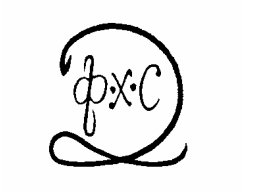

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RELATIONS BETWEEN FREE ENERGY AND GRAIN COMPOSITION OF SWEET MAIZE FROM ECOLOGICAL PRODUCTION

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ABSTRACT

The aim of this study was to investigate the influence of different cover crops, in combination with microbiological fertilizer on variability of main kernel components: proteins, starch and oil and their relation with different water types: free, bulk and chemically bound water (present in the form of Gibbs free energy) as factors which contribute to kernel nutritional quality. Applied cover crops and microbiological fertilizer expressed variable effect on content of starch, oil and particularly of proteins. Free energy of free water was negatively correlated with protein and starch and positive with oil in sweet maize kernel, indicating its significance in accumulation of all three examined components. Leguminous cover crops were important for protein accumulation in grain, together with decrease in available sorption sites and decrease in endergonic reactions, what could in result contribute to the increased nutritional quality of produced kernel.

INTRODUCTION

Food that originates from ecological and so organic production is characterised by higher nutritional value, it is richer in minerals, vitamins and other phytonutrients [1]. Important source of nutrients and energy in maize based food systems is given to sweet maize [2]. It is mainly consumed fresh or processed, but opposite to other types of maize, it is harvesting in milky, i.e. technological maturity (lesser dry substance concentration), when many nutrients are highly digestible.

From this point of view it is important to examine relations between applied cropping practices and nutritional value of produced crops. Many strategies have been involved in ecological production with aim to maintain soil fertility and parallel, to enable maximal utilization of environment with savings in inputs. These strategies imply application of organic and

microbiological fertilizers, intercrops, cover crops, etc. Some studies describe reaction of sweet maze to application of organic fertilizers [3], as well as preceding crops [4,5], which influence not only growth and yielding capacity, but also kernel composition.

The objective of this study was to investigate the influence of different cover crops in combination with microbiological fertilizer on variability of main kernel components: proteins, starch and oil and their relation with different water types: free, bulk and chemically bound water, as factors which contributes to kernel nutritional quality.

EXPERIMENTAL

A field experiment was carried out over 2014/15, at the Experimental Field of Maize Research Institute in Zemun Polje (44°52'N 20°20'E). The experiment was established as a block design with four replications with winter cover crops as treatment: T1 - common vetch (*Vicia sativa*L.), T2 - winter oats, (*Avena sativa* L.), T3 - fodder kale (*Brassica oleracea* (L.) *convar. acephala*), T4 - field pea (*Pisum sativum*L.) + winter oats, T5 - dead organic mulch, T6 - common vetch + winter oats, T7 - field pea and T8 - classical variant, uncovered during the winter.

The cover crops were sown at the end of October or in early November. Green mass of the cover crops were incorporated in the soil in early May. After that bio-fertilizer – Uniker (containing proteolytic and cellulolytic bacteria) was applied to accelerate mineralization of cover crops, which was followed by sweet maize (ZPSC 421*su*) sowing.

The kernels were harvested at the stage of milk maturity (end of August). The content of protein, starch and oil in grain was determined after drying in ventilation dryer at 80 °C, on infrared analyser (Infraneo, Chopin Technologies, France). The difference between fresh and dry mass (after drying at 60 °C, 105 °C and 130 °C) referred to contents of free, bulk and chemically bound water, calculated by free energy by sorption isotherm [6]:

$$\Delta G = -RT \ln(a_w)$$

where a_w is the relative water content achieved after drying at T (60, 105 and 130 °C), R is the gas constant (8.3145 J mol^{-1} K^{-1}) and ΔG is differential free energy.T he experimental data were statistically processed by standard deviation and correlation (Pearson coefficients).

RESULTS AND DISCUSSION

According to results presented in Tab. 1, the highest variation in examined kernel constituents was in oil content (15.8%), while the lowest variation was in starch content (3.7%). Among tested treatments, the highest protein content was in T4 treatment, followed by T1 and T7, what could be

explained by the positive response of sweet maize to nitrogen enrichment caused by leguminous plants present in those treatments [4, 5]. The highest starch content was in T5 and the other treatments with non-leguminous cover crops [5]. The highest oil content was in T3 treatment. Other than that, free energy values (ΔG 60°C) varied in the widest range among all examined parameters (31.1%) and ΔG 105°C varied in the lowest degree (6.4%). Since free energy presents the work necessary to make the sorption sites available, and so the higher the moisture content is, the number of available sites are lower [1], results in this research indicate that the lowest available sites are present for ΔG 60°C averagely. Similar trend was observed for T1 treatment, where the lowest values of all three free energy parameters were noticed. The highest values of ΔG 60°C and ΔG 105°C were in T2 and the highest value of ΔG 130°C was in T7 treatment, indicating higher availability of sorption sites, as well as domination of endergonic reactions.

Table 1. The influence of different cover crops in combination with Uniker to variation on main composition and free energy in sweet maize grain

Treatm.	Protein (%)	Starch (%)	Oil (%)	ΔG 60°C (J mol^{-1})	ΔG 105°C (J mol^{-1})	ΔG 130°C (J mol^{-1})
T1	11.16	62.2	5.2	0.60	9.38	7.08
T2	10.04	60.6	6.7	1.16	10.43	8.87
T3	10.87	59.7	6.8	0.92	10.07	8.91
T4	11.64	61.7	6.1	0.94	9.53	8.81
T5	10.27	63.4	6.5	0.82	9.94	8.35
T6	11.33	60.0	6.2	0.86	9.92	8.27
T7	11.36	58.7	6.6	0.88	9.45	9.02
T8	11.36	61.3	5.3	0.82	9.70	8.63
CV%	8.8	3.7	15.8	31.2	6.4	16.6

The significant and negative correlation was observable between protein content and ΔG 60°C and ΔG 105°C (Tab. 2), as well as between starch content and ΔG 60°C and ΔG 130°C, pointing that increase in content of polymers such protein and starch correspond with decrease in available sites for free and bound water sorption, as well as lowering of endergonic reactions [7, 8]. Oil correlated positively with all three examined free energy parameters, indicating importance of all three water types for their accumulation, as well as increase in available sites for all three types of water.

Table 2. The correlation between free energy and main grain constituents

	Protein (%)	Starch (%)	Oil (%)
ΔG 60°C	-0.428*	-0.371*	0.703*
ΔG 105°C	-0.778*	-0.085	0.597*
ΔG 130°C	-0.067	-0.521*	0.682*

*The significant values at the level of significance of 0.05

CONCLUSION

The combination of different cover crops and microbiological fertilizer expressed variable effect not only on accumulation of main kernel components (nutrients), but also on desorption properties of free, bulk and bound water. Free energy of free water was negative correlated with protein and starch and positive with oil in sweet maize kernel, indicating its importance in accumulation of all three components. Leguminous cover crops were important for protein accumulation, together with decrease in available sorption sites and decrease in endergonic reactions, what could in result contribute to the increased nutritional quality of produced kernel.

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