The use of amaranth (genus *Amaranthus* L.) in the diets for broiler chickens

B. Pisarikova[1], Z. Zraly[1], S. Kracmar[2], M. Trckova[1], I. Herzig[1]

[1]Veterinary Research Institute, Brno, Czech Republic
[2]Mendel University of Agriculture and Forestry, Brno, Czech Republic

ABSTRACT: The objective of our study was to test amaranth grain or dried biomass in the diet for broiler chickens as a resource of protein replacing animal protein. Further, the effect of amaranth on broiler performance, carcass characteristics and meat quality were assessed in a feeding trial. The experimental groups of broilers were fed feed mixtures with crude amaranth grain (AC), heat processed amaranth grain (AP) or dried above-ground biomass (AB). Control groups (C) received the diet containing animal proteins. The results obtained in the experimental groups of broiler chickens can be compared to the control group in all the production indicators under investigation. On day 42 of the experiment, live weight (g) of female broilers ranged from 2 205.1 ± 152.5 (AP) to 2 254.0 ± 136.5 (C), and that of male broilers from 2 375.1 ± 233.0 (AC) to 2 506.0 ± 286.0 (C). Feed conversion ranged from 1.80 kg in control group of male broiler chickens to 1.91 kg in experimental group of male broilers (AB). Percentage yield in female broiler chickens ranged from 70.8 ± 1.74 (AB) to 72.4 ± 3.34 (AC) or 72.4 ± 1.98 (C), and in male broilers from 72.8 ± 3.55 (AP) to 75.1 ± 2.44 (AB). Our results showed that amaranth can fully replace meat-and-bone meals in the diets for broiler chickens.

Keywords: animal protein; amino acids; fatty acids; performance; carcass characteristics; meat quality

In connection with the ban on meat-and-bone meals (MBM) for feeding to farm animals including poultry, alternative sources of proteins and other substances have to be found. Fish meal, which is not banned for feeding, contains a lot of protein, amino acids and readily usable source of phosphorus, however, high price does not allow a broader use in the diets for broilers. Therefore there is a need to replace animal protein with vegetable protein. Of vegetable protein feeds, imported soybean prevails, followed by domestic legumes (pea, bean and lupin), oil plants (rape and sunflower), and pseudo-cereals (amaranth).

Amino acid composition of amaranth compared to that of other feeds is reported by Andrasofszky et al. (1998). The contents of limiting amino acids lysine, methionine and threonine in crude amaranth grain, soya and MBM (59% CP) were 6.88, 6.41, 5.85; 1.43, 1.40, 1.54 and 3.97, 4.19, 2.81 g/16 g N, resp., which indicates amaranth to be a high quality source of protein. Composition of amino acids and biological value of protein in several amaranth species were compared with egg protein in a study conducted by Pisarikova et al. (2005a) who found index of essential amino acids (EAAI) in popped grain and raw one 85.4 and 90.4%, respectively.

Apparent metabolizable energy (AME) and nitrogen-corrected AME (AMEn) of extruded grain amaranth as a feed ingredient for broilers determined Tillman and Waldroup (1988). Using regression analysis, the predicted values from the total collection method (TCM) were 3.382 kcal/kg of AME and 3.267 kcal/kg of AMEn on as-fed basis. When expressed on a dry-matter basis these values

Supported by the Ministry of Agriculture of the Czech Republic (Projects No. QF 3112 and No. MZe 0002716201).

were 3.646 and 3.522 kcal/kg for AME and AMEn, respectively.

Even the green parts of amaranth can be used as feedstuffs for some species of farm animals. Dry matter of amaranth biomass contains according to data from literature and based on plant age 16.3 to 29.5% of crude protein, 2.0 to 3.02% of fat, 11.1 to 24.4% of fibre, and 13.1 to 17.8% of ash (Alfaro et al., 1987; Skultety et al., 1991; Zeman et al., 1995).

The suitability of amaranth grain or green parts for animal diets has been tested in trials on rats (Andrasofszky et al., 1998), lambs (Pond and Lehmann, 1989), rabbits (Alfaro et al., 1987), ruminants (Skultety et al., 1991; Jalc et al., 1999), pigs (Sokol et al., 2001; Zraly et al, 2004) and broiler chickens (Serratos, 1996; Rouckova et al., 2004). In most of the trials, no negative effects on feed intake, feed conversion and live weight gains were recorded. However, the use of more than 40% amaranth in a diet resulted in lower weight gains due to antinutritional substances (ANF) (Alfaro et al., 1987). Data on the content of trypsine inhibitor, phenols, tanine, saponines and phytohaemaglutinines can be found in the literature (Correa et al., 1986; Imeri et al., 1987). In tanine the concentrations ranged from 0.08 to 0.119 %, in phytic acid from 0.34 to 0.61 %, and in trypsine inhibitor from 3.07 to 5.46 UTI/mg (Paredes-Lopez, 1995). Antinutritional substances were partially or totally degraded by heat treatment, i.e. autoclaving, extruding and popping (Andrasofszky et al., 1998).

Nutrient digestibility of feed mixtures with 10% crude, heat treated amaranth grain or of amaranth-free diet was studied by Pisarikova et al. (2005b) in balance trials on male broiler chickens. Higher coefficients of nutrient digestibility (crude protein, ether extract, NDF, ADF, and gross energy) were recorded in the diet with crude amaranth grain compared to amaranth-free diet.

Sensory indicators of meat of chicken broilers fed diets supplemented with 10% amaranth (crude or heat treated amaranth grain and dried biomass) were examined by Juzl et al. (2005). Meat samples from chickens fed amaranth in the diet showed better in all sensory indicators under testing (taste, tenderness, texture, colour) compared to the diet containing fish meal.

The objective of our study was to test various forms of amaranth as a replacement of animal protein in diets for broiler chickens in order to obtain comparative parameters of performance (live weight, feed conversion, EEF, carcass yield, meat quality).

MATERIAL AND METHODS

240 day-old broiler chickens ROSS 308 (120 males, 120 females) were included in the experiment. The experiment was carried out in an accredited experimental stable with controlled light and heat regime in compliance with the requirements for biological testing (Anonymous, 2000). The chickens were divided into eight groups, separated according to their gender and housed in boxes with slot floor without bedding.

The chickens were fed *ad libitum* using feed mixtures with animal protein (C) or amaranth supplements (AP, AC, AB) in two phases, from day 1 to day 21 of age, and from day 22 to day 42 of age. The feed mixtures used were in compliance with nutrient requirements of broiler chickens (Zelenka et al., 1999). Their composition is shown in Table 1.

Amaranth used in our experiment was provided by the company AMR Amaranth, Ltd. (Hradec Kralove, Czech Republic). Amaranth flour (AC) was obtained by grinding of crude amaranth grain. Popped amaranth grain (AP) was treated at 170°C for 30 s and ground. Dried biomass (AB) was obtained by drying and subsequent grinding of the above-ground biomass at the stage of milky ripe.

The used amaranth products and experimental feed mixtures were analysed prior to starting our experiment. Dry matter, crude protein (N × 6.25), ether extract, crude fibre and ash were determined using the methods AOAC (2001). Nitrogen free extractives (NFE) and organic matter (OM) were calculated.

Analyses of neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were carried out according to the procedures of Goering and Van Soest (1970). Cellulose content was obtained after subtraction of ADL from ADF, and hemicellulose after subtraction of ADF from NDF.

Samples for amino acid determination were adjusted using acidic and oxidative acidic hydrolysis (6 mol/l HCl). The chromatographic analysis of sample hydrolysates was performed in the analyser AAA 400 (INGOS Prague, Czech Republic), and using Na-citrate buffers and ninhydrin detection (Kracmar et al., 1998).

The method of extraction and methylation according to Liu (1994) was used to determine fatty acids in amaranth. Methylesters of fatty acids were determined using gas chromatograph TRACE GC (ThermoQuest Italia S.p.A., Italy) with flame

Table 1. Composition and nutrient contents in feed mixtures for broiler chickens

	Diet							
	1st stage of fattening				2nd stage of fattening			
	C	AP	AC	AB	C	AP	AC	AB
Components (%)								
Winter wheat	47.6	36.9	37.0	40.5	37.1	33.2	33.4	36.8
Maize 10% CP	15.0	15.0	15.0	15.0	25.0	20.0	20.0	20.0
Soya extracted meal 48% CP	25.7	29.6	29.5	30.8	25.7	27.5	27.3	28.6
Yeast Vitex	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Fish meal 64% CP	3.00	–	–	–	2.00	–	–	–
Amaranth (AP)	–	8.00	–	–	–	8.00	–	–
Amaranth (AC)	–	–	8.00	–	–	–	8.00	–
Amaranth (AB)	–	–	–	3.00	–	–	–	3.00
Sunflower oil	2.10	3.60	3.50	3.70	4.36	5.50	5.43	5.50
Bolifor–MCP–F	–	0.13	0.13	0.10	0.27	0.28	0.28	0.49
Fodder limestone	0.86	0.78	0.78	1.02	1.00	0.86	0.86	1.00
Fodder salt	0.10	0.18	0.18	0.18	0.01	0.14	0.15	0.15
Lysine 60%	0.20	0.30	0.31	0.30	–	–	–	–
Methionine 40%	–	0.10	0.10	0.10	–	0.10	0.10	0.10
Threonine 20%	0.40	0.35	0.50	0.42	–	0.03	0.03	0.03
UK VD 1*	3.00	3.00	3.00	3.00	–	–	–	–
UK VD 2**	–	–	–	–	2.50	2.50	2.50	2.50
Content of nutrients (g/kg)								
Dry matter	880.7	887.5	885.3	883.0	884.5	895.0	892.1	888.6
Crude protein	235.4	230.8	234.0	231.4	224.3	220.4	223.2	221.9
Fat	41.0	54.3	52.8	52.2	58.6	58.1	63.4	57.6
Fibre	22.6	26.4	29.2	29.1	23.6	27.1	23.9	24.1
Ash	64.8	62.4	60.2	55.6	56.0	62.0	56.8	58.4
NFE	516.9	513.6	509.1	514.7	522.0	527.4	524.8	526.6
Organic matter	815.9	825.1	825.1	827.4	838.5	843.0	863.3	840.2
ME (MJ/kg)***	12.7	12.6	12.6	12.6	13.3	13.3	13.3	13.2

C = control diet; AP = popped amaranth grain; AC = raw amaranth grain; AB = dried amaranth biomass

Analysis of AP (g/kg): dry matter 932.0, crude protein 172.5, ether extract 53.5, fibre 35.2, ash 34.5, NFE 636.2, organic matter 897.5, NDF 99.9, ADF 58.4; **AC**: dry matter 915.3, crude protein 166.0, ether extract 71.5, fibre 45.0, ash 33.7, NFE 599.1, organic matter 881.6, NDF 87.5, ADF 62.1; **AB**: dry matter 915.7, crude protein 113.2, ether extract 33.5, fibre 144.0, ash 167.4, NFE 457.6, organic matter 748.2, NDF 292.6, ADF 271.9

*Commercial supplement contained the following substances per kg: 560 000 IU vitamin A, 200 000 IU vitamin D_3, 98 mg vitamin K, 2 100 mg vitamin E, 98 mg vitamin B_1, 270 mg vitamin B_2, 150 mg vitamin B_6, 0.9 mg vitamin B_{12}, 1 200 mg niacin, 32 mg folic acid, 390 mg calcium panthotenate, 30 000 mg cholinchloride, 3.5 mg biotin, 85 g L-lysine HCl, 74 g D,L-methionine, 50 g L-threonine, 10.5 mg cobalt, 15 mg iodine, 5.2 mg selenium, 280 mg copper, 3 300 mg manganese, 1 800 mg zinc, 3200 mg iron, 20 g sodium, 6 g phosphorus, 100 g calcium, 400 mg avilamycine

**Commercial supplement contained the following substances per kg: 395 000 IU vitamin A, 190 000 IU vitamin D_3, 110 mg vitamin K, 1 400 mg vitamin E, 90 mg vitamin B_1, 230 mg vitamin B_2, 120 mg vitamin B_6, 0.8 mg vitamin B_{12}, 1 100 mg niacin, 50 mg folic acid, 300 mg calcium panthotenate, 30 000 mg cholinchloride, 3 mg biotin, 135 g L-lysine HCl, 60 g D, L-methionine, 43 g L-threonine, 10 mg cobalt, 30 mg iodine, 3 mg selenium, 80 mg copper, 2 800 mg manganese, 1 800 mg zinc, 250 mg iron, 28 g sodium, 2 g phosphorus, 80 g calcium, 333 mg avilamycine, 18 550 mg ZY 28, 926 mg Endox 5 × conc.

***determined by calculation

ionizing detector (FID) and a capillary column SP^{TM}-2560. A standard mixture of 37 methylesters of fatty acids Supelco 37 Component FAMEmix (Supelco, Sigma-Aldrich, St. Luis, MO, USA) has been used for the detection.

The weight of chicks was monitored at the age of one day, 21 days, and 42 days i.e. at termination of the experiment. Feed consumption was monitored at the same dates. Health status of chicks was monitored during the experiment by view, and in case of death, pathological anatomic examination was carried out.

The value European efficiency factor (EEF) was calculated from the basic values of performance of broiler chickens according to the following formula: EEF = survival (%) × live weight (kg)/age (days) × feed conversion × 100. Survival = 100 – (% of deaths + % of culling) + the calculated feed conversion. At termination of the experiment on day 42, ten chickens representing weight average of the group were taken carcass characteristics, and chemical composition of breast and thigh muscles were determined.

Chemical analysis of breast and thigh meat were completed according to the standards ISO 1442 (1997), ISO 1444 (1997) and CSN 57 0153 (1986). The yield of selected indicators of carcass characteristics (pure trunk without giblets with neck skin, unskinned breast muscles, unboned leg without skin, liver, stomach and heart) was determined in relation to live weight (Anonymous, 1996).

The obtained results were evaluated using the programme STAT-plus (Matouskova et al., 1992).

Basic statistical characteristics were calculated using analysis of variance and Tukey's test.

RESULTS AND DISCUSSION

Increased requirements for food safety necessitates in certain measures to be taken in livestock production. Consumers need to feel secure that the food of animal origin they eat is safe and healthy. At the same time those measures should lead to minimization of negative impacts of animal protein absence in feed mixtures with regard to performance, health state and meat quality.

Testing was carried out under conditions which allowed an objective assessment of the effect of particular feed mixtures on selected indicators of performance. The results of analyses of diets used in the first and second stages of fattening showed a balanced nutrient content and corresponded with the standard requirements (Zelenka et al., 1999) (Table 1). The proportion of amaranth was, with regard to the expected presence of ANF, 8% (AP, AC), and 3% (AB).

The content of crude protein was 172.5, 166.0 and 113.2 g/kg in AP, AC and AB, respectively. The corresponding contents of fat were 53.5, 71.5 and 33.5 g/kg. The contents of NDF were 99.9, 87.5 and 292.6 g/kg; those of ADF were 58.4, 62.1 and 271.9 g/kg. No lignin was found in any of the amaranth products used (Table 1). The results are in accordance with the data reported by several authors (Carlsson, 1979; Vetter, 1994; Dodok et al., 1997; Andrasofszky et al., 1998).

Biological value of protein used in amaranth components is supported by the convenient amino acid composition. The content of lysine was 7.7 to 9.2 g/kg, methionine 2.1 to 2.5 g/kg, cystine 2.3 to 4.2 g/kg, threonine 6.0 to 6.7 g/kg, and arginine 12.8

Table 2. Proportion of amino acids in amaranth products (g/kg)

Amino acid	AP	AC	AB	Amino acid	AP	AC	AB
Cys	4.1	4.2	2.3	Val	7.4	6.8	8.0
Asp	13.8	13.2	13.3	Ile	5.6	5.2	5.8
Met	2.5	2.2	2.1	Leu	8.4	7.9	7.9
Thr	6.5	6.0	6.7	Tyr	0.2	0.3	0.6
Ser	12.3	11.0	9.4	Phe	–	–	0.5
Glu	24.9	25.0	17.0	His	3.0	2.8	2.0
Pro	4.1	4.1	4.5	Lys	8.8	9.2	7.7
Gly	19.1	20.0	14.1	Arg	14.2	12.8	15.0
Ala	9.2	8.8	6.4				

Table 3. Proportion of fatty acids in lipids of amaranth products (%)

MEMK	AP	AC	AB
Lauric acid C12:0	0.24	0.01	0.04
Tridecanoic acid C13:0	0.00	0.00	0.20
Myristic acid C14:0	0.10	0.09	0.59
Myristic–oleic acid C14:1 n9c	0.00	0.04	0.28
Palmitic C16:0	10.4	9.49	17.6
Palmitic–oleic acid C16:1 n9c	0.45	0.40	0.28
Heptadecanoic acid C17:0	0.27	0.20	0.34
Stearic acid C18:0	4.31	3.85	7.00
Elaidic acid C18:1 n9t	0.00	0.15	0.40
Oleic acid C18:1 n9c	17.6	19.3	26.7
Linoleic acid C18:2 n6c	54.7	53.1	29.5
Linolenic acid C18:3 n3	1.06	1.76	3.70
Arachidonic acid C20:0	0.44	0.34	1.18
Cis-11-eicosanoic acid C20:1	0.56	0.75	0.95
Cis-11.14-eicosadienic acid C20:2	0.00	0.00	10.1
Cis-11.14.17-eicosatrienic acid C20:3 n3	9.79	10.3	0.49
Behenic acid C22:0	0.00	0.20	0.62

to 15.0 g/kg (Table 2). Heat treatment in popped amaranth did not exhibit any significant effect on amino acid contents as found by Andrasofszky et al. (1998) and Pisarikova et al. (2005a).

The proportion of fatty acids in the lipid component of amaranth products is shown in Table 3. The results are in accordance with the composition of fatty acids in cereal lipids (wheat, ray) and some important plant oils (soya oil and sunflower oil) (Davidek et al., 1983). Polyunsaturated fatty acids are in AP, AC and AB represented especially by linoleic acid (54.7, 53.1 and 29.5%), linolenic acid (1.06, 1.76 and 3.70%); monounsaturated acids are represented by oleic acid (17.6, 19.3 and 26.7%), saturated acids are represented by palmitic acid (10.4, 9.49 and 17.6%) and stearic acid (4.31, 3.85 and 7.00%). The ratio unsaturated/saturated acids was 0.19, 0.16 and 0.38 in AP, AC and AB, respectively. These data are in accordance with those presented by Singhal and Kulkarni (1990). Regarding a lower fat content by approximately 25% in popped amaranth compared to untreated one (most probably due to heat process), lower content of particular fatty acids in AP compared to AC can be expected.

The average weight of one-day-old chickens was 44 g. Live weights of male and female chickens during the fattening are shown in Table 4. The average live weights of male and female chickens were insignificantly lower on the experimental diets (AP, AC, AB) compared to the control diet. Lower live weights were recorded in male chickens on day 21 of the experiment in the group AB (by 12.3%) and AC (by 9.6%), and on day 42 in the group AC (by 5.2%). Feed consumption (kg) per one broiler chicken in fattening ranged from 3.93 (AB) to 4.20 (C) in female chickens, and from 4.40 (AC) to 4.67 (AB) in male chickens. Feed conversion (kg) ranged in female chickens from 1.83 (AB) to 1.90 (C), and in male chickens from 1.80 (C) to 1.91 (AB) (Table 5).

Selected indicators of performance on day 42 of fattening are in individual groups, without gender differentiation, shown in Table 6. The average live weight (g) in the control group was 2 382.1 ± 257.4, and insignificantly lower average live weights were recorded in the experimental groups: AB 2 324.8 ± 285.5 (by 2.4%), AP 2 317.0 ± 270.6 (by 2.7%) and AC 2 303.5 ± 222.4 (by 3.3%). Feed conversion (kg) was 1.86 in the control group, and 1.87, 1.88 and 1.89 in the groups AP, AB and AC, respectively. EEF

Table 4. Mean weights (g) of female and male chickens in fattening fed particular diets

Parameter	Diet			
	C	AP	AC	AB
Live weight on day 21 of age				
Female chickens	607.8 ± 85.4	600.7 ± 77.2	600.1 ± 51.6	586.2 ± 86.3
Index (%)	100	98.8	98.7	96.4
n	29	30	30	30
Male chickens	643.7 ± 94.3	634.5 ± 117.3	581.6 ± 110.5	564.8 ± 105.6
Index (%)	100	98.6	90.4	87.7
n	30	29	30	30
Live weight on day 42 of age				
Female chickens	2 254.0 ± 136.5	2205.1 ± 152.5	2 234.2 ± 190.8	2 188.3 ± 211.9
Index (%)	100	97.8	99.1	97.1
n	29	30	30	30
Male chickens	2 506.0 ± 286.0	2 432.6 ± 316.6	2 375.1 ± 233.0	2 466.0 ± 285.8
Index (%)	100	97.1	94.8	98.4
n	30	29	30	29

Table 5. Feed consumption and conversion (kg) in female and male chickens on day 42 of fattening in particular diets

Parameter	Diet							
	C		AP		AC		AB	
	F	M	F	M	F	M	F	M
Feed consumption	4.20	4.43	4.03	4.50	4.10	4.40	3.93	4.67
Conversion	1.90	1.80	1.86	1.88	1.89	1.87	1.83	1.91

F = female chicken; M = male chicken

Table 6. Selected parameters of performance in particular diets on day 42 of fattening (female + male)

Diet	*n*	Live weight (g)	Index (%)	Feed conversion (kg)	Mortality (%)	EEF*
C	59	2382.1 ± 257.4	100	1.86	1.66	299.9
AP	59	2317.0 ± 270.6	97.3	1.87	1.66	290.1
AC	60	2303.5 ± 222.4	96.7	1.89	0.00	290.2
AB	59	2324.8 ± 285.5	97.6	1.88	1.66	289.5

*European efficiency factor

was 299.9 in the control and slightly lower in the experimental groups AC, AP and AB (290.2, 290.1 and 289.5) (Table 6). The results of selected indicators of performance in the control and experimental groups correspond with the performance characteristics of the hybrid ROSS 308 and no negative effects of diets with amaranth on the above indicators were observed. Higher content of fibre in dry amaranth exerted no effect on the studied indicators; the effect of heat treatment in broiler chickens on diets containing popped amaranth was not confirmed either, compared to AC. Similarly,

Table 7. Selected parameters of carcass value in female and male chicks in particular diets (n = 10)

Parameter		Diet			
		C	AP	AC	AB
Live weight (g)	F	2 253.8 ± 56.1	2 210.8 ± 9.02	2 239.3 ± 33.3	2 183.3 ± 34.4^{c*}
	M	2 518.3 ± 77.4	2 451.2 ± 50.6	2 393.0 ± 45.0^{b**}	2 473.0 ± 48.8
Yield (%)	F	72.4 ± 1.98	72.1 ± 2.83	72.4 ± 3.34	70.8 ± 1.74
	M	74.5 ± 2.44	72.8 ± 3.55	74.3 ± 3.66	75.1 ± 2.44
Yield of breast muscles without skin (%)	F	19.8 ± 1.07	19.3 ± 2.31	18.6 ± 1.30	18.5 ± 0.69
	M	19.1 ± 0.92	18.1 ± 1.70	19.0 ± 1.86	19.0 ± 1.27
Yield of boned thigh without skin (%)	F	19.3 ± 0.75	18.8 ± 1.42	19.4 ± 1.63	19.1 ± 0.97
	M	20.9 ± 1.22	20.2 ± 0.71	20.0 ± 1.37	20.6 ± 0.75
Yield of abdominal fat (%)	F	0.78 ± 0.29	1.18 ± 0.46	0.82 ± 0.32	0.92 ± 0.39
	M	0.50 ± 0.18	0.58 ± 0.24	0.72 ± 0.26	0.67 ± 0.32
Yield of viscera (heart. liver. stomach) (%)	F	3.51 ± 0.36	3.64 ± 0.33	3.45 ± 0.56	3.41 ± 0.29
	M	3.60 ± 0.46	4.00 ± 0.35	4.09 ± 0.23	4.31 ± 0.24^{c*}
Yield of liver (%)	F	1.89 ± 0.27	1.98 ± 0.17	1.82 ± 0.19	1.84 ± 0.17
	M	2.04 ± 0.36	2.13 ± 0.17	2.28 ± 0.15	2.57 ± 0.23^{c**g*}
		Chemical composition of muscles			
Dry matter (%)					
B	F	25.5 ± 0.68	25.6 ± 0.63	26.1 ± 0.79	25.7 ± 0.68
	M	25.9 ± 0.58	25.6 ± 0.68	25.5 ± 0.52	25.6 ± 0.80
T	F	27.4 ± 1.32	27.4 ± 1.45	27.9 ± 0.60	27.2 ± 1.31
	M	28.2 ± 1.90	27.4 ± 0.78	27.2 ± 1.07	27.6 ± 0.87
Crude protein (%)					
B	F	22.1 ± 0.67	22.0 ± 0.52	22.9 ± 1.02	22.0 ± 0.56
	M	22.0 ± 0.57	22.3 ± 0.66	22.1 ± 0.57	22.3 ± 0.70
T	F	18.3 ± 0.78	18.0 ± 0.73	18.5 ± 0.66	18.2 ± 0.41
	M	18.2 ± 0.78	18.1 ± 0.95	18.2 ± 0.99	18.6 ± 0.20
Intramuscular fat (%)					
B	F	2.42 ± 0.32	2.47 ± 0.19	2.24 ± 0.43	2.25 ± 0.34
	M	2.51 ± 0.30	2.30 ± 0.13	2.39 ± 0.25	2.34 ± 0.41
T	F	8.21 ± 0.97	8.44 ± 1.20	8.42 ± 0.77	8.18 ± 1.17
	M	8.92 ± 1.25	8.32 ± 0.59	8.20 ± 0.88	8.16 ± 0.94

*P < 0.05; **P < 0.01; b = C:AC; c = C:AB; g = AP:AB; B = breast muscles; T = thigh muscles

Acar et al. (1988), Serratos (1996) and Rouckova et al. (2004) did not find differences in live weights of broiler chickens fed diets with amaranth both heat treated and untreated, compared to the control.

After termination of the experiment on day 42, slaughter weight of the female chickens was 1.63 kg in the controls, and 1.59, 1.62 and 1.55 kg in the experimental group AP, AC and AB, respectively. In male chickens, the corresponding weight was 1.87 kg in the controls, and 1.78, 1.77 and 1.86 in the experimental groups. Carcass yield ranged from 70.8 to 75.1 (Table 7). The differences in percentage yield (without edible organs) among the control cockerels and pullets and the experimental groups were not significant. The obtained results are nearly identical with those recorded by Kralik et al. (2003)

who tested the effect of rape seed or oil on carcass yield of broilers. The values obtained by Rouckova et al. (2004) in the tests using diet with amaranth were higher compared to ours because the authors included edible organs into the percentage yield of poultry. Lower percentage yield was obtained by Suchy et al. (2002) in broiler chickens fed vegetable diets with specially treated rape seed cake. No significant differences were found between the control and experimental groups in the yield of breast muscles, skin-free thighs and abdominal fat. The obtained values were higher compared to the results of Mala et al. (2002) at testing of a vegetable diet with addition of Ca salts of fatty acids in broiler chickens COBB 500. The yield of heart, liver and stomach was significantly higher in the group AB compared to the control (4.31 vs. 3.60, $P < 0.05$, and $P < 0.01$ in liver).

The results of chemical analyses of breast and thigh muscles did not show significant differences between the control and test groups in the contents of dry matter, crude protein and intramuscular fat (Table 7). Significant differences ($P < 0.05$, $P < 0.01$) in the determined parameters were found in male and female chickens between breast and thigh muscles. The obtained results are in accordance with the findings of Pipek and Pour (1998), Suchy et al. (2002) and other authors which can lead to the conclusion that diets with amaranth did not have any effect on percentage yield nor on the quality of carcass or selected indicators of chemical composition of meat.

Experimental groups of chickens fed amaranth containing diets gave results that were comparable in all performance characteristics with the control group fed animal protein. The contents of essential nutrients in amaranth grain may be considerably variable relative to the variant and climatic conditions (Prakash and Pal, 1992) and therefore the nutrition specialists should take this fact into consideration when formulating feed rations. We can conclude that respecting the above mentioned fact amaranth is a suitable replacement of meat-and-bone meals in the diets for broiler chickens.

REFERENCES

Acar N., Vohra P., Becker R., Hanners G.D., Saunders R.M. (1988): Nutritional evaluation of grain amaranth for growing chickens. Poultry Science, 67, 1166–1173.

Alfaro M.A., Martinez A., Ramirez R., Bressani R. (1987): Yield and chemical composition of the vegetal parts of the amaranth *(Amaranthus hypochondriacus* L.*)* at different physiological stages. Archivos Latinoamericanos de Nutricion, 37, 108–121.

Andrasofszky E., Szöcz Z., Fekete S., Jelenits K. (1998): Evaluation of the nutritional value of the amaranth plant. I. Raw and heat-treated grain tested in experiments on growing rats. Acta Veterinaria Hungarica, 46, 47–59.

Anonymous (1996): Notice No. 194/1996, Annex 3 (in Czech). Ministry of Agriculture of the Czech Republic, Praqgue.

Anonymous (2000): Notice No. 451/2000, Annex 20 (in Czech). Ministry of Agriculture of the Czech Republic, Prague.

AOAC – Association of Official Analytical Chemists International (2001): Horwitz W. (ed.): Official Methods of Analysis. 17th ed. AOAC Inc., Arlington, USA.

Carlsson R. (1979): Quantity and quality of amaranthus from plants on temperate, cold and hot and subtropical climates – A rewiew. In: Proc. Second Amarant Conference Rodale Emmaus, PA, 48–58.

Correa A.D., Jokl L., Carlsson R. (1986): Chemical constituents, *in vitro* protein digestibility, and presence of antinutritional substances in amaranth grains. Archivos Latinoamericanos de Nutricion, 36, 319–326.

CSN 57 0153 (1986): Examination of meat products and canned sterilized food. The determination of nutrient content according to Kjeldahl (in Czech).

Davidek J., Janicek G., Pokorny J. (1983): Food chemistry (in Czech). SNTL, Prague. 632 pp.

Dodok L., Modhir A.A., Buchtova V., Halasova G., Polacek I. (1997): Importance and utilization of amaranth in food industry. 2. Composition of amino acids and fatty acids. Nahrung, 41, 108–110.

Goering H.K., Van Soest P.J. (1970): Forage fiber analysis. Agriculture Handbook, 379, ARC, USDA, Washington, 1–12.

Imeri A., Flores R., Elias L., Bressani R. (1987): The effect of processing and supplementation with amino acids on the protein quality of amaranth *(Amaranthus caudatus).* Archivos Latinoamericanos de Nutricion, 37, 160–173.

ISO 1442 (1997): Examination of meat products and canned sterilized food. The determination of water content (Reference method) (in Czech).

ISO 1444 (1997): Meat and meat products. Determination of free fat content (in Czech).

Jalc D., Baran M., Sikora P. (1999): Use of grain amaranth *(Amaranthus hypochondriacus)* for feed and its effect on rumen fermentation *in vitro*. Czech Journal of Animal Sciience, 44, 163–167.

Juzl M., Simeonovova J., Pisarikova B. (2005): Sensory analysis of meat of cockerels and pullets fed diets containing Amaranth or fishmeal. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, LIII, 5, 79–90.

Kracmar S., Gajdusek S., Jelinek P., Zeman L., Kozel V., Kozlova M., Kracmarova E. (1998): Changes in amino acid composition of goat's colostrum during the first 72 hours after birth. Czech Journal of Animal Science, 44, 541 – 545.

Kralik G., Skrtic Z., Kusec G., Kadlec J.(2003): The influence of rape seed/oil on the quality of chicken carcasses. Czech Journal of Animal Science, 48, 77–84.

Liu K. (1994): Preparation of fatty acids methyl esters for GC analysis of lipids in biological materials. Journal of the American Oil Chemists' Society, 71, 1179–1187.

Mala S., Stercova E., Pazout V. (2002): Percentage yield of meat in meat type hybrids ROSS 508 (in Czech). In: Workshop on Animal Nutrition. The Slovak Agricultural University, Nitra, VPHP Banska Bystrica, 80–83. ISBN 80-8069-068.

Matouskova O., Chalupa J., Cigler M., Hruska K. (1992): STAT Plus – User's Guide (in Czech). Veterinary Research Institute, Brno. 168 pp.

Paredes-Lopez O. (1994): Amaranth, Biology, Chemistry and Technology. Chapter 10, CRC Press. 185–205.

Pipek P., Pour M. (1998): Quality assessment of products of animal origin (in Czech). KUFR Prague. 139 pp. ISBN 80-213-0442-1.

Pisarikova B., Kracmar S., Herzig, I. (2005a): Amino acid contents and biological value of protein in various amaranth species. Czech Journal of Animal Science, *50*, 169–174.

Pisarikova B., Zraly Z., Kracmar S., Trckova M., Herzig I. (2005b): Nutritive value of amaranth grain (*Amaranthus L.*) in the diets for broiler chickens. Czech Journal of Animal Science, 50, 568–573.

Pond W.G., Lehmann J.W. (1989): Nutritive value of a vegetable amaranth cultivar for growing lambs. Journal of Animal Science, 67, 3036–3039.

Prakash D., Pal M. (1992): Seed protein, fat and fatty acid profile of *Amaranthus* species. Journal of the Science of Food and Agriculture, 58, 145–147.

Rouckova J., Trckova M., Herzig I. (2004): The use of amaranth grain in diets for broiler chickens and its effect on performance and selected biochemical indikators. Czech Journal of Animal Science, 49, 532–541.

Serratos A.J.C. (1996): Amaranth (*Amaranthus hypochondriacus*) seed in broiler feeding. Advances en Investigacion Agropecuaria, 5, 46–50.

Singhal R.S., Kulkarni P.R. (1990): Effect of puffing on oil characteristics of amaranth (Rajgeera) seeds. Journal of the American Oil Chemists' Society, 67, 952–954.

Skultety M., Skultetyova N., Bencova E. (1991): Intake of dry matter and digestibility of nutrients from green ensilaged and pelleted amaranth *Amaranthus hypochondriacus* varieta 1008 (in Slovak). Zivocisna Vyroba, 36, 793–798.

Sokol J. L., Bobel B. K., Fabijanska M., Bekta M. (2001): Preliminary results on the influence of amaranthus seeds on carcass and meat quality of fatteners. Journal of Animal Science, 10, 203–208.

Suchy P., Strakova E., Vecerek V., Slezackova I. (2002): Replacement of animal origin feed by plant origin feed in the diet of broiler chickens. Czech Journal of Animal Science, 47, 365–373.

Tillman P.B., Waldroup P.W. (1988): Assesment of extruded grain amaranth as a feed ingredient for broilers. 1. Apparent metabolizable energy values. Poultry Science, *67*, 641–646.

Vetter J. (1994): Minerals and amino acids in the seeds of the new, cultivated „cereal-like" species *Amaranthus hypochondriacus*. Zeitschrift fur Lebensmittel-Untersuchung und -Forschung, 198, 284–286.

Zelenka J., Heger J., Zeman L. (1999): The Need of Nutrients and Nutritive Value of Feeds for Poultry. Commission for Farm Animal Nutrition, Czech Academy of Agricultural Sciences, Brno. 63 pp.

Zeman L., Simecek K., Krasa A., Simek M., Lossmann J. (1995): The Tables for Nutritional Values of Feeds (in Czech). VUVZ, Pohorelice. 465 pp. ISBN 80-901598-3-4.

Zraly Z., Pisarikova B., Hudcova H., Trckova M., Herzig I. (2004): Effect of feeding amaranth on growth efficiency and health of market pigs. Acta Veterinaria Brno, 73, 437–444.

Received: 2006–01–17
Accepted after corrections: 2006–07–10

Corresponding Author:

Ing. Bohumila Pisarikova, Veterinary Research Institute, Hudcova 70, 621 32 Brno, Czech Republic
Tel. +420 533 331 616, fax +420 541 211 229, e-mail: pisarikova@vri.cz