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Influence of nitrogen fertilization on the energy value of maize grain in non-ruminants

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Abstract. *Maize is the most widely spread energy source used in rations for farm animals and poultry, especially in countries in America, Southern Europe and Asia, where maize grain is the main cereal used for feed. The quality of maize grain is formed under the influence of several interrelated factors. The aim of the study is to determine the effect of different rates of nitrogen fertilization on the chemical composition and energy value of maize grain grown under irrigation conditions in non-ruminants. The study was conducted in the experimental field of the Agricultural Institute - Stara Zagora under irrigation conditions on cinnamon-meadow soil with maize for grain, medium late hybrid LG 35.36 with density of crops - 70000 plants per hectare. The study includes the following four treatments of fertilization: 1 experimental variant* $N_0P_{80}K_{60}$ *– non-fertilizer control, 2 experimental variant* $N_{100}P_{80}K_{60}$ *– fertilization with 100 kg* $N.ha^{-1}$*, 3 experimental variant* $N_{150}P_{80}K_{60}$ *– fertilization with 150 kg* $N.ha^{-1}$ *and 4 experimental variant* $N_{200}P_{80}K_{60}$ *– fertilization with 200 kg* $N.ha^{-1}$*. Nitrogen fertilizer was applied during the vegetation of the crop in phase 3-5 leaf, and phosphorus and potassium fertilizers in rates 80 kg* $P_2O_5.ha^{-1}$ *and 60 kg* $K_2O.ha^{-1}$ *in the main tillage. During the vegetation of the maize, pre-irrigation humidity of 80-85% of field capacity (FC) was maintained by 3 waterings. As the fertilization rate increases, the crude protein content in the maize grain also grows up. During the treatment with the highest fertilizer rate of 200 kg* $N.ha^{-1}$*, 9.5% per 1 kg of dry matter (DM) was obtained, followed by the treatment with 150 kg* $N.ha^{-1}$ *– with a value of 9.1% per 1 kg of dry matter. The content of crude fiber in the grain of maize with increasing fertilization rate decreases, being the smallest in the treatment with rate 100 kg* $N.ha^{-1}$ *– 0.8% per 1 kg of dry matter. The fertilization rate does not have a significant effect on the content of digestible and metabolite energy in corn grain grown under irrigated conditions in pigs and poultry.*

Keywords: nitrogen fertilization, maize, grain, energy value

Introduction

Maize is the most widely spread energy source used in rations for farm animals and poultry, especially in countries in America, Southern Europe and Asia, where maize grain is the main cereal used for feed (Dei, 2017). Due to the high percentage in the ration, maize can contribute for up to 65% of the metabolite energy and 20% of the protein in poultry mixtures (Gehring et al., 2013; Naderinejad et al., 2016). The nutritional value of maize grain can vary widely (Summers, 2001; Cowieson, 2005) depending on the strain, agronomic conditions and pre- and post-harvest processing. Maize is the main source of energy in swine rations in many countries. The amount of energy in maize used for swine maintenance and growth is not constant mainly due to variation in chemical composition (Li et al., 2014).

It has the highest energy value among forage grains. The grain yields obtained from it are high (Terziev et al., 2001) with a well-balanced biochemical composition in terms of its utilization as a forage and fodder crop (Nankov and Glogova, 2004; Krasteva et al., 2005). The

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quality of maize grain is formed under the influence of several interrelated factors – type of hybrid, environmental conditions - climate, soil conditions, and crop fertilization (Tomov et al., 1984). In our country, there are a number of studies on the influence of mineral fertilization alone and in a complex with other agrotechnical practices on the productivity of maize grain, under different soil-climatic conditions and types of crop rotations, with the participation of earthed-up crops (Dimitrova and Borisova, 2001; Nankov and Atanasov, 2001; Toncheva et al., 2006; Petrov and Georgiev, 2009). Nevertheless, a number of constraints could be discovered in these studies, namely, their focus predominantly on their impact on grain yield from the crop. This has implied broadening of research scope to evaluate the nutritional value of irrigated maize grain in ruminants and non-ruminants.

The aim of the study is to determine the influence of different rates of nitrogen fertilization on the chemical composition and energy value of maize grain grown under irrigated conditions in non-ruminant animals.

Material and methods

The research was conducted in the period 2017-2018 in the experimental field of the Agricultural Institute, Stara Zagora under irrigated conditions on cinnamon-meadow soil with maize for grain, medium late hybrid LG 35.36, with seeding density of 70,000 plants per hectare. Regarding the content of nutrients, the soil type is characterized by very low supply of mineral nitrogen (31.3-38.1 $mg.kg^{-1}$ soil), poorly stocked with mobile phosphorus (3.1-4.3 $mg.g^{-1}$ soil), and well stocked with absorbable potassium (42.3-48.1 mg.100 g^{-1} soil). The soil reaction is slightly acidic (pH 5.23-5.44). The humus horizon is moderately developed. The experiment was conducted using the method of long plots in four repetitions with a harvest plot size of 25 m^2. The study included the following four fertilization treatments: 1. $N_0P_{80}K_{60}$ – unfertilized control, 2. $N_{100}P_{80}K_{60}$ – fertilization with 100 kg $N.ha^{-1}$, 3. $N_{150}P_{80}K_{60}$ – fertilization with 150 kg $N.ha^{-1}$ and 4. $N_{200}P_{80}K_{60}$ – fertilization with 200 kg $N.ha^{-1}$. The nitrogen fertilizer was applied during the vegetation of the crop in 3-5 leaf stage, and the phosphorus and potassium fertilizers in doses of 8 kg $P_2O_5.ha^{-1}$ and 6 kg $K_2O.ha^{-1}$ with the main tillage. During the maize growing season, three waterings were used to maintain a pre-irrigation humidity of 80-85% of the field capacity.

The chemical composition of the grain was analyzed according to the classic Weende method described by Krasteva et al. (1983). The content of the main nutrients was determined including crude protein (calculated with a factor of 6.25), ether extract, crude fiber and ash. The content of nitrogen-free extractable substances (NFE) was calculated by subtracting from 100 the listed nutrients, including the water. The energy content of the feed for non-ruminant animals - swine and poultry, was calculated according to the formulas of Todorov (2004), based on the data obtained from the chemical analyses.

DEs = 0.0242DP + 0.0394DEE + 0.0184DF + 0.017DNFE
MEs = 0.021DP + 0.0374DEE + 0.0144DF + 0.0171DNFE,
DEp = 0.0239DP + 0.0398DEE+0.0177DCF + 0.0177DNFE
MEp = 0.0178DP + 0.0397DEE+0.0177DCF + 0.0177DNFE,

where:
DEs is digestible energy for swine, MJ/kg
MEs – metabolite energy for swine, MJ/kg
DEp is digestible energy for poultry, MJ/kg
MEp - metabolite energy for poultry, MJ/kg
DP – digestible protein,
DEE – digestible ether extract,
DF – digestible fiber,
DNFE – digestible non-nitrogen extractive substances.

Results and discussion

Table 1 presents the data from the laboratory analyses of maize for grain at the different levels of fertilization. Upon application of 100 kg of nitrogen per hectare, the crude protein content of the grain was 8.7% DM. In the variant with fertilization with 150 kg nitrogen per hectare, the obtained crude protein content was 9.1% DM and at a fertilization level of 200 kg nitrogen per hectare it was 9.5% DM.

The influence of nitrogen fertilization on ether extract content is not unidirectional. The values of this indicator vary from 4.8% upon fertilization with 200 kg of nitrogen per hectare to 5.3% for the variant with 150 kg of nitrogen per hectare.

The applied rate of fertilization lowered the crude fiber content in 1 kg of maize grain from 1.1% in the unfertilized control to 0.8% when applying 100 kg of nitrogen per hectare. For the other variants, these values are 0.9% in 1 kg of dry matter.

With an increase in the rate of fertilization, a decrease in the content of non-nitrogenous extractive substances in the maize grain is observed. From 84.7% in the non-fertilized variant, a reduction of nitrogen-free extractive substances was found to 84.1%; 83.4% and 83.3% in 1 kg of dry matter for fertilization rates of 100, 150 and 200 kg nitrogen per hectare.

Table 1. Forage chemical composition, % DM

Treatments (Variatios)	Crude protein	Ether extract	Crude fiber	Ash	NFE
1. $N_0P_{80}K_{60}$ – non-fertilized	7.9	4.9	1.1	1.4	84.7
2. $N_{100}P_{80}K_{60}$ – 100 kg N.ha^{-1}	8.7	5.1	0.8	1.3	84.1
3. $N_{150}P_{80}K_{60}$ – 150 kg N.ha^{-1}	9.1	5.3	0.9	1.3	83.4
4. $N_{200}P_{80}K_{60}$ – 200 kg N.ha^{-1}	9.5	4.8	0.9	1.5	83.3

Similar results (Bazitov et al., 2007) were obtained in other studies on the influence of nitrogen fertilization and tillage on the chemical composition of maize grain under irrigated conditions. Mineral fertilization with $N_{100}P_{80}K_{60}$ increased crude protein content by an average of 11.2% and fat content by 16.1%. The same rate of fertilization reduced crude fiber content by 16.4% compared to the unfertilized control.

An increase in the content of protein, fat and ash was also found in a study by Souza et al. (2016), as well as a decrease in the content of starch and total carbohydrates when applying nitrogen fertilizer in the amount of 240 kg.ha $^{-1}$ compared to the unfertilized control.

Almodovares et al. (2009) also reported an increase in crude protein content and a decrease in soluble carbohydrates and fiber when applying fertilization rate from 50 to 200 kg.ha $^{-1}$.

Table 2 illustrates digestible nutrient content of maize grain for swine at different levels of fertilization. When calculating the values of the digestible nutrients, the digestibility coefficients were taken as follows: crude protein – 79%, ether extract – 75%, crude fiber – 40% and NFE – 93% (Todorov, 2007).

The obtained results for digestible energy and metabolite energy in swine are presented in Table 3.

Table 2. Digestible organic matter for swine, g.kg^{-1} DM

Treatments (Variants)	Digestible protein	Digestible ether extract	Digestible fiber	Digestible NFE
1. $N_0P_{80}K_{60}$ – non-fertilized	62.6	36.8	4.3	787.3
2. $N_{100}P_{80}K_{60}$ – 100 kg N.ha^{-1}	68.4	38.5	3.0	782.4
3. $N_{150}P_{80}K_{60}$ – 150 kg N.ha^{-1}	71.5	39.6	3.7	775.9
4. $N_{200}P_{80}K_{60}$ – 200 kg N.ha^{-1}	75.3	36.5	3.5	774.5

Table 3. Energy value of forage for swine, MJ kg^{-1}DM

Treatments (Variants)	DEs MJ kg^{-1}	MEs MJ kg^{-1}
1. $N_0P_{80}K_{60}$ – non-fertilized	16.43	15.66
2. $N_{100}P_{80}K_{60}$ – 100 kg N.ha^{-1}	16.53	15.69
3. $N_{150}P_{80}K_{60}$ – 150 kg N.ha^{-1}	16.55	15.67
4. $N_{200}P_{80}K_{60}$ – 200 kg N.ha^{-1}	16.49	15.57

The content of digestible energy in 1 kg of dry matter in maize grain is the highest in the variant with 150 kg N. ha^{-1} – 16.55 $MJ.kg^{-1}$. In the non-fertilized version, the level of digestible energy is 16.43 $MJ.kg^{-1}$ of dry matter in maize grain. The content of metabolite energy varied from 15.57 to 15.69 $MJ.kg^{-1}$ of dry matter in maize grain at different levels of nitrogen fertilization. Based on the data on the chemical composition, the digestible nutrients were calculated with digestibility coefficients as follows: crude protein – 82%, ether extract – 75%, crude fiber – 28% and nitrogen-free extractive substances – 90% (Table 4).

Table 5 summarizes the digestible and metabolite energy values for poultry of maize grain obtained under irrigated conditions and different levels of fertilization.

Table 4. Digestible organic matter for poultry, $g.kg^{-1}$DM

Treatments (Variants)	Digestible protein	Digestible ether extract	Digestible fiber	Digestible NFE
1. $N_0P_{80}K_{60}$ – non-fertilized	64.9	36.8	3.0	761.9
2. $N_{100}P_{80}K_{60}$ – 100 kg $N.ha^{-1}$	71.0	38.5	2.1	757.2
3. $N_{150}P_{80}K_{60}$ – 150 kg $N.ha^{-1}$	74.2	39.6	2.6	750.9
4. $N_{200}P_{80}K_{60}$ – 200 kg $N.ha^{-1}$	78.2	36.5	2.4	749.5

Table 5. Energy value of forage for swine, MJ kg^{-1}DM

Treatments (Variants)	DEs MJ kg^{-1}	MEs MJ kg^{-1}
1. $N_0P_{80}K_{60}$ – non-fertilized	16.56	16.16
2. $N_{100}P_{80}K_{60}$ – 100 kg $N.ha^{-1}$	16.67	16.12
3. $N_{150}P_{80}K_{60}$ – 150 kg $N.ha^{-1}$	16.69	16.23
4. $N_{200}P_{80}K_{60}$ – 200 kg $N.ha^{-1}$	16.63	16.15

The obtained results demonstrate that the differences in the digestible energy values in dry matter are minor, ranging from 16.56 $MJ.kg^{-1}$ in the unfertilized control variant and 16.69 $MJ.kg^{-1}$ in the variant with 150 kg $N.ha^{-1}$.

The same tendency is observed in the metabolic energy values, which are within the range between 16.12 $MJ.kg^{-1}$ for the variant with 100 kg $N.ha^{-1}$ and 16.23 $MJ.kg^{-1}$ for the variant with 150 kg $N.ha^{-1}$. Similar results were obtained in other studies conducted by our team regarding the influence of fertilization level on the energy value of maize grain in non-ruminant animals (Bazitov and Mihaylova, 2007).

Conclusion

Based on the findings of the present study, the following conclusions can be drawn:

As the fertilization rate grows, the crude protein content in the maize grain also increases. At the variant with the highest fertilizer rate – 200 kg $N.ha^{-1}$ – the crude protein content was 9.5% in 1 kg DM, followed by the variant with 150 kg $N.ha^{-1}$ – 9.1% in 1 kg of DM. The content of crude fibers in the maize grain decreases from 1.1% DM to 0.9% DM, as the rate of fertilization increases, being the least in the variant with a rate of 100 kg $N.ha^{-1}$ – 0.8% in 1 kg of dry matter. Fertilization rate has no significant effect on digestible and metabolite energy content of maize grain in pigs and poultry grown under irrigated conditions.

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