396508	0.680377	0.999161	**0.000185**	**0.000185**	**0.000185**	**0.000185**		0.296404	**0.001017**	**0.000185**	**0.000185**	**0.000185**	**0.000185**
MF var. Fantazja	**0.000606**	0.999794	**0.003312**	**0.000185**	0.999690	1.000000	0.957324	**0.000192**	0.095222	1.000000	1.000000	0.983002	**0.000185**	**0.000189**	**0.000341**	**0.000215**	0.296404		0.855033	**0.000185**	**0.000185**	**0.000185**	**0.000185**
MF var. Skiba	0.203162	0.999997	0.560481	**0.001378**	0.140233	0.989738	**0.030309**	**0.012587**	0.998161	0.761478	0.479364	**0.046690**	**0.000224**	**0.009103**	0.107285	**0.036333**	**0.001017**	0.855033		**0.000792**	**0.000288**	**0.000373**	**0.000185**
T var. Egida	0.900860	**0.000204**	0.537081	1.000000	**0.000185**	**0.000186**	**0.000185**	0.999996	**0.045347**	**0.000185**	**0.000185**	**0.000185**	1.000000	1.000000	0.975298	0.999208	**0.000185**	**0.000185**	**0.000792**		1.000000	1.000000	**0.000187**
T var. Skald	0.613203	**0.000187**	0.236268	1.000000	**0.000185**	**0.000185**	**0.000185**	0.997423	**0.011334**	**0.000185**	**0.000185**	**0.000185**	1.000000	0.999136	0.800936	0.963598	**0.000185**	**0.000185**	**0.000288**	1.000000		1.000000	**0.000199**
CB var. Liryka	0.721009	**0.000190**	0.317907	1.000000	**0.000185**	**0.000185**	**0.000185**	0.999482	**0.017887**	**0.000185**	**0.000185**	**0.000185**	1.000000	0.999866	0.880431	0.985819	**0.000185**	**0.000185**	**0.000373**	1.000000	1.000000		**0.000192**
SF var. Noni	**0.000185**	**0.000185**	**0.000185**	**0.000186**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000223**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000187**	**0.000199**	**0.000192**	

Bold font indicates statistically significant differences, numbers {1}–{23} varieties of grass according to the order in the first column.

Table A5. Statistically significant differences according to Tukey's test between particular grass varieties in lower heating value (p = 0.05).

Grass	{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}	{9}	{10}	{11}	{12}	{13}	{14}	{15}	{16}	{17}	{18}	{19}	{20}	{21}	{22}	{23}
KB var. Alicja		1.000000	0.660479	**0.000248**	0.060298	0.734995	**0.001712**	0.705364	1.000000	**0.011559**	**0.015134**	**0.000239**	**0.000196**	0.129669	0.154592	0.255866	**0.001264**	0.442819	1.000000	**0.005611**	**0.002163**	0.287851	**0.000185**
KB var. Tęcza	1.000000		0.415438	**0.000201**	0.141519	0.914831	**0.004908**	0.459447	1.000000	**0.031555**	**0.040553**	**0.000389**	**0.000187**	0.054587	0.066721	0.120412	**0.003563**	0.688803	0.999989	**0.001950**	**0.000794**	0.138818	**0.000185**
KB var. MHR-NT-1419	0.660479	0.415438		0.131005	**0.000203**	**0.002700**	**0.000185**	1.000000	0.798467	**0.000186**	**0.000187**	**0.000185**	**0.041984**	0.999996	0.999999	1.000000	**0.000185**	**0.000809**	0.964360	0.870514	0.685646	1.000000	**0.000185**
KB var. MHR-NT-1318	**0.000248**	**0.000201**	0.131005		**0.000185**	**0.000185**	**0.000185**	0.112434	**0.000330**	**0.000185**	**0.000185**	**0.000185**	1.000000	0.663574	0.608925	0.439645	**0.000185**	**0.000185**	**0.000850**	0.999362	0.999992	0.398943	**0.000196**
KB var. Morfa	0.060298	0.141519	**0.000203**	**0.000185**		0.998584	0.999689	**0.000209**	**0.034131**	1.000000	1.000000	0.834106	**0.000185**	**0.000185**	**0.000185**	**0.000186**	0.998979	0.999995	**0.009928**	**0.000185**	**0.000185**	**0.000187**	**0.000185**
KB var. Struga	0.734995	0.914831	**0.002700**	**0.000185**	0.998584		0.551895	**0.003291**	0.587577	0.922320	0.949027	0.091928	**0.000185**	**0.000278**	**0.000315**	**0.000488**	0.477478	1.000000	0.303786	**0.000186**	**0.000185**	**0.000561**	**0.000185**
KB var. Harfa	**0.001712**	**0.004908**	**0.000185**	**0.000185**	0.999689	0.551895		**0.000185**	**0.000942**	1.000000	1.000000	0.999996	**0.000185**	**0.000185**	**0.000185**	**0.000185**	1.000000	0.828053	**0.000350**	**0.000185**	**0.000185**	**0.000185**	**0.000185**
RF var. Nimba	0.705364	0.459447	1.000000	0.112434	**0.000209**	**0.003291**	**0.000185**		0.834689	**0.000187**	**0.000188**	**0.000185**	**0.035151**	0.999986	0.999997	1.000000	**0.000185**	**0.000974**	0.975439	0.838459	0.640113	1.000000	**0.000185**
RF var. Oaza	1.000000	1.000000	0.798467	**0.000330**	**0.034131**	0.587577	**0.000942**	0.834689		**0.006102**	**0.008053**	**0.000209**	**0.000210**	0.207190	0.242490	0.376775	**0.000698**	0.309614	1.000000	**0.010655**	**0.004121**	0.416483	**0.000185**
RF var. Leo-Pol	**0.011559**	**0.031555**	**0.000186**	**0.000185**	1.000000	0.922320	1.000000	**0.000187**	**0.006102**		1.000000	0.991621	**0.000185**	**0.000185**	**0.000185**	**0.000185**	1.000000	0.993444	**0.001673**	**0.000185**	**0.000185**	**0.000185**	**0.000185**
RF var. Adio	**0.015134**	**0.040553**	**0.000187**	**0.000185**	1.000000	0.949027	1.000000	**0.000188**	**0.008053**	1.000000		0.984077	**0.000185**	**0.000185**	**0.000185**	**0.000185**	1.000000	0.996956	**0.002193**	**0.000185**	**0.000185**	**0.000185**	**0.000185**
RF var. Nawojka	**0.000239**	**0.000389**	**0.000185**	**0.000185**	0.834106	0.091928	0.999996	**0.000185**	**0.000209**	0.991621	0.984077		**0.000185**	**0.000185**	**0.000185**	**0.000185**	1.000000	0.234886	**0.000189**	**0.000185**	**0.000185**	**0.000185**	**0.000185**
PR var. Pinia	**0.000196**	**0.000187**	**0.041984**	1.000000	**0.000185**	**0.000185**	**0.000185**	**0.035151**	**0.000210**	**0.000185**	**0.000185**	**0.000185**		0.352760	0.307296	0.190880	**0.000185**	**0.000185**	**0.000318**	0.973471	0.997403	0.167138	**0.000249**
PR var. Info	0.129669	0.054587	0.999996	0.663574	**0.000185**	**0.000278**	**0.000185**	0.999986	0.207190	**0.000185**	**0.000185**	**0.000185**	0.352760		1.000000	1.000000	**0.000185**	**0.000204**	0.449923	0.999892	0.996525	1.000000	**0.000185**
PR var. Nira	0.154592	0.066721	0.999999	0.608925	**0.000185**	**0.000315**	**0.000185**	0.999997	0.242490	**0.000185**	**0.000185**	**0.000185**	0.307296	1.000000		1.000000	**0.000185**	**0.000210**	0.503729	0.999706	0.993395	1.000000	**0.000185**
PR var. Gazon	0.255866	0.120412	1.000000	0.439645	**0.000186**	**0.000488**	**0.000185**	1.000000	0.376775	**0.000185**	**0.000185**	**0.000185**	0.190880	1.000000	1.000000		**0.000185**	**0.000249**	0.674102	0.996432	0.967507	1.000000	**0.000185**
MF var. Kaskada	**0.001264**	**0.003563**	**0.000185**	**0.000185**	0.998979	0.477478	1.000000	**0.000185**	**0.000698**	1.000000	1.000000	1.000000	**0.000185**	**0.000185**	**0.000185**	**0.000185**		0.766913	**0.000293**	**0.000185**	**0.000185**	**0.000185**	**0.000185**
MF var. Fantazja	0.442819	0.688803	**0.000809**	**0.000185**	0.999995	1.000000	0.828053	**0.000974**	0.309614	0.993444	0.996956	0.234886	**0.000185**	**0.000204**	**0.000210**	**0.000249**	0.766913		0.126566	**0.000185**	**0.000185**	**0.000266**	**0.000185**
MF var. Skiba	1.000000	0.999989	0.964360	**0.000850**	**0.009928**	0.303786	**0.000350**	0.975439	1.000000	**0.001673**	**0.002193**	**0.000189**	**0.000318**	0.449923	0.503729	0.674102	**0.000293**	0.126566		**0.036429**	**0.014933**	0.715904	**0.000185**
T var. Egida	**0.005611**	**0.001950**	0.870514	0.999362	**0.000185**	**0.000186**	**0.000185**	0.838459	**0.010655**	**0.000185**	**0.000185**	**0.000185**	0.973471	0.999892	0.999706	0.996432	**0.000185**	**0.000185**	**0.036429**		1.000000	0.994036	**0.000185**
T var. Skald	**0.002163**	**0.000794**	0.685646	0.999992	**0.000185**	**0.000185**	**0.000185**	0.640113	**0.004121**	**0.000185**	**0.000185**	**0.000185**	0.997403	0.996525	0.993395	0.967507	**0.000185**	**0.000185**	**0.014933**	1.000000		0.954894	**0.000185**
CB var. Liryka	0.287851	0.138818	1.000000	0.398943	**0.000187**	**0.000561**	**0.000185**	1.000000	0.416483	**0.000185**	**0.000185**	**0.000185**	0.167138	1.000000	1.000000	1.000000	**0.000185**	**0.000266**	0.715904	0.994036	0.954894		**0.000185**
SF var. Noni	**0.000185**	**0.000185**	**0.000185**	**0.000196**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000249**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	**0.000185**	

Bold font indicates statistically significant differences, numbers {1}–{23} varieties of grass according to the order in the first column.

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