

THE EFFECT OF ORGANIC AMENDMENTS ON THE CHEMICAL COMPOSITION OF SAFFLOWER (*Carthamus tinctorius* L.) MEAL

Violina R. Angelova, Vanja I. Akova, Krasimir I. Ivanov

University of Agriculture, Department of Chemistry, Plovdiv, Bulgaria

Abstract

The effects of organic soil amendments (compost and vermicompost) on the chemical composition of safflower meal (heavy metals, micro and macroelements and amino acid composition) were studied. Field experiments with randomized complete block design with five treatments (control, compost amendments added at 5 and 10% , and vermicompost amendments added at 5 and 10%) were carried out. Tested organic amendments significantly influenced the chemical composition of safflower meal. The compost and vermicompost treatments significantly reduced heavy metals concentration in safflower meals, but the effect differed among them. Addition of compost affected significantly the mineral contents of the safflower meal. Treatment with vermicompost leads to a slight decrease in nutrient content, the decrease was more pronounced with the introduction of 5% vermicompost. In potassium and calcium was observed almost no influence of the additive. Crude protein and amino acids composition was affected by compost and vermicompost amendment treatments. The composition of nonessential and essential amino acids affect both organic amendments, which in most cases is opposite. The effect of amendments was mainly manifested in the non-essential amino acid content of meal, the 10% compost treatment entrained an increase by about 48%. At the same time, also the essentials content increased, but moderately, exceeding control by max. 29.6%. The C. tinctorius is a good source of protein supplement in livestock. It is necessary to supplement safflower seed meal based diets with the sulphur-containing amino acids (methionine and cystine) in order prevent nutritional deficiencies of these essential amino acids.

Key words: safflower meal, organic amendments, chemical composition, amino acid content

1. INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is an annual plant originally grown for its flowers, which were used in aking red and yellow dyes for clothing and food preparation. Today, safflower it is primarily cultivated for its oil, which is used for food and industrial purposes. Safflower can be used as animal feeds, birds feed and in small quantity for ruminants feed as whole seeds or meals (Oelke et al., 1992). The seed contains nearly 35–50% oil, 15–20% protein, and 35–45% hull fraction (Betschart, 1975; Rahamatalla et al 1998, 2001)]. The proteins from the safflower seeds are of good nutritional quality Betschart, 1979). The total protein contains high amounts of aspartic acid, glutamic acid, valine, glycine and phenylalanine (Latha and Prakash, 1984). The utilization of safflower protein concentrate in food has been limited because of color and bitter principles and also the high content of crude fiber [6]. Whole safflower seeds are mainly used for petfood, either as birdseeds for wild birds, racing pigeons, parrots and other pet birds, or for pet mammals such as gerbils, hamsters and chinchillas. Safflower seeds are normally too expensive to be used as a feed ingredient for farm animals (Oelke et al., 1992; Mündel et al., 2004).

Safflower meal, a by-product of the oil industry, is mostly used as a protein ingredient for animal feeding. Dehulling improves crushing efficiency, but the hardness of the seed coat and the extreme softness of the kernel make the operation costly and only economically viable if there is a market for hulls (GRDC, 2010; Smith, 1996). Protein content is about 20-25 % in the undecorticated meal but can be over 40 % in decorticated meals (Dajue et al., 1996; Göhl, 1982). Crude fibre content is about 30-40 % for undecorticated meal and can be as low as 10 % in the dehulled meal (GRDC, 2010). High-protein meals containing more than 40 % protein can be obtained by sifting the regular meal and removing hull fragments (Alvarez-Gonzalez et al., 2007). The quality of safflower meal is highly variable as it depends on the amount of hulls and on the extent of oil extraction.

Commercial safflower meal with 25% protein is considered a high protein by-product. Meal from de-hulled seeds is a high quality protein supplement similar to canola meal, but with slightly more protein and energy. Most commercial safflower meals includes hulls. This results in a medium protein (25% CP) meal that is high in fiber content (50% ADF) (Alobeid et al, 2010). The fiber content of this meal is too high for most swine and poultry diets. Hulled safflower meal is comparable to dried brewers' grains as a feed for ruminants, although the fiber is less digestible. Limited information indicates that safflower meal is relatively high in ruminal bypass

protein, making it a good alternative protein supplement for lactating dairy cows. Studies on safflower meal is rare and their use in livestock feed are limited.

In our previous studies, it was found that the safflower may be grown on the contaminated soils with heavy metals (Angelova et al., 2011b). Addition of organic matter amendments, such as compost, and vermicompost in soil leads to immobilization of heavy metals and soil amelioration of contaminated soils (Clemente et al, 2005, Angelova et al., 2011a). Organic amendments are able to improve soil physical, chemical and biological properties by: (i) raising the pH, (ii) increasing the organic matter content, (iii) adding essential nutrients for plant growth, (iv) increasing the water holding capacity, and (v) modifying heavy metals bioavailability (Walker et al, 2003, 2004; Angelova et al., 2011a).

The aim of this experiment was to compare the effect of organic soil amendments (compost and vermicompost) applied to the soil on the chemical composition of safflower meal (heavy metals, micro and macroelements and amino acid composition).

2. MATERIALS AND METHODS

The experiment was performed on an agricultural field contaminated by the Non-Ferrous-Metal Works near Plovdiv, Bulgaria. The field experimental was a randomized complete block design containing five treatments and four replications (20 plots). The treatments consisted of a control (no organic amendments), compost amendments (added at 5 and 10 g/kg), and vermicompost amendments (added at 5 and 10 g/kg). Plot size was 24 m² (3 m x 8 m). The soil from each plot were combined and mixed with amendments. The soils used in this experiment were slightly acidic, moderate content of organic matter and essential nutrients (N, P and K). The pseudo-total content of Zn, Pb and Cd is high (1430.7 mg/kg Zn, 876.5 mg/kg Pb and 31.4 mg/kg Cd, respectively) and exceeds the maximum permissible concentrations (200 mg/kg Zn, 70 mg/kg Pb, 1.5 mg/kg Cd).

The test plant was safflower (*Carthamus tinctorius L.*). Upon reaching commercial ripeness, the safflower plants were gathered and the seeds were ground in a Wiley mill with the 1 mm mesh sieve. The oil from ground safflower seed was derived under laboratory conditions through an extraction method with Soxhlet's apparatus. The contents of heavy metals, micro and macroelements in meals of safflower were determined by the method of the dry mineralization. To determine the chemical composition in the samples, inductively coupled emission spectrometry (Jobin Yvon Emission - JY 38 S, France) was used. Nitrogen determinations were made on the ground extracted seed by the Kjeldahl procedure (BDS EN ISO 5983-1), and crude protein content was calculated by the factor N X 5.3.

For amino acid analysis, representative samples of safflower meal from each treatment were ground (25 mesh). A sample containing 100 mg of nitrogen, was hydrolyzed with 20 cm³ 6 N HCl in a flask of 50 cm³ per 24 h in a desiccator at 105°C. Then it was filtered in a volumetric flask of 100 cm³ and made up to the mark with double distilled water. For analysis was taken 15 cm³ hydrolyzed sample and the sample was evaporated at a temperature of 60°C in a water bath to dryness. To the residue was added 10 cm³ buffer (pH 2.2) and filtered again before being injected into the amino analyzer. Methionine and cystine were determined after oxidation. In this process, methionine is converted to methionine sulfone, and cystine - to cysteic acid by the oxidation mixture. It was prepared from 30% hydrogen peroxide and concentrated formic acid in the ratio 1:9, allowed to stand for 1 hour at room temperature and cooled in a refrigerator for 10 minutes. The sample, containing 100 mg of nitrogen, pour the oxidation mixture and spent one night in the icebox, then evaporated at a temperature of 60 °C in a water bath to remove performic acid and acid hydrolysis was performed as described above. Samples were analyzed for amino acids with an Amino Acid Analyzer T 339 M (Microtechna- Praha) by a procedure based on the Moore and Stein procedure. By this method can be determined following amino acids: lysine, histidine, arginine, aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, cystine, valine, methionine, isoleucine, leucine, tyrosine and phenylalanine. The amino acids were expressed as grams of amino acid per 100 g of protein and percent of sample. Data for each amino acid were analyzed statistically by the analysis of variance method and means were compared by Duncan's multiple range test. Simple correlation coefficients between amino acids also were calculated.

3. RESULTS AND DISCUSSION

3.1. Influence of organic additives applied to soil on the content of heavy metals, micro and macronutrients in the safflower meal

Analyses for heavy metals and nutrients are essential to guarantee the quality of any food product. There are many elements that are considered nutrients and are vital for the proper functioning of the body. Equally, there are a number of elements (lead and cadmium) that are toxic to the human and animals and interfere with its functioning and undermine health. Potassium plays an important role in human physiology, and sufficient amounts of it reduce the risk of heart stroke, while calcium plays an important role in building stronger, denser bones early in life and keeping bones strong and healthy later in life.

The content of heavy metals and minerals in the control sample is presented in Table 1. In the Table 1 are shown the maximum values for feed and the values obtained by other authors. Our results for nutrients show good agreement with published values from Rahamatalla et al. (1998) and Ingale and Shrivastava (2011b). However, the content of Fe and Mn reached up to 122.8 mg/kg and 20.4 mg/kg, respectively and these values are lower than obtained by Smith (1966) and Heuze et al. (2012). The content of zinc was higher because in our experiment safflower is grown on heavy metal contaminated soils. According to lead and cadmium there is no published data and it is not possible to make a comparison of the obtained from us results. The content of Pb in the control sample of the meal reached up to 3.9 mg /kg, Zn - 155.2 mg /kg, Cu - 21.1 mg /kg and Cd - 2.6 mg /kg. The amounts of Pb, Cu and Zn in the meal did not reach critical values of 30 mg/kg Pb, 25 mg/kg Cu and 300 mg/kg Zn, while cadmium content exceeds the critical value of 0.5 mg/kg Cd feed.

Table 1. Content of heavy metals, micro and macroelements in safflower meal

Element	Mesured values	Reference values		Limit values for livestock
	Control	Smith (1996)	Heuze et al. (2012)	
Pb, mg/kg	3.9	-	-	30
Cu, mg/kg	21.1	10-26	24	25-100
Zn, mg/kg	155.2	34-44	64	500-750
Cd, mg/kg	2.6	-	-	0.5
Fe, mg/kg	122.8	560-600	422	500-1000
Mn, mg/kg	20.4	44	-	1000
K, %	8.8	8-13.3	-	
Ca, g/kg	3.6	3-4	2.7	
Mg, g/kg	3.5	3.3-3.9	2.8	
P, g/kg	8.1	8-14	6.7	
N, %	2.95			
Protein (% N X 5.3)	15.61		24.8	

Heavy metal contents in the meal of safflower decreased in the plants treated with all amendments used in the experiments. Impact of organic amendments on Pb, Cu, Zn and Cd accumulation in meal of safflower depended significantly on their quantity. Figure 1 summarises the results of the impact of applied to soil organic amendments on the chemical composition of the meal. Application of 10% compost leads to a higher reduction in the content of heavy metals in the comparison with vermicompost (Fig.1). Increase in the quantity of compost and vermicompost (10%) led to a decrease of Pb content in safflower meal to 1.6 mg/kg and 2.1 mg/kg, respectively and these concentrations were below the maximum permissible concentrations for fodder (30 mg/kg). The application of 10% compost and 10% vermicompost led to a decrease of the Zn content in meal to 83.7 mg/kg and 114.9 mg/kg, respectively and these concentrations were below the maximum permissible concentrations (500 mg/kg). Cu showed similar tendency. When the soil was treated with 10% compost and 10% vermicompost Cu content in meal decreased to 12.7 mg/kg and 14.5 mg/kg, respectively and these concentrations were below the maximum permissible concentrations (25 -100 mg/kg) for fodder. Application of organic additives leads to a significant reduction in the cadmium content of meal, this decrease is more

pronounced in the 10% compost treatment. When the soil was treated with 10% compost Cd content in meal decreased to 0.93 mg/kg, but this concentration were higher than maximum permissible concentrations (0.5 mg/kg) for fodder (Hapke, 1991).

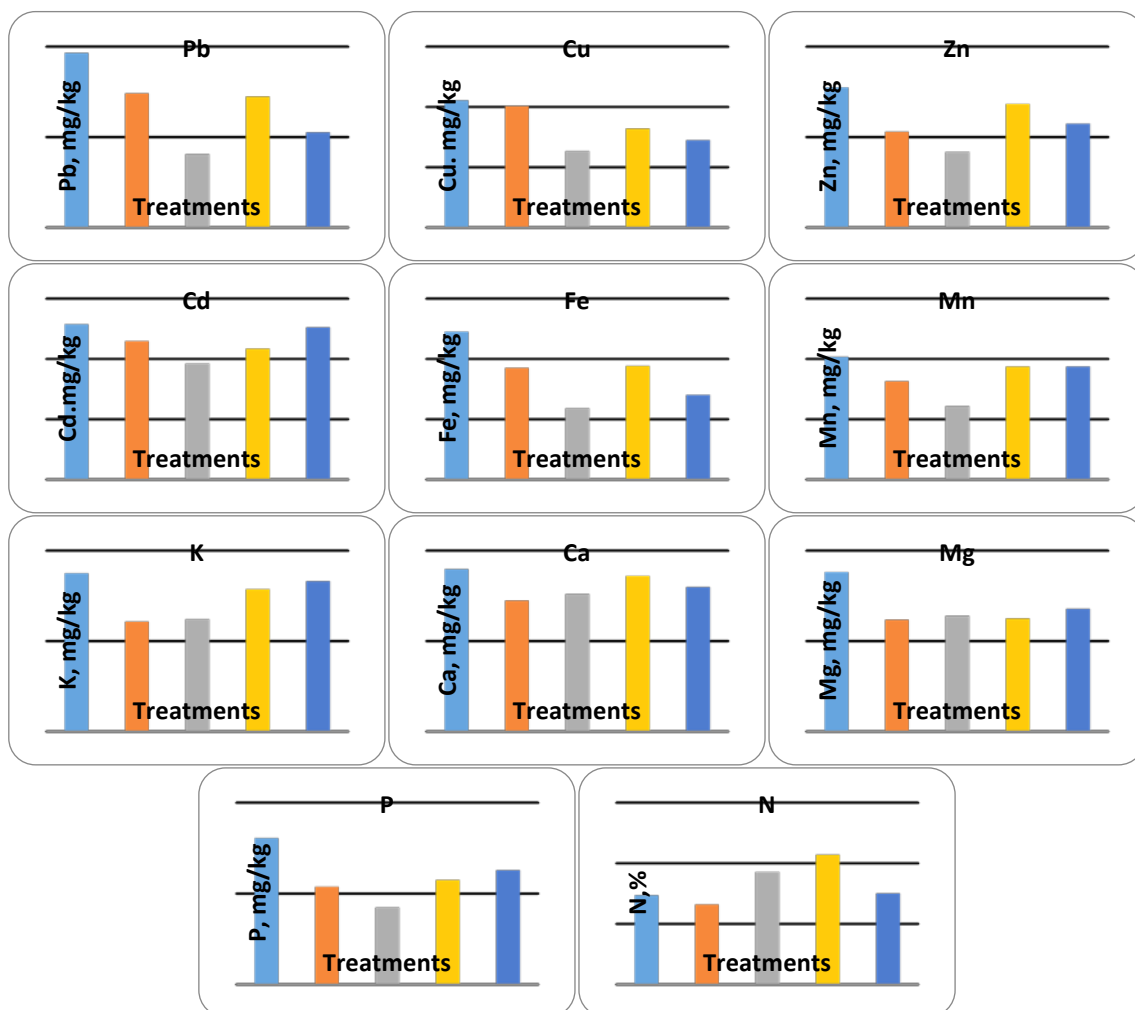


Figure 1. Effect of compost (C) and vermicompost (V) treatments on uptake of heavy metals, micro and macroelements in safflower meal

Concentrations of major elements such as K, Ca, Mg and P in control (8.8 g/kg, 3.6 g/kg, 3.5 g/kg and 8.1 g/kg, respectively) were significantly ($P < 0.05$) higher than in safflower meal obtained after the introduction of organic additives. Impact of organic amendments on mineral composition in meal of safflower depended significantly on their quantity. Addition of compost affected significantly ($P < 0.05$) the mineral contents of the safflower. Addition of 10% compost decreased the potassium, calcium, magnesium and phosphorous content of meal by 6.2, 3.0, 2.6 and 4.2 g/kg, respectively. Addition of vermicompost leads to a slight decrease in nutrient content, this decrease was more pronounced with the introduction of 5% vermicompost. In potassium and calcium was observed almost no influence of the additive.

Organic amendments also influence the nitrogen content of the meal. Adding of vermicompost increased nitrogen content. It was observed significantly greater increase in the addition of 5% vermicompost (4.29%) compared to 10% vermicompost (3.01%). The addition of 10% compost also increases the content of nitrogen (to 3.72%). These variations may be due to the differences in the level of crude fiber in the seed which decreases the protein content of the seed and meal (Latha and Prakash, 1984).

Compost and vermicompost treatments led to decreased Fe and Mn content in the safflower meal. Application of 10% compost decreased the iron and manganese content of meal by 59.1 mg/kg and 12.2

mg/kg respectively. Addition of vermicompost leads to a decrease in the iron content, this decrease was more pronounced with the introduction of 5% vermicompost. In respect of manganese does not observed the effect of the additive.

3.2. Impact of organic additives on the amino acid composition

The determination of amino acid composition is helpful in feed formulation, it is also an important parameter in the evaluation of protein quality. The human and animal bodies do not synthesise the essential amino acids, but can be obtained from food. Eight amino acids are generally regarded as essential for humans: phenylalanine, valine, threonine, tryptophan, isoleucine, methionine, leucine and lysine (Young, 1994; Mariod et al. 2012). Additionally, cysteine (or sulphur-containing amino acids), tyrosine (or aromatic amino acids), deficiency in these amino acids may hinder healing recovery process (Mat et al., 1994). All of these essential amino acids are found to be present in the safflower meal samples investigated except tryptophan, which was not determined. The amino acid contents of the fat-extracted safflower seeds are presented in Table 2 on the basis of g/100 g sample and percentage in the crude protein. The reference pattern of essential amino acid requirements of the Food and Agriculture Organization (FAO) (1957) is also given for comparison. However, FAO did not give a requirement for arginine or histidine; the requirement listed for arginine is taken from the pattern proposed by Rose (1937), and that for histidine is one given by the Food and Nutrition Board of the National Academy of Sciences (1963) for both human infants and albino rats. The obtained values were compared with values obtained by other authors.

The data shows that in the safflower meal the higher content was observed of glutamic (27.4 g/100g) and aspartic acid (11.14 g/100g), followed by arginine (8.11 g/100g), leucine (6.87 g/100g), proline (5.71 g/100g), alanine (4.67 g/100g), valine (4.66 g/100g), serine (4.57 g/100g), and phenylalanine (3.76 g/100g). It was found the lowest content of methionine in the meal (1.55 g/100g), respectively. The obtained results showed that the content of valine is in accordance with the recommended values from FAO and other authors (Smith, 1966; Heuze, 2012). The content of methionine, isoleucine and lysine is less, while leucine, tyrosine, histidine and arginine are in a larger quantity with respect to the FAO recommended pattern for adult (Kratzer and Williams, 1951; Bandemer and Evans, 1963). According to Evans and Bandemer (1967) and Rahamatalla et al. (1998) the total protein of safflower meal contains high amounts of aspartic acid, glutamic acid, arginine, threonine, leucine, glycine, proline and phenylalanine. The variation in the chemical composition of safflower meal depends on the amount of hulls and on the extent of oil extraction (Heuze et al., 2012).

Essential amino acids in oil seeds contribute to good health and well being. Deficiency of lysine leads to physical and mental handicap (Papes et al., 2001). The antioxidant activity of these amino acids suggests a disease preventive role as exemplified by arginine which is beneficial for prevention of cardiovascular disease (Balsubramanian et al., 1980). Arginine is a factor for maintaining the nitrogen balance in muscles; and can enhance the lean tissue to fat tissue body fat ratio; a great factor for weight management (Amino acid, 2005). Aspartic acid deficiency decreases cellular energy and may like be a factor in chronic fatigue (Amino acid, 2005). Adequate methionine prevents disorder of hair, skin and nail; reduces liver fat and protect the kidney (Amino acid, 2005).

Table 2. Amino acid content in safflower meal

Amino acid	Measured values (control)		Reference values		
	g/100 g sample	g/100 g protein	FAO g/100g protein	Smith (1966) g/100g protein	Heuze et. al. (2012) g/100g protein
Asparagine acid	1.74	11.14		9.22	
Threonine*	0.49	3.16	2.8	2.93	2.9
Serine	0.71	4.57		4.17	
Glutamic acid	4.29	27.48		18.56	
Proline	0.89	5.71		3.68	
Glycine	0.31	2.00		1.63	1.8

Alanine	0.84	5.40		5.27	
Valine*	0.73	4.67		3.97	
Cystine	0.73	4.66	4.2	5.32	4.9
Methionine*	0.24	1.55	2.2	1.38	1.4
Isoleucine*	0.47	3.04	4.2	3.80	3.8
Leucine*	1.07	6.87	4.8	5.86	
Tirosine*	0.32	2.07		2.39	
Phenylalanine*	0.59	3.76	2.8	4.29	5.2
Hystidine	0.42	2.70	2.4*	2.23	2.0
Lysine*	0.49	3.11	2.0*	2.63	2.9
Arginine	1.27	8.11		8.34	7.8
Total, %	15.61	100			

* essential amino acid

However all these values of amino acid composition of safflower meal proteins under study were found to be good agreement with their other oil seeds reported earlier (Nagraj, 1995; Singh et al., 2003; Gupta and Shrivastava, 2006; Ingale and Shrivastava, 2011a).

The composition of amino acid is influenced by amendments used in the experiments (type and rate). The main effects of compost and vermicompost treatment on amino acid composition are shown in Fig. 2. In general, some amino acids increased with organic treatments while others significantly decreased. The effect of treatments with organic amendments is significant for most of the amino acids. The effect of amendments was mainly manifested in the non-essential amino acid content of meal, the 10% compost treatment entrained an increase by about 48%. At the same time, also the essentials content increased, but moderately, exceeding control by max. 29.6%. The ratio of essential to non-essential amino acid content in the safflower meal showed to have caused shifts in some treatments. Compost treatment changed the proportion between amino acids in favour of non-essential amino acids in the safflower meal (Fig.3). As concerns the ratio of essential to non-essential amino acids within the complex of amino acids, slight variations (± 2 to 5%) were found in dependence on organic amendments applied to soil.

The composition of nonessential and essential amino acids affect both organic amendments, which in most cases is opposite. Compost and vermicompost treatments leading to increased content of threonine, serine and glycine. Compost treatment increases the aspartic acid, threonine, serine, glycine, phenylalanine, lysine and arginine, and results in a reduction of cysteine, valine, isoleucine, leucine, tyrosine and histidine. Impact of organic amendments on amino acid content in meal of safflower depended significantly on their quantity. In some cases, the increase or decrease is greater in the addition of 5% compost, and others - with 10% compost. For example, in treatment with 5% compost was observed higher increase in the content of aspartic, threonine, serine, glycine, alanine, methionine, whereas 10% compost treatment increases are observed in glutamic acid. Treatment with vermicompost increases the content of threonine, serine, cystine, glycine and tyrosine. Impact of vermicompost on amino acid content in safflower meal depended significantly on the quantity. Addition of 10% vermicompost leads to increase the content of alanine, methionine and histidine, while for the 5% vermicompost treatment was observed opposing trend.

The percentage of sulphur-containing amino acids (methionine and cystine) in safflower meal of control sample was 1.55 g/100g protein and 2.0 g/100g protein, respectively, and this percentage was affected by organic amendments applied to soil. Addition of 5% vermicompost leads to decreases their contents, while the introduction of 10% vermicompost leads to their increase. Introduction of compost does not affect significantly the content of methionine, and leads to significant reduction of cystine (up to 1.09 g/100g protein in treatment with 10% compost). These sulphur-containing amino acids were found to be the most limiting in safflower meal. Similar reports were made by Gupta and Shrivastava (2006) and Ingale and Shrivastava (2011a) who reported that lysine was the most limiting amino acid in safflower.

The total aromatic amino acid levels (phenylalanine and tyrosine) found in safflower meal in control sample was 3.76g/100g protein and 2.07g/100g protein is also affected by the applied organic amendments. The introduction of the compost resulting in an increase in phenylalanine (5.01g/100g protein) and a decrease in tyrosine content (up to 1.67g/100g protein). Addition of vermicompost leads to an increase in tyrosine content (to 2.37g/100g protein) and no effect on the content of phenylalanine.

Because of the apparent close relationship among amino acids, correlation coefficients were calculated (Table 3).

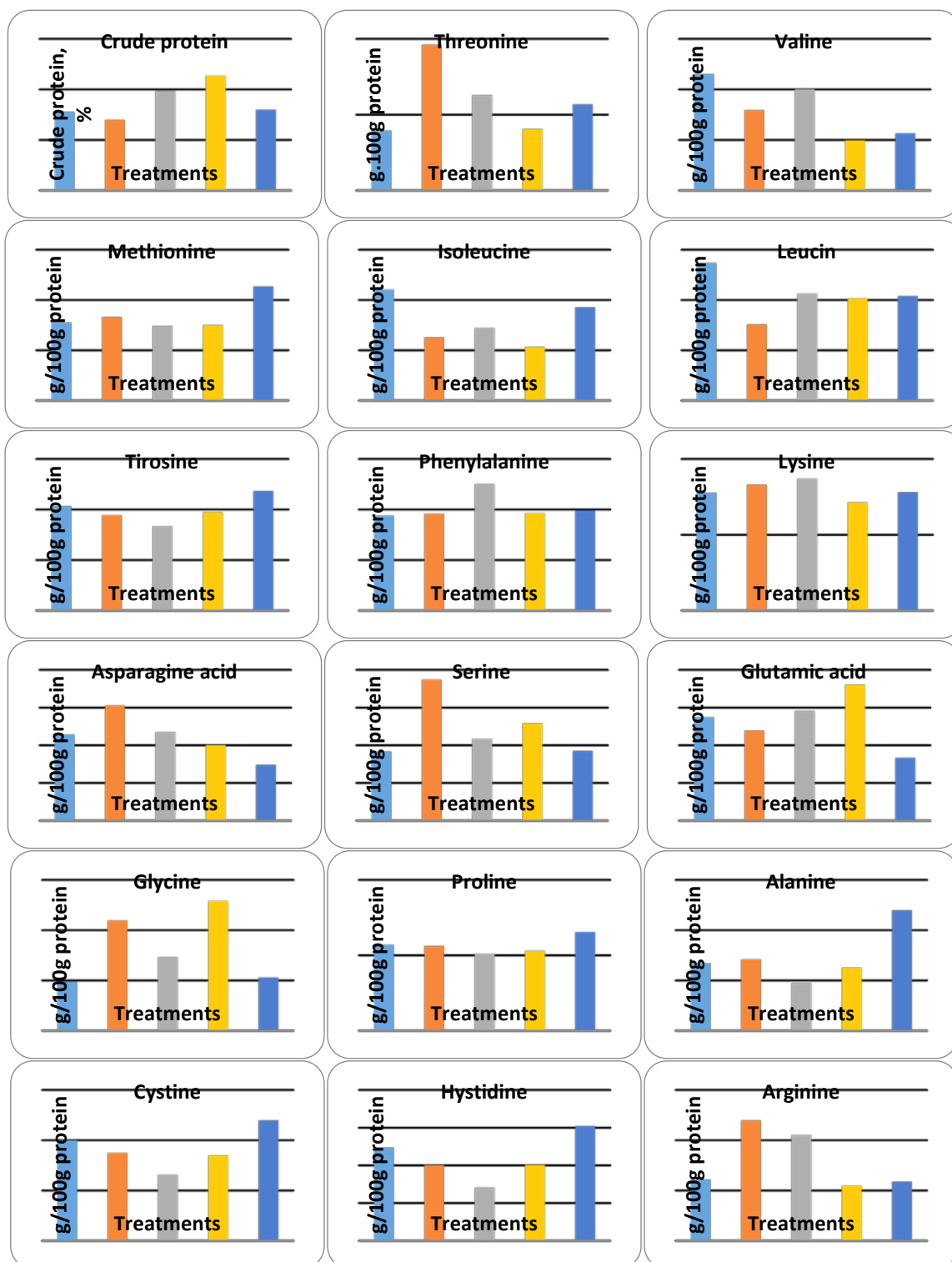


Figure 2. Effect of compost (C) and vermicompost (V) treatments on crude protein and amino acid composition of safflower meal**Table 3.** Correlations between amino acids in safflower meal

	Asp	Thr	Ser	Glu	Pro	Cys	Gly	Ala	Val	Met	Ise	Leu	Tyr	Phe	His	Lys	Arg
Asp	1																
Thr	0.67	1															
Ser	0.78	0.77	1														
Glu	Ns	0.42	ns	1													
Pro	0.53	ns	ns	0.85	1												
Cys	0.55	ns	ns	0.69	0.96	1											
Gly	0.39	ns	0.74	0.61	0.51	0.45	1										
Ala	0.60	ns	ns	0.80	0.98	0.92	0.39	1									
Val	0.44	ns	ns	ns	ns	ns	0.53	0.49	1								
Met	0.59	ns	ns	0.86	0.94	0.83	0.43	0.98	0.46	1							
Ile	Ns	ns	0.68	0.50	0.53	0.57	0.93	ns	0.57	ns	1						
Leu	0.42	0.81	0.83	ns	ns	ns	0.64	ns	0.53	ns	0.76	1					
Tyr	0.66	ns	0.39	0.63	0.95	0.99	0.42	0.93	0.39	0.85	0.52	ns	1				
Phe	-	ns	ns	ns	0.47	0.65	ns	0.42	ns	ns	ns	ns	0.61	1			
Hys	0.58	ns	0.38	0.66	0.95	0.99	0.48	0.89	ns	0.81	0.60	ns	0.99	0.65	1		
Lys	0.49	0.63	ns	ns	ns	0.46	ns	ns	0.56	ns	ns	ns	0.53	0.72	0.48	1	
Arg	0.81	0.88	0.67	ns	0.40	0.58	ns	0.40	ns	ns	0.37	0.70	0.66	0.43	0.62	0.83	1

Alanine (Ala), Arginine (Arg), Aspartic acid (Asp), Cysteine(Cys), Glutamic acid (Glu), Glycine (Gly), Histidine (His), Isoleucine (Ile), Leucine (Leu), Lysine (Lys), Methionine (Met), Phenylalanine (Phe), Proline (Pro), Serine (Ser), Threonine (Thr), Tyrosine (Tyr), Valine (Val), ns- not significant

Each amino acid was significantly correlated with one or more of the other amino acids. For example, methionine was positively correlated with the tyrosine and histidine, cysteine to alanine, methionine, tyrosine and histidine, phenylalanine with threonine, proline, cysteine, alanine, methionine, tyrosine, histidine. Aspartic acid negatively correlated with the proline, cysteine, methionine, tyrosine, glycine-isoleucine, proline-isoleucine, alanine.

The increase in some amino acids in meal agrees with the rise in protein content (Fig.3). A positive correlation was found between the content of nonessential and essential acids to the protein content in the meal.

The crude protein range of 15.61% obtained in this study is lower to the mean value of 20-22% reported by Weiss (2000). Introduction of compost in high doses increased the raw protein content. The increase reached about 26% in average comparing with control samples grown without adding organic additives. Similar results were obtained with vermicompost. 5% vermicompost treatment leads to an increase in protein with about 45% (Fig.2). It can be generally stated that the increase in protein content is connected with a decrease in the essential to non-essential amino acid ratio.

The values obtained by Latha and Prakash (1984) for amino acids agree fairly well with those reported in this study for the extracted total protein. The high content of aspartic acid and glutamic acid is very similar to that of other oilseed proteins, indicating it to be acidic in nature (Rahamatalla et al., 1998).

Similar results for changes in amino acid composition of protein that occurred as a result of addition of soil amendments have been found by the other authors. Nitrogen fertilizer whether applied to the soil (Dubetz, 1972) or to the crop (Kolderup, 1974) can be used to increase the protein content of wheat (*Triticum aestivum* L.), and changes in amino acid composition are associated with increased grain protein. Results from a greenhouse

experiment (Larsen and Nielsen, 1966) showed that increased applications of nitrogen resulted in increases in glutamic acid and proline and decreases in lysine and arginine, when expressed on a nitrogen basis. An application of nitrogen at 134 kg/ha (Abrol et al, 1971) increased glutamic acid, proline, phenylalanine, and leucine appreciably and decreased lysine, valine, and threonine contents of wheat grain when calculated on a percentage basis. When the protein content of wheat increased after application of 46.5 kg/ha of nitrogen, glutamic acid, proline, and phenylalanine increased but most of the other amino acids, especially lysine, decreased (Kolderup, 1974).

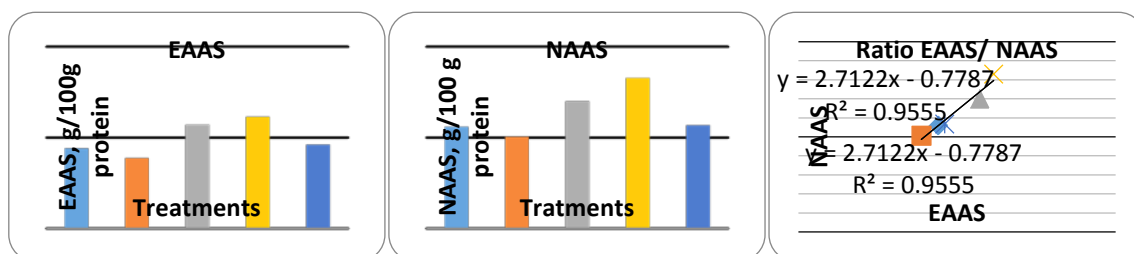


Figure 3. Effect of compost (C) and vermicompost (V) treatments on essential (EAAS), non essential (NAAS) and essential to non essential amino acid ratio

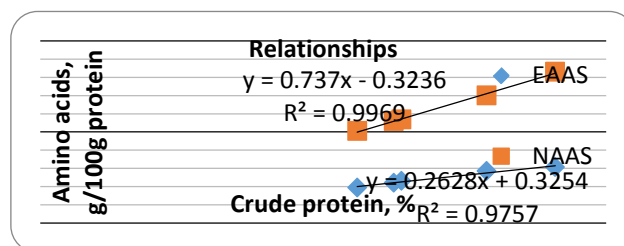


Figure 4. Relationships among crude protein and essential and non essential amino acids

High positive correlations between essential and non-essential amino acids suggest that these amino acids are closely related in crude proteins (Fig.4). Kolderup (1974) and Dubetz et al. (1979) suggested that nitrogen fertilization changed the proportions of the soluble protein fractions of wheat grain but did not change the proportions of the amino acids in the individual fractions.

3.3. Comparative analysis between meal of safflower and the most commonly used meal

In Table 4 are presents a comparative analysis of crude protein and amino acid composition of safflower meal with that of soybean, rapeseed, cottonseed, sunflower, coconut, palm and coconut meal.

Safflower meal has a much lower content of crude protein (15.6%) than other meal (compared with rapeseed (44%), cottonseed (45%), soybean (47.5%) and sunflower (50.3%) meal), which are used in animal nutrition.

The amino acid composition of safflower meal is close to the composition of soybean, canola and cotton meal. It was found that the amount of valine, glycine, phenylalanine, methionine and histidine are comparable. The content of arginine, proline, cysteine was higher, while the content of lysine, leucine, isoleucine is lower. Notably, the content of essential amino acid lysine is two times lower compared with soybean meal and rapeseed meal, which is a limitation for feed use as well as fiber content (Stringhini et al., 2000).

Safflower meal is a good source of protein and can be used as animal feed. Safflower meal is similar in quality to palm meal, because it contains much crude fiber (Weiss, 2000). Safflower meal contains less minerals from soybean meal, but a good source of calcium, phosphorus and iron. The vitamin in safflower meal is a little higher than soybean, although it contains very little vitamin B6 and vitamin E. Poor safflower meal can be used as a supplement vegetable proteins in animal feed, and partially replacing cotton meal, and in this way reduce the bitterness of feed (Weiss, 2000). It can be a good substitute to linseed meal for instance (Smith, 1996). Comparisons with soybean meal were satisfying only when safflower meal was fed in low amounts (Smith, 1996).

Table 4. Content of crude protein, mineral substances and amino acid content in meal, % compared to crude protein

Parameter	Safflower meal	Soybean meal	Canola meal	Cottonseed meal	Peanut meal	Sunflower meal	Coconut meal	Palm meal
Crude protein, %	15.6	47.5	44.0	45.0	49.3	50.3	21.9	-
Ca, g/kg	3.6	3.8	7.2	1.7	2.7	4.0	2.0	3.4
P, g/kg	8.1	7.2	10.1	13.1	6.7	11.0	6.6	7.1
Mg, g/kg	3.5	3.1	6.0	5.9	1.7	5.9	3.4	3.6
K, g/kg	8.8	21.9	12.0	15.1	12.7	17.4	16.9	7.7
Fe, mg/kg	122.8	191	200	172	155	279	742	360
Mn, mg/kg	20.4	36	60	24	35	31	68	-
Asparagine acid	11.14	11.2	8.0	-	-	-	-	3.63
Threonine*	3.16	3.80	4.5	3.3	2.6	3.2	3.1	2.75
Serine	4.57	5.0	4.39	-	-	-	-	4.11
Glutamic acid	27.48	18.00	16.69	-	-	-	-	16.80
Proline	5.71	4.89	7.00	-	-	-	-	-
Glycine	5.40	4.60	4.96	-	-	-	-	4.17
Alanine	4.67	-	-	-	-	-	-	3.83
Valine*	4.66	5.00	5.11	4.30	4.00	4.10	4.90	5.05
Cystine	2.00	0.65	1.23	1.50	1.00	2.30	1.40	1.13
Methionine*	1.55	1.40	1.78	1.70	1.00	1.70	1.30	1.75
Methionine*+ Cystine	3.55	2.05	3.01	3.20	2.00	4.00	2.70	2.88
Isoleucine*	3.04	4.69	3.98	3.10	3.60	3.40	3.40	3.22
Leucine*	6.87	7.49	6.97	6.00	5.80	5.50	6.20	6.07
Tirosine*	2.07	2.80	2.46	2.70	3.70	2.30	2.00	2.60
Phenylalanine*	3.76	4.80	4.01	5.10	4.70	4.40	4.10	3.96
Phenylalanine*+Tirosine*	5.83	7.60	6.47	8.30	8.50	6.40	6.50	6.56
Hystidine	2.70	2.40	2.81	2.80	2.30	2.20	1.80	1.91
Lysine*	3.11	6.22	5.98	3.00	3.30	3.60	2.60	3.00
Arginine	8.11	6.44	6.11	11.0	10.40	6.90	10.90	11.56

Undecorticated safflower meal can be used in ruminant rations as a protein source in replacement of soybean meal, cottonseed meal or linseed meal if used on equal protein basis and if adequate energy is supplied (Kohler et al., 1965). When high levels of safflower meal are included in ruminants diets, lower performances have been observed (Walker, 2006). Safflower meal is slightly bitter and less palatable than other common ingredients (Smith, 1996). However, its palatability is variable and it may be readily eaten by ruminants when mixed with other feeds (Göhl, 1982). Early trials in the 1950s and 1960s showed that it sometimes presented palatability problems with beef cattle but that dairy cows found it palatable (Smith, 1996). Safflower meal well accepted

when fed to rams (Sudhamayee et al., 2004). Past research have shown safflower meal to be a valuable ingredient for dairy cows, with no noticeable effect on flavour or odour of milk produced. Adding 1 kg of safflower meal in the rations of dairy cows increased milk yield and milk fat and the substitution of 1 kg of concentrate by similar amount of safflower meal gave similar results (Juknevičius et al., 2005). With low-producing Friesian cows and buffaloes (< 10 kg milk/d), 3.75 kg of safflower meal successfully replaced 3 kg of uncorticated cottonseed oilmeal, slightly increasing milk fat content (El-Shinnawy et al., 1979).

4. CONCLUSIONS

Based on the results obtained we can make the following important conclusions:

1. Tested organic amendments significantly influenced the chemical composition of safflower meal. The compost and vermicompost treatments significantly reduced heavy metals concentration in safflower meals, but the effect differed among them. Also, there was a dose effect for amendments. The 10% compost treatment led to decreased the content of cadmium in sunflower meal to 0.93 mg/kg, but this concentration were higher than maximum permissible concentrations (0.5 mg/kg) for fodder. Addition of compost affected significantly the mineral contents of the safflower meal. Treatment with vermicompost leads to a slight decrease in nutrient content, this decrease was more pronounced with the introduction of 5% vermicompost. In potassium and calcium was observed almost no influence of the additive.
2. Crude protein and amino acids composition was affected by compost and vermicompost amendment treatments. 10% compost and 5% vermicompost treatments increased protein content in the meal. Compost treatment increases the aspartic acid, threonine, serine, glycine, phenylalanine, lysine and arginine, and results in a reduction of cysteine valine, isoleucine, leucine, tyrosine and histidine. Treatment with vermicompost increases the content of threonine, serine, cystine, glycine and tyrosine.
3. The effect of treatments with organic amendments is significant for most of the amino acids. The composition of nonessential and essential amino acids affect both organic amendments, which in most cases is opposite. Impact of organic amendments on amino acid content in meal of safflower depended significantly on their quantity. In some cases, the increase or decrease is greater in the addition of 5% compost, and others - with 10% compost.
4. The effect of amendments was mainly manifested in the non-essential amino acid content of meal, the 10% compost treatment entrained an increase by about 48%. At the same time, also the essentials content increased, but moderately, exceeding control by max. 29.6%.
5. The *C. tinctorius* is a good source of protein supplement in livestock. It is necessary to supplement safflower seed meal based diets with the sulphur-containing amino acids (methionine and cystine) in order prevent nutritional deficiencies of these essential amino acids.

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