FLUE GASES EMITTED BY TIMOTHY AND MEADOW FESCUE PELLETS

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Abstract. Due to the fact that we are running short of fossil energy and the world needs more environmentally friendly energy sources, plant biomass may be one of the solutions. Hoverer, biomass fuel faces difficulties related to cultivation of grass with particular chemical content (fertilisers along with the climatic and soil conditions are vital for productivity and yield quality, e.g., nitrogen fertilisers increase the yield and quality of grass plants notably), whereas combustion of this fuel may negatively impact the air quality (the whole process of thermal utilisation of solid biofuels is influenced by the kind of the solid biofuel used, its physical characteristics and its chemical composition. The chemical composition of solid biofuels has various effects on thermal utilisation thereof). This study aims at assessing the amounts of exhaust gasses emitted when burning meadow fescue and timothy biomass, changes thereof depending on the type and norm of the fertiliser applied, as well as researching the suitability of such biomass for biofuel production. It was found that timothy biomass has the lowest S and C content, while meadow fescue biomass tends to have the highest S content. The lowest S content was discovered in biomass fertilised with N dose F + N60, the smallest N volume when treating cops with F + N30, and the highest C with F + N120(60 + 60).

Keywords: meadow fescue, timothy, flue gases, biomass, nitrogen.

Introduction

Effective use of nutrients is of a great significance for sustainable agricultural production. Sufficient amount of nutrients ensures favourable conditions for long-term and stable use of soil resources and high crop yields. Fertilisers along with the climatic and soil conditions are vital for productivity and yield quality.

The yield and chemical content of grass biomass suitable for biofuel production both are largely influenced by the fertilisers the plants are treated with – type (nitrogen mineral fertilisers, vermicompost) and norms (amounts) – especially ones applied during the growing period.

Chemical composition of solid biofuels (as defined in [1; 2]) has various effects on thermal utilisation thereof. C, H and O are the main components of solid biofuels and are of special relevance for the gross calorific value; H in addition also for the net calorific value. The N content in fuel is responsible for NO_x formation. NO_x emissions belong to the main environmental impact factors of solid biofuel combustion. Cl and S are responsible for deposit formation and corrosion and are therefore relevant for high plant availability.

The whole process of thermal utilisation of solid biofuels (fuel supply, combustion system, solid and gaseous emissions) is influenced by the kind of the solid biofuel used, its physical characteristics (e.g., particle size, bulk density, moisture content, gross calorific value) and its chemical composition [3]. C, H and O are the main components of solid biofuels. C and H are oxidised during combustion by exothermic reactions (formation of CO_2 and H_2O). The content of C and H contributes positively to the gross calorific value (GCV). H also influences the net calorific value (NCV) due to the formation of water. The C contents of wood fuels (including bark) are higher than those of herbaceous biofuels, which explains the slightly higher GCV of wood fuels. CO_2 is formed and emitted as a major product of complete combustion. However, CO_2 emissions from biomass combustion are regarded as being CO_2-neutral with respect to the greenhouse gas effect if sustainable utilisation is assumed [3]. Incomplete combustion can lead to emissions of unburnt carbon based pollutants such as carbon monoxide, hydrocarbons, polycyclic aromatic hydrocarbons, tar and soot. An effective reduction of these pollutants can be achieved by an optimised combustion process, providing good mixing between fuel and air, sufficient retention time (>1.5 s) at high temperatures (>850 ºC). In modern furnaces with effective process control systems the concentrations of unburned pollutants can be reduced to levels close to zero [4].

Nitrogen (N) quantities, use efficiency as well as the energy input are important for environmental impact and production of energy crops. Nitrogen fertilisers increase the yield and quality of grass plants notably as soil has high humus content and low nitrogen supply. Several researches indicate that higher norms of nitrogen fertilisers affect the yield of grass dry matter [5].

According to CEN/TC 335-WG 2 N94 Final draft [2], coniferous and deciduous wood has the lowest N content. Higher concentrations are found in bark, logging residues, short rotation coppice (willow and poplar) and straw from wheat, rye and barley. The concentrations are usually still higher in rape straw (wheat, rye and barley straw can also have N contents in this range), miscanthus and fruit residues (e.g., olive or grape cakes, kernels, shells). Grains and grasses usually show the highest values.

Like Cl, the S contained in the solid biofuel forms mainly gaseous SO_2 (to a certain extent also SO_3) and alkali assection of the combustion plant. SO_x forms sulphates and condenses on the heat exchanger surfaces or forms fine fly ash particles, or reacts directly with fly ash particles deposited on the heat exchanger surfaces (sulphation). Investigations have shown that 40 to 70 % or 60 to 90% of the fuel S were integrated in the ash in the case of wood chip or bark combustion. In the case of (wheat) straw or cereal combustion (plants equipped with baghouse filters) only 40 to 55 % were integrated in the ash. The efficiency of S fixation in the ash depends on the concentration of alkali and earth-alkali metals (especially Ca) in the fuel (fuels like wood chips and bark can contain high Ca contents and therefore cause a high S fixation) [6]. The residual S remains in the flue gas as aerosols and in a gaseous form as SO_2 (in minor quantities as SO_3). Emissions of SO_2 are usually not significant for wood combustion due to the typically low concentrations of S in the fuel, and, especially in the case of wood chips and bark utilisation, because of the relatively high embedment in the ash. According to Obernberger I. [7] emission related problems are to be expected at S concentrations above 0.2 w- % (d.b.). This can be of relevance for rape straw and grasses. The technological possibilities to reduce SO_x emissions are the same as already outlined for Cl emissions. The importance of S does not primarily result from SO_2 emissions but from its role in corrosion processes. Higher SO_2 concentrations in the flue gas cause sulphation of alkali and earth-alkali chlorides with decreasing flue gas temperature. This leads to the release of Cl. If these reactions take place in ash particles precipitated on the surface of the heat exchanger tubes, the released Cl can cause corrosion by $FeCl_2$ or $ZnCl_2$ formation at the heat exchanger surfaces [7].

This study aims at quantifying the S, C and N content in meadow fescue and timothy biomass depending on the type and norm of the fertiliser applied, as well as on assessing the amounts of exhaust gasses emitted when burning such biomass and researching suitability of such biomass for biofuel production.

Materials and methods

Research objects: Meadow fescue (*Festuca pratensis* Huds.) and timothy (*Phleum pratense* L.) are perennial grasses that under suitable conditions yield for 6-8 years or more and have good cold tolerance. The stem length varies between 0.6 m and 1.4 m or more. These grasses are modest in terms of requirements for soil and may grow in marginal soils, moreover, they are suitable for cultivation in moisture meadows, with a strong root system and excel also with durability against draughts, cold tolerance and high yields [5].

The field trial was carried out during 2011-2012 in the research and study farm "Peterlauki" (56º53'N, 23º71'E) of the Latvia University of Agriculture, in sod calcareous soils pH KCl 6.7, containing available for plants P 52 mg·kg $^{-1}$, K 128 mg·kg $^{-1}$, organic matter content 21 to 25 g·kg^{-1} in the soil. The field test fertiliser norms applied were the following (kg·ha^{-1}): N0P0K0 (control) P_2O_5 – 80, K_20 – 120 (F – background), F + N30, F + N60, F + N90, F + N120 (60 + 60), F + N150 (75 + 75), F + N180 (90 + 90), vermicompost – 10 t·ha^{-1}. Seed sowing norm – 1000 germinant seeds per 1 m^2; usage type: mowing two-three times.

Sulphur (S), carbon (C) and nitrogen (N) content in various samples was found in the agricultural scientific laboratory for agronomic analyses of the University of Latvia using the analyser "Eltra CS-500 Analizator", and in compliance with the standard LVS EN ISO 5983-2:2009.

For each sample three parallel experiments were carried out, repeating each tested combination three times. The data were analysed and graphs were made using MS Office program Excel.

Results and discussion

Nitrogen (N) content in grass biomass fertilised varies around 0.91 ± 0.05 %. The highest N amount was found with fertiliser F + N180 (90 + 90) in meadow fescue (1.08 %) and timothy

(1.05 %), whereas the lowest with fertiliser F + N30 (0.63 %) in meadow fescue, and in timothy when treating it with vermicompost (0.88 %), (Fig. 1).

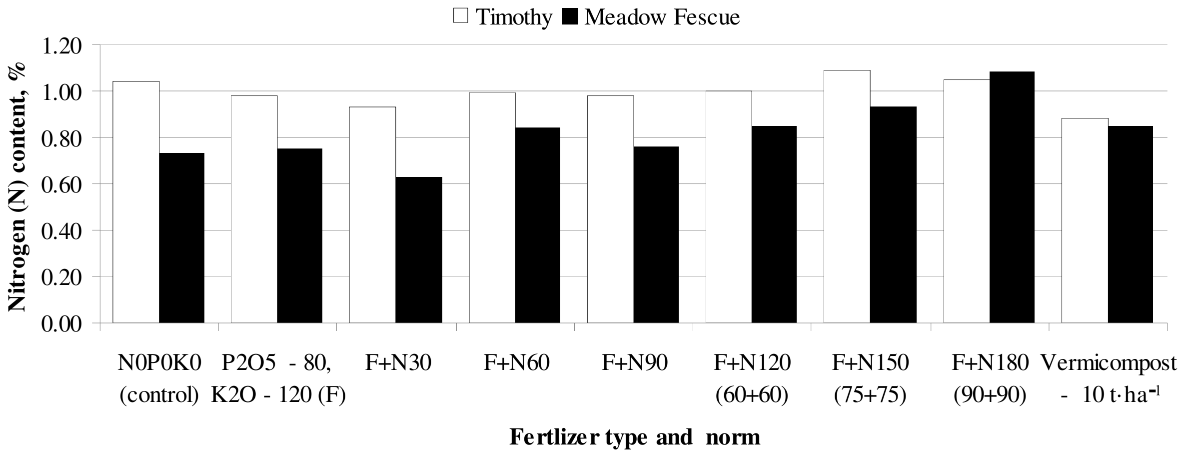


Fig. 1. **Nitrogen content in timothy and meadow fescue biomass depending on fertiliser type and norm**

Carbon content in grass biomass treated with various types and norms of fertilisers on average comprised 48.32 ± 0.05 %. The highest C amount was found in timothy samples fertilised with F + N120 (60 + 60) and vermicompost – 48.97 %, in meadow fescue biomass treated with vermicompost – 48.38 % (Fig. 2). T.G.Bridgeman and other researchers (2008) have found that the C content in RCG comprises 48.6 %, and that is rather similar to our findings – 48.68 % [8].

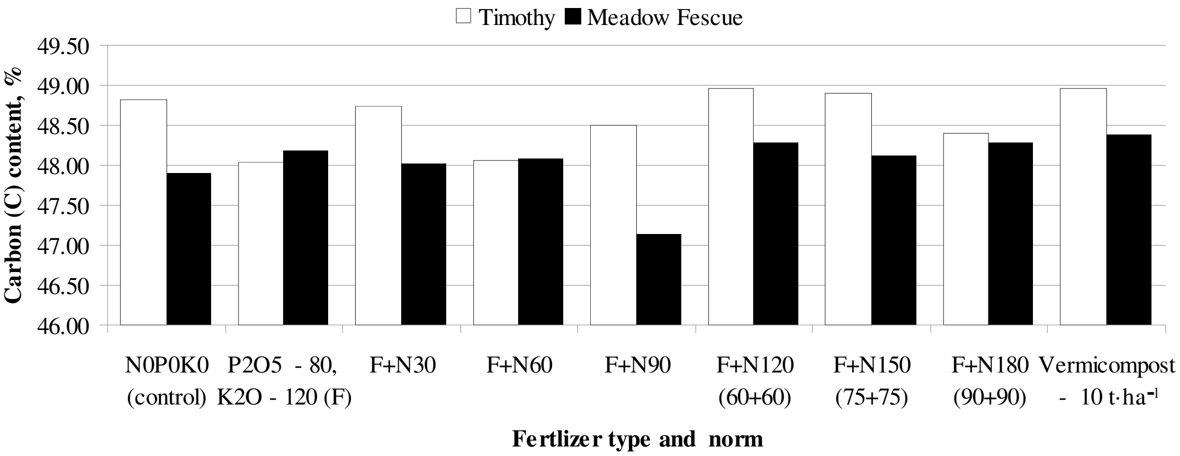


Fig. 2. **Carbon content in timothy and meadow fescue biomass depending on fertiliser type and norm**

Average S content in biomass treated with various types and norms of fertilisers constituted 0.046 ± 0.06 %. The lowest and highest S indicators were the following (Fig. 3): the lowest in timothy biomass with F + N30 – 0.034 %, and the highest with N0P0K0 (control) – 0.05 %; the lowest in meadow fescue with F + N60 – 0.041 %, and the highest with vermicompost – 10 t·ha^{-1} – 0.059 % (Fig. 3).

Chemical analysis of timothy and meadow fescue samples from crops treated with various fertiliser types allowed us to conclude that the lowest S content is in timothy fertilised with vermicompost – 0.040 %, while in not fertilised meadow fescue it was the highest – 0.089 % (Fig.4, a). On average, if comparing the grass species, timothy has lower S content (0.06 %) than meadow fescue (0.08 %).

Application of various types of fertilisers lead to the highest C content in biomass fertilised with vermicompost – 47.80 %, 47.03 % in samples without fertiliser, and 46.77 % in biomass treated with fertiliser (Fig.4, b). Moreover, timothy samples had the highest C content – 47.96 %.

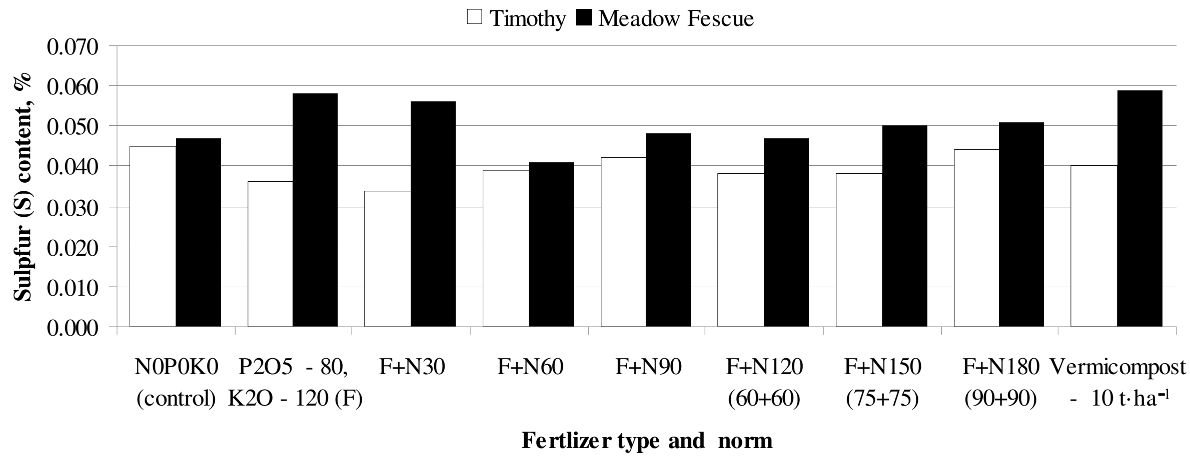
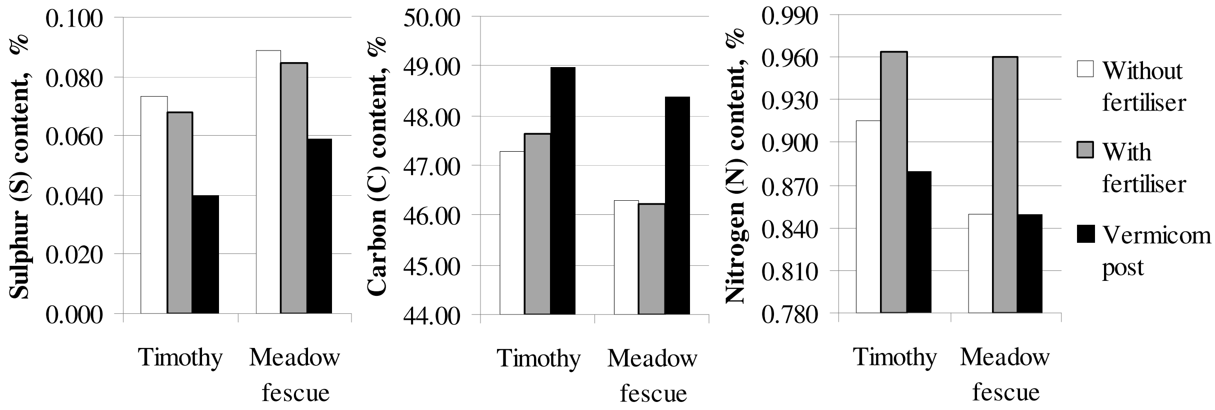


Fig. 3. **Sulphur content in timothy and meadow fescue biomass depending on fertiliser type and norm**

Heat production requires grass biomass with a possibly lower S content. Also other researches have noted that too high S amount may cause corrosion of metal chimneys and other metal structures, as well as favours emission of sulphur dioxide into atmosphere [9].



a) b) c)

Fig. 4. **Sulphur carbon and nitrogen content in perennial grass biomass depending on fertiliser type**

In turn, the N content was the lowest in biomass treated with vermicompost – 0.75 %, and the highest in samples on which fertiliser was applied – 0.83 %. Lower N content was found in meadow fescue – 0.89 %, and the highest in timothy – 0.96 % (Fig.4, c). In general, Figure 4 shows that, if meadow fescue and timothy are fertilized with vermicompost, biomass contains more carbon and less sulphur and nitrogen as compared to the samples fertilized or not fertilized at all.

Conclusions

1. Average sulphur content was slightly lower in timothy – 0.068 %, while in meadow fescue it went up to 0.084 %. Mean carbon content, in turn, was slightly higher (47.62 %) in timothy, but in meadow fescue it accounted for 46.22 %. Average N content in both grasses constituted 0.96 %.
2. Biomass having lower sulphur content is more environmentally friendly.
3. Comparison of grass biomasses by the fertilizer type and norm showed that the lowest it was in biomass fertilized with N dose F + N60, while the highest in the samples treated with vermicompost. The smallest N content was found when treating cops with F + N30, and the highest carbon amount with F + N120 (60 + 60). Heat production requires grass biomass with possibly lower sulphur content and possibly highest carbon content.

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