Chemical composition analysis of the *Miscanthus* leaves and stems

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Abstract. A comparative analysis of the chemical composition of the stems of a herbaceous plant and a whole plant indicates that the values of such indicators as the mass fraction of protein, crude fat, ash, and acid-insoluble lignin are higher in the whole *Miscanthus* plant; therefore, for further research aimed to develop scientific and technological foundations for processing and use of *Miscanthus* biomass in the fuel and energy, cellulose, microbiological, and other industries, it is recommended to use whole *Miscanthus* plants, including the leaves and stems.

Keywords: *Miscanthus*, crude protein, fat, ash, fiber, cellulose, lignin, stems, leaves.

Introduction

Miscanthus or silvergrass is a genus of perennial herbaceous plants of the *Poaceae* family. Currently, the areas for the cultivation of herbaceous plants are constantly growing. This phenomenon can be explained by high growth rates and the prospects for its application in the national economy. All over the world, including the Russian Federation, the opportunities of using this plant in the chemical and energy industries are being studied [27, 37, 43].

Miscanthus is a very valuable raw material due to its ability to accumulate a large amount of solar energy. The main advantage of this plant is its high yield. This plant can grow actively on nutrient-depleted soils while still preserving its good quality and high lignin content [11, 138].

The fuel problems that have arisen at present can be solved by using renewable energy sources, among which *Miscanthus* is a promising raw material for use as biofuel and for the production of bioethanol on its basis. Large-scale cultivation of crops for bioenergy requires the study and introduction of new technologies for obtaining planting material.

In addition to biofuel production, plants of the *Miscanthus* genus can be used to obtain biologically active substances from them. *Miscanthus* extracts include fatty acids, sterols, and other aromatic compounds. The main structures of phenolic compounds and sterols of the bark and core of *Miscanthus giganteus* include vanillic acid, para-coumaric acid, vanillin, para-hydroxybenzaldehyde, syringaldehyde, campesterol, stigmasterol, β-sitosterol, stigmasta-3,5-dien-7-one, stigmast-4-en-3-one, stigmast-6-en-3,5-diol, 7-hydroxy-β-sitosterol, and 7-oxo-β-siterol [1, 53, 114].

According to the research of T.N. Goryachkovskaya and K.G. Starostina, lignocellulosic biomass, obtained from *Miscanthus* plants, contains approximately 70% polysaccharides, consisting of hexose (cellulose) and pentose (hemicellulose) residues. Upon complete hydrolysis of these polysaccharides, a mixture of hexoses (glucose, galactose, mannose) and pentoses (arabinose, xylose) is formed, which can later be used as substrates for bacterial cultivation [73].

Simple hydrocarbons, such as glucose and fructose, can be converted into products such as bioethyl alcohol, vitamins, enzymes, proteins, amino acids, lipids, organic acids, technical cellulose using bacteria and fungi.

It was found that the hydrolysates of the herbaceous plant *Miscanthus sinensis,* in addition to peptoses and hexoses, contain a large amount of high and low molecular weight organic acids, alcohols, ketones, humic acids, and minerals. The qualitative and quantitative content of the substances depends on the method of obtaining hydrolysates of *Miscanthus sinensis* [6, 139].

This study aimed to study the chemical composition of non-wood lignocellulosic raw materials – *Miscanthus*.

Materials and methods

Miscanthus sinensis, which grows in the Northwestern Federal District of the Russian Federation, was selected for this study:

– *Miscanthus sinensis* “Ferner Osten”, harvested in 2019;

–*Miscanthus sinensis* “Strictus”, harvested in 2019;

–*Miscanthus sinensis* “Zebrinus”, harvested in 2019.

Mature plants were selected to analyze the chemical composition of the samples. Plants with a higher height and containing the maximum number of inflorescences were selected for analysis. The chemical composition of individual parts (leaves and stem of the plant) of *Miscanthus sinensis* and a whole herbaceous plant were studied in the experiment. As the leading indicators characterizing the chemical composition of cellulose-containing raw materials, we chose the mass fraction of crude protein, mass fraction of fiber, mass fraction of fat (crude fat), mass fraction of ash, lignin, and cellulose.

The content of crude protein, mass fraction of fiber, and crude fat was assessed in accordance with the requirements of GOST 32040-2012 “Fodder, mixed and animal feed raw stuff. Spectroscopy in near infra-red region method for determination of crude protein, crude fiber, crude fat, and moisture”. The mass fraction of crude ash was determined following GOST 32933-2014 (ISO 5984: 2002) “Animal feeding stuffs - Determination of crude ash”. The mass fraction of lignin was evaluated according to GOST 11960-79 “Fiber semi-products and raw materials of annuals for pulp and paper industry. Method for determination of content of lignin”. GOST 16932-93 (ISO 638-78) “Pulps — Determination of dry matter content” was used to determine the mass fraction of cellulose. To study the chemical composition, all samples were cut with scissors to a size of 0.5-1.0 cm.

Results and discussion

The results of studying the chemical composition of whole *Miscanthus sinensis* samples are present in Table 1.

Table 1 – The results of studying the chemical composition of whole *Miscanthus sinensis* samples

Indicator	Indicator value of *Miscanthus* sample		
	Miscanthus sinensis “Ferner Osten”	*Miscanthus sinensis* “Strictus”	*Miscanthus sinensis* “Zebrinus”
Moisture content, %	9,00±0,54	8,50±0,51	8,80±0,53
Mass fraction of crude protein, %	5,25±0,31	4,42±0,26	5,12±0,31
Mass fraction of fiber, %	10,35±0,62	11,31±0,68	12,88±0,77
Mass fraction of crude fat, %	0,95±0,05	1,23±0,07	1,02±0,06
Mass fraction of crude ash, %	4,20±0,25	3,21±0,19	4,68±0,28
Mass fraction of lignin, %	12,00±0,72	18,00±1,08	10,00±0,60
Mass fraction of cellulose, %	62,00±3,72	57,00±3,42	64,00±3,84

Analysis of the results presented in Table 1 indicates that the moisture content of all three studied *Miscanthus* samples is no more than 9.0%, which does not contradict the literature data. It was shown that *Miscanthus sinensis* is not distinguished by a high content of lipid and protein compounds. The content of crude protein in *Miscanthus sinensis* “Ferner Osten” was 5.25% and in *Miscanthus sinensis* “Strictus” – 4.42%. A record amount of fiber (12.88%) was noted in the *Miscanthus sinensis* “Zebrinus”. *Miscanthus sinensis* “Strictus” contains 11.31% fiber. The smallest mass fraction of fiber was observed in the sample of *Miscanthus sinensis* “Ferner Osten”. It has been found that the herb is rich in cellulose. The maximum cellulose content (64.0%) was found in the *Miscanthus sinensis* “Zebrinus”, and the minimum – in the *Miscanthus sinensis* “Strictus” (57.0%). *Miscanthus sinensis* “Strictus” contains a record amount of lignin (18.0%), *Miscanthus sinensis* “Zebrinus” contains 1.8 times less lignin (10 %).

The results of studying the chemical composition of the leaf part of the *Miscanthus* samples are presented in Figure 1.

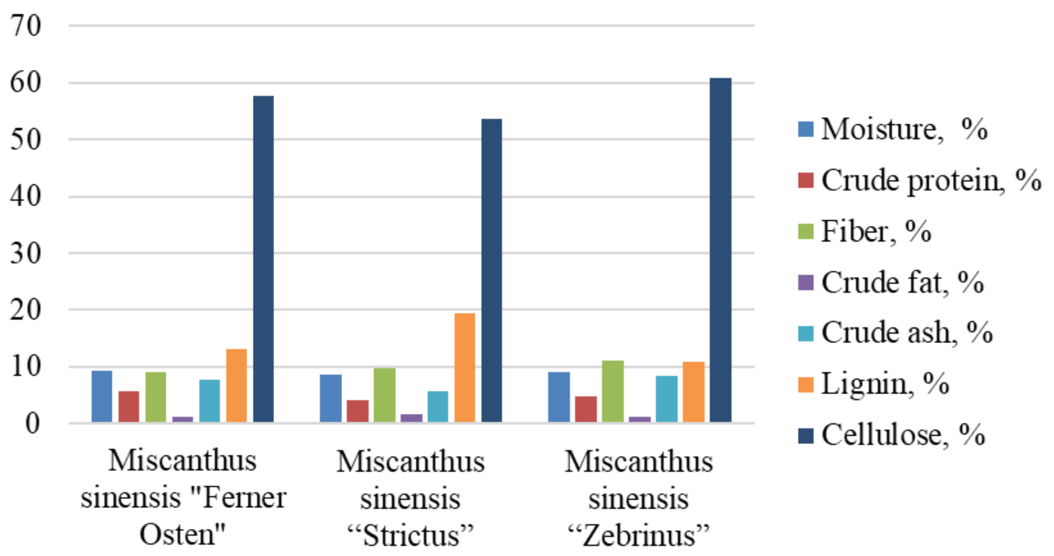

Figure 1 – The results of studying the chemical composition of the leaf part of the *Miscanthus sinensis* samples

Figure 1 shows that the leaf part of *Miscanthus sinensis* is characterized by an increased content of acid-insoluble lignin, ash, and fiber. So, for example, the leaf part of *Miscanthus sinensis* “Strictus” contains 19.44% of lignin, the leaf part of the *Miscanthus sinensis* “Zebrinus” – 10.88% of lignin. The mass fraction of acid-insoluble lignin of the leaf part of the *Miscanthus sinensis* “Ferner Osten” was 13.21%. The mass fraction of fiber in the leaf part of the *Miscanthus sinensis* “Zebrinus” reaches 11.07%, which is 1.23% higher than the fiber content in the leaf part of the *Miscanthus sinensis* “Strictus” and 2% higher than the fiber content in the leaf part of the *Miscanthus sinensis* “Ferner Osten”.

Comparative analysis of the chemical analysis results of the whole *Miscanthus sinensis* and its leaf part shows that the leaf part contains more acid-insoluble lignin and lipid fraction than the whole plant. Thus, the lignin content in the leaf part of the *Miscanthus sinensis* “Ferner Osten” is 13.21%, which is 1.1 times more than the lignin content in the whole plant. The lignin content in the leaf part of the *Miscanthus sinensis* “Strictus” is 1.09 times higher than the lignin content in the whole plant. The mass fraction of lignin in the leaf part of the *Miscanthus sinensis* “Zebrinus” exceeds 1.08 times the content of lignin in the whole plant. The crude fat content of the leaf part of the *Miscanthus sinensis* “Ferner Osten” is 1.33 times higher than the crude fat content of the whole plant. The content of the lipid fraction in the leaf part of the *Miscanthus sinensis* “Strictus” is 1.66%, which is 1.34 times more than the lipid content in the whole plant. Reduced content of fiber and cellulose in the leaf part of the samples was noted in comparison with the whole plant samples. So, for example, in the leaf part of the *Miscanthus sinensis* “Zebrinus”, the mass fraction of cellulose is 60.81%, which is 3.19% lower than the cellulose content in the whole plant. In the leaf part of the *Miscanthus sinensis* “Zebrinus”, the mass fraction of fiber is 11.07%, which is 1.15 times lower than the fiber content in the whole plant. A similar trend was noted for other samples under study.

Figure 2 shows the results of the chemical composition study of the *Miscanthus sinensis* stems.

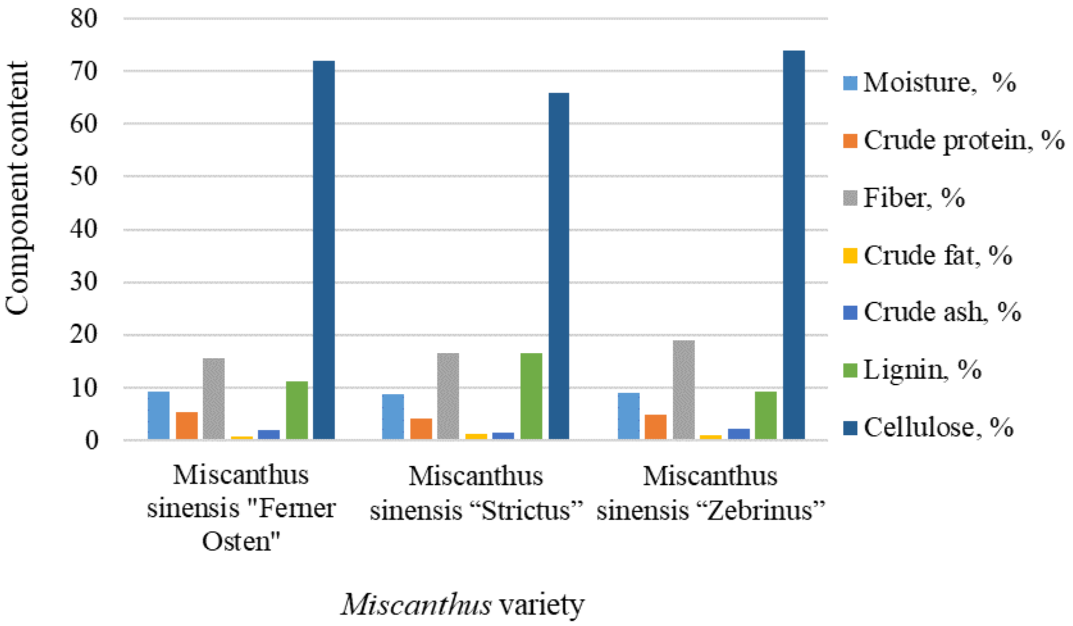

Figure 2 – Chemical composition study of the *Miscanthus sinensis* stems

The results presented in Figure 2 indicate that the *Miscanthus sinensis* stem is characterized by an increased content of acid-insoluble lignin, ash, fiber, and cellulose. For example, the *Miscanthus sinensis* “Zebrinus” stem contains 73.83% cellulose, 9.20% lignin, and 19.06% fiber. The mass fraction of acid-insoluble lignin in the *Miscanthus sinensis* “Ferner Osten” stem was 11.07%. The mass fraction of fiber in the *Miscanthus sinensis* “Ferner Osten” stem reaches 15.49%.

Comparative analysis of the chemical analysis results of the whole *Miscanthus sinensis* plant and its stem samples shows that the stems of the plant contain more cellulose and fiber than the whole plant. The cellulose content in the *Miscanthus sinensis* “Zebrinus” stem is 71.92%, which is 1.16 times more than the cellulose content in the whole plant. The fiber content in the *Miscanthus sinensis* “Zebrinus” stem exceeds the cellulose content in the whole plant by 1.49 times. The cellulose content in the *Miscanthus sinensis* “Strictus” stems is 65.89%, which is 1.15 times more than the cellulose content in the whole plant. The fiber content in the *Miscanthus sinensis* “Strictus” stems exceeds the content of this component in the whole plant by 1.46 times. The same tendency was noted for the *Miscanthus sinensis* “Zebrinus”.

A comparative analysis of the chemical composition of the herbaceous plant stem and whole plant indicates that the values of such indicators as the mass fraction of protein, crude fat, ash, and acid-insoluble lignin are higher in the case of a whole plant.

Conclusion

Thus, it is recommended to use whole *Miscanthus* plants, including the leaves and stems, for further research to develop scientific and technological foundations for processing and using *Miscanthus* biomass in the fuel and energy, cellulose, microbiological, and other industries.

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