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Responses of cereals grain quality on organical and conventional farming

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Abstract. Commodity-based conventional farming induced applying heavy amounts of mineral and organic fertilizers and stimulated the decline of the animated part of the soil. Integrated, extensive and ecologically sustainable organic agriculture systems started to spread inherently as an alternative to such aggressive conventional farming. The main aim of this research was to evaluate and compare chemical composition of forage cereals (barley, wheat, rye, oat and triticale) cropped in different farming systems. Dry matter (DM), crude ash (CA), crude fat (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), content of mineral, trace elements and heavy metals were determined for estimation of the feed value of tested cereals grain. The highest content of important essential amino acid methionine+cystine (5.0 g kg^{-1} DM) and lysine (4.7 g kg^{-1} DM) was determined in chemical composition of oat. The equal content of tryptophane (1.2) was determined in wheat, oat and barley. The smallest content (0.95 g kg^{-1} DM) of this amino acid was found in rye. Mineral and trace element concentrations in DM ranged as follows: Ca– 0.3–0.9, P – 3.3–3.7, Mg – 1.1–1.2 and Na – 0.16–0.35 g kg^{-1}. Organically cropped grain contained less crude protein (CP) and fat, but crude fiber content increased as compared to those conventionally cropped. CP varied from 8.2 (triticale) to11.5% (oat) in organically cropped grains. CP content was markedly higher in intensively cropped grain and ranged between 11.9–14.5%.

Keywords: cereals, organic and intensive/conventional farming, chemical composition

INTRODUCTION

About 60 years ago, commodity-based conventional farming induced the application of heavy amounts of mineral and organic fertilizers and various pesticides in many areas of the world, including Europe. Due to this chemical load the animated part of the soil started to decline. Intensive farming systems influenced the decrease of different soil fauna (insects, earthworms) and microorganisms (bacteria, actinomycetes, algae, fungi and protozoa). As an alternative to such aggressive farming, integrated, extensive and organic agriculture systems started to spread. Chemical content in intensive or conventional agriculture transgressed safe delimitations and an organic agriculture groundswell arose (EU Regulation 2092/91).

Organic agriculture progressed in different manners and formats, starting in Western Europe: Britain, Switzerland, and Holland. Organic farming has been understood as a part of sustainable farming systems and a viable alternative for the more traditional approaches to agriculture (EU Regulation 1257/99). Since the EU rules on organic farming came into force in 1992, tens of thousands of farms have been converted to this system, as a result of increased consumer awareness of, and demand for, organically grown products. Although it only represented around 3 % of the total EU utilized agricultural area (UAA) in 2000, the organic farm sector grew by about 25% a year between 1993 and 1998. In addition, annual growth since 1998 is estimated at about 30 % (EC Doc AGRI/2007/63506). Organic farming has in fact developed into one of the most dynamic agricultural sectors in the European Union. However, it now seems to have reached a plateau in some Member States.

In Lithuania the first organic farms were registered 15 years ago (www.Ekoagros.lt, 2009 03 14). In 2008, 2805 organic farms with a total area of 125 000 ha were certificated in Lithuania; 49% of this area was mostly occupied by cereals for forage and human food. Therefore recovery of organic grain is pronounced in the market. In contradiction to organic grain consumption for its internal needs in previous years, grain stock intended for processing enterprises has increased. The quota of organic grain was exported abroad in 2007.

Not only organic production but also assessment of production quality is required. Therefore the aim of this study was to establish chemical composition of cereals (barley, wheat, rye, oat and triticale) cropped in organic farms.

Both high productivity and good quality are required for organically cropped forage cereals. Quality depends both on content and ratio of food materials in forages. Earlier research determined that the quality of cereals was lower than expected (Pekarskas & Sliesaravičius, 2004; Rutkoviene et al., 2008). It was proven also that yield and quality of winter wheat depend on meteorological conditions (Pekarskas, 2005; Rutkovienė et al., 2003; Sileikiene et al., 2006).

MATERIALS AND METHODS

Assayed forage cereals were cropped at an organic farm (S. Gecas) during 2004–2007. Soil type – *Dystri-Endohypogleyic Albeluvisol*, JIg4-n and 6.7 pH_{HCl}. Chemical composition (ChC) and feed value of grain barley *Aura*, wheat *SW Maxi*, rye *Joniai*, triticale *Tornado*, and oat *Migla DS* were assayed and its relevance for forage usage was estimated. Crops were fertilized with 40 t ha^{-1} of manure. Chemical composition data of organic cereals were compared with analogous data (excluding data of different fiber fractions) of an intensive farm (Animal ..., 2007).

Examined crops and dry matter (DM), crude ash (CA), crude fat (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) of grain were assayed according to commonly used chemical methods of Weender forage analysis (Nauman & Baasler, 1993) in the Agronomical and zoo-technical analysis laboratory of the Lithuanian Agricultural University: crude fat (CF) – Sokslet, crude protein (CP) – Kjaeldal, crude fiber (CF) – Van Soest, organic material (OM) and crude ash (CA) – dry burning at 500±25°C. Concentrations (mg kg^{-1}DM) of studied trace elements (Cu, Zn, Ni, Pb and Cd) in DM were analyzed using the atomic absorbance method (Perkin Elmer 603). Mineral element (Ca, Mg and P) concentrations (g kg^{-1} DM) in DM were analyzed using near-infrared reflectance (NIR) spectroscopy (PSCO/ISI IBM-PC 4250; Pacific Scientific, USA) according to the database of researched plants.

Brutto metabolic energy (BME MJ kg^{-1}) of grains was expressed by the following formula (Jeroch, 1993):

$$BME = 0.0239 \times CP + 0.0398 \times CR + 0.0201 \times CF + 0.0175 \times NEM;$$

means:

CR– crude fat g kg^{-1};

CF– crude fiber g kg^{-1};

CP– crude protein g kg^{-1};

NEM – nitrogen–free extractives

The level of statistical confidence ($P < 0.05$) of the data was calculated by the method of dispersion analysis using the statistical package ANOVA. The least significant difference (LSD) method was used to evaluate differences between the studied cereals' chemical composition, ME and NEL.

RESULTS AND DISCUSSIONS

The essential forage quality index is protein content which was determined to be the lowest in all organically cropped grain. The highest protein content (133, 128.4 and 123 g kg^{-1} DM) was determined in conventionally cropped wheat, barley and oat and was followed by organically cropped winter wheat (95.5–97.0 g kg^{-1} DM) and barley (108 g kg^{-1} DM) (Table 1). As many authors report, amino acids play an important role both in the building blocks of proteins and in different metabolism processes, providing a guarantee of normal livestock physiology (Dozier et al., 2008; Yin et al., 2008; Shan et al., 2007). The determined content of important essential amino acid methionine+cystine (4.0 g kg^{-1} DM) and lysine (5.5 g kg^{-1} DM) that was determined in chemical composition of conventionally cropped oat was higher than that of the organically cropped. The lowest content of tryptophane (0.95 g kg^{-1} DM) was determined in organically cropped barley. Significantly higher content of tryptophane – precursor of the neurotransmitter serotonin – accumulated under the influence of intensive farming. The smallest content (0.95 g kg^{-1} DM) of this amino acid was found in organic rye and barley.

The data show grain quality dependence on farming type and the biological characteristics of plant species. Intensive technologies produced higher and better quality yield than those in organic farming. This issue points out the necessity of improving cropping technologies in organic farming.

Table 1. Protein content (g kg^{-1}DM) in grain.

Cereal	Farming system	Crude protein g kg^{-1}DM	Lysine, g kg^{-1}DM	Methionine+ cystine, g kg^{-1}DM	Tryptophan, g kg^{-1}DM
Wheat	Organic	95.5–97.0	3.1	2.0	1.2
	Intensive	133.0	4.0	3.9	1.7
Rye	Organic	80.5–83.0	3.6	2.3	0.95
	Intensive	101.0	4.5	2.9	1.2
Oat	Organic	85.0–88.0	3.7	2.7	1.1
	Intensive	123.0	5.5	4.0	1.8
Barley	Organic	108.0	4.1	3.0	0.95
	Intensive	128.4	4.8	3.7	1.5
LSD_{05}		9.21	0.56	0.11	0.14

Table 2. Content (mg kg^{-1}DM) of trace elements and heavy metals in grain.

Cereal	Farming system	Cu	Zn	Ni	Pb	Cd
Wheat	Organic	2.16	18.5	0.13	0.11	0.0457
	Intensive	5.9	30.0	-	-	-
Rye	Organic	3.2	22.2	0.13	0.10	0.037
	Intensive	5.8	30.0	-	-	-
LSD_{05}		0.21	3.16	0.01	0.01	0.0014

Table 3. Fiber matter content in organically cropped grain.

Cereal	Sample, un.	g kg-1 DM					
		DM	NDF	ADF	Hemicellulose	ADL	Cellulose
Barley	4	880	171	71	100	18	53
Oat	4	890	295	157	138	31	126
Rye	4	860	139	47	92	19	28
Wheat	4	870	129	43	86	13	30
LSD_{05}		9.10	8.36	2.75	10.50	2.90	11.08

Conventional cropping significantly increased Zn and Cu accumulations in the grain tested (Table 2). Heavy metals accumulation depends on their concentration in the environment (Goodsell et al., 2009) therefore their content in grain has not been compared. As Kan & Meijer (2007) report, depending on their physical–chemical characteristics, some toxic substances are metabolized into generally harmless constituents as a natural occurrence, but heavy metals are not metabolized at all. Some metals are irreversibly bound to body tissues, *e.g.* lead to bone or cadmium to kidneys. Possible sources and reasons for heavy metal and other toxic contamination through the diet are also addressed (Pulina et al., 2006). The content of heavy elements (Ni, Pb and Cd) harmful for health and the environment did not exceed safe quotas, therefore organic wheat and rye DM were deemed healthy for livestock nutrition (EEC Council Directive 86/278/).

Fiber content determines dietary and feed value in forages (Clóvis et al., 2008; Nader & Robinson, 2008). As Baurhoo et al. reports (2008), lignin, the second most abundant natural compound after cellulose, is a high–molecular weight polymer of phenolic compounds that occurs naturally in plants and is present primarily in the cell wall, conferring structural support, impermeability and resistance to microbial attack. The highest content of NDF was found in oat (295 g kg^{-1} DM), less in barley (171 g kg^{-1} DM), rye (139 g kg^{-1} DM) and wheat (129 g kg^{-1} DM) cropped organically (Table 3). In comparison with NDF, ADF content accounted for less and ranged between 43–157 g kg^{-1} DM in different organically cropped cereals. As Baurhoo et al. (2008) suggest, purified lignin may exert health benefits in monogastric animals and could potentially be considered as a natural feed additive. Adversely, lignin is the least digestible fiber, therefore large quantities are not preferred in forages. Lignin content in organically cropped cereals composed 13–31 g kg^{-1} DM and increased in traditionally cropped cereals. The highest total content of cellulose was determined in oat grain (126 g kg^{-1} DM); in other cereals it ranged between 28–53 g kg^{-1} DM.

Table 4. Mineral concentration (g kg $^{-1}$ DM) in grain.

Cereal	Farming system	Ca	P	Mg
Barley	Organic	0.46	3.06	1.20
	Intensive	0.59	3.07	1.49
Oat	Organic	0.30	3.05	1.10
	Intensive	0.91	3.42	1.57
Rye	Organic	0.49	2.70	1.10
	Intensive	0.59	2.80	1.33
Wheat	Organic	0.70	3.30	1.10
	Intensive	1.28	4.16	1.34
LSD_{05}		0.01	0.04	0.01

Table 5. Comparing chemical composition and energetic value of organically and intensively cropped cereal grain.

Cereal	Farming system	Crude protein, %	Crude fat, %	Crude fiber, %	Crude ash, %	NEM, MJ kg $^{-1}$	BME, MJ kg $^{-1}$
Wheat	Organic	9.6	2.0	3.4	2.3	82.7	18.16
	Intensive	13.9	2.1	2.9	1.9	79.3	18.54
Triticale	Organic	8.2	1.7	3.1	2.4	84.6	18.06
	Intensive	14.5	1.8	2.8	2.2	78.7	18.52
Barley	Organic	9.8	2.2	5.8	3.2	79	18.2
	Intensive	11.9	2.3	5.2	2.7	77.9	18.43
Oat	Organic	11.5	4.8	12.8	3.8	67.1	18.97
	Intensive	12.1	5.3	11.6	3.3	67.7	19.16
LSD_{05}		0.10	0.08	0.09	0.01	0.91	0.89

According to references (Mäntysaari et al., 2007), concentration of all types of fibres (NDF, ADF, ADL and cellulose) in organically cropped cereals gained over traditionally cropped cereals and is partly digested.

DF provides negligible amounts of digestible or metabolic energy. As Noblet & Le Goff reported (2001), components of DF are digested differently: lignin is undigested while pectins are almost totally digested; hemicellulose tends to be more digested than cellulose, although both are partly digested. Digestion of DF is also associated with energy losses. Consequently, increased concentration of DF makes a negative contribution to feed value and energy supply of forages cropped in organic farming. The potential impact of minerals and trace elements on animal productivity and health should not be ignored. Many reports (Laswai et al., 2008; Leeson & Caston, 2008; Pulina et al., 2006) concluded that minerals effectively improved nutritive value of low quality roughage during short-time feeding without detrimental effect on their concentration in the urine and blood of animals. Ca content ranged 0.3–0.9, P – 3.3–3.7, Mg – 1.1–1.2 and Na – 0.16–0.35 g kg $^{-1}$ DM organic cereals (Table 4). Mineral concentrations in organic cereals were significantly smaller than those in conventional cropping, therefore problems of additional fertilizing should be solved in organic technologies.

It was determined that organically cropped grain had less protein and fat content, but crude fiber content increased in comparison with those intensively cropped (Table

5). CP varied from 8.2 (triticale) to 11.5% (oat) in organic cropped grains. CP content was significantly higher in intensively cropped grain and constituted from 11.9–14.5%.

Presumably, decreased protein and fat concentration of cereals under organic farming was caused by insufficient fertilizing. The chemical composition and calculated generalized index of *brutto* metabolic energy (BME) of intensively cropped grain were significantly better than those of organically farmed grains. BME differences between organic and intensive farming were not significant in all other treatments.

CONCLUSIONS

Application of environmentally sustainable organic farming with a fertilizing rate of 40t ha-1 manure cannot guarantee the same high protein and fat or the same low fiber content as implementation of intensive technologies in conventional farming. But risk of organic grain contamination with heavy elements (Ni, Pb and Cd) harmful for health and the environment disappeared when cropping forage in certified plots of the organic farm. Therefore organic wheat and rye were safe for livestock nutrition.

Significantly poor concentration of minerals (Ca, P, Mg) and trace elements (Cu, Zn) were determined in organically cropped grain, possibly due to insufficient supplementation with fertilizers.

The BME of intensively cropped grain gained in organic grain due to better chemical composition. Nonetheless BME differences between organic and intensive farming were insignificant.

The insufficient quality of organically cropped forage grain highlights the necessity of improving cropping technologies in organic farming.

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