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The effect of supplemental vitamin E and dietary rape seed oil level on broiler performance, meat and fat quality

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ABSTRACT

The effect of increasing dietary vitamin E levels in diets containing animal fat and rape seed oil on the performance, α-tocopherol content of tissues, meat and fat quality, and health of broiler chickens was investigated.

A total of 360 Ross broiler chickens were fed diets with the addition of different levels of vitamin E (5, 20 and 50 mg · kg^{-1}) during the starter (0-17 days of age) and grower (18-42 days of age) periods. Grower diets were supplemented with animal fat with or without 10 or 20% rape seed oil. 10% rape seed oil supplemented to blended fat increased the weight gains of chickens ($P \leq 0.05$). With increasing dietary vitamin E supplementation, the level of α-tocopherol in the liver, blood serum and breast muscle increased ($P \leq 0.01$). The level of vitamin E and the source of dietary fat affected the oxidative stability of abdominal fat, but not the organoleptic properties of broiler meat. The increasing proportion of rape seed oil in the feed was accompanied by a decreasing proportion of SFA, and an increasing proportion of PUFA, n-3 PUFA and linolenic acid ($C_{18:3\ n-3}$) in abdominal fat.

KEY WORDS: broilers, rape seed oil, alpha-tocopherol, meat quality, fat quality, fatty acids

INTRODUCTION

Rape seed oil is a good source of α-linolenic acid (LNA; $C_{18:3\ n-3}$), which is a precursor of long chain n-3 derivatives like eicosapentaenoic acid (EPA;

$C_{20:5\ n-3}$) and docosahexaenoic acid (DHA; $C_{22:6\ n-3}$). Polyunsaturated n-3 acids (n-3 PUFA) have a beneficial effect in prevention of coronary heart disease and other disorders (Simopoulos, 1999), but their consumption in Western countries is below recommended levels (about 0.5-1.0 g/day). Rape seed oil contains about 10% LNA (Koreleski et al., 1998; Pisarski and Malec, 2001) and is characterized by a desirable proportion of n-6 to n-3 fatty acids (about 2 to 1). Addition of rape seed oil to the diet had a beneficial effect on broiler performance (Koreleski et al., 1998), increased the LNA and PUFA contents and decreased the n-6:n-3 fatty acid ratio in abdominal fat and meat (Barteczko and Borowiec, 2001; Mieczkowska et al., 2001; Banaszkiewicz, 2002).

Like other fats with high PUFA contents, rape seed oil is sensitive to oxidation, which leads to formation of free radicals, peroxides and other products. Oxidized fat could negatively influence broiler performance (Lin et al., 1989) and lead to deterioration of the quality of poultry products (poor stability, loss of PUFA, developments of off-flavours).

Fat-added feeds used in poultry nutrition sometimes cause the birds to die as a result of fat oxidation and encephalomalacia, e.g. softening of the brain. One of the factors that prevents this disease is vitamin E. Its presence in the body reduces the amount of peroxides and free radicals (Scott, 1980; Sheffy and Williams, 1980).

Supplementing diets with vitamin E above its requirement specified by poultry nutrition standards led to a greater concentration of α-tocopherol in the liver and blood serum in chickens (Soto-Salanova and Sell, 1994, 1996; Młodkowski et al., 2002), in turkeys (Mallorino et al., 1992; Sell et al., 1997) and in laying hens (Cherian et al., 1996).

In turkeys, Sheldon et al. (1997) demonstrated that high dietary vitamin E levels can influence oxidative stability and processing functionality of breast muscle, resulting in organoleptic properties of turkey meat. Cherian et al. (1996) found that the presence of tocopherols helped maintain lipid stability of eggs, meat and other edible parts of laying hens enriched in n-3 polyunsaturated fatty acids.

Erf et al. (1997) concluded that high dietary vitamin E levels appear to enhance the immune system of growing broilers. Also Qureshi et al. (1993) reported that high dietary vitamin E doses improve the immune functions of the humoral and cellular systems in turkeys.

It could be expected that simultaneous application of vitamin E and rape seed oil to broiler diets will have a beneficial effect on stability and fatty acid composition of broiler meat.

The aim of the present experiment was to determine the effect of various vitamin E levels in broiler feeds with added animal fat and rape seed oil on the performance, α-tocopherol content in meat and fat tissues, and quality and fatty acid composition of abdominal fat.

MATERIAL AND METHODS

Starter (0-17 days) and grower diets (18-42 days of age) were supplemented with increasing α-tocopherol levels, i.e. 5, 20 (standard) and 50 mg · kg^{-1} of feed. Rape seed oil was added to starter diets, and blended fat without or with 10 or 20% rape seed oil was added to grower diets (Tables 1 and 2). Blended fat (97% ether extract) of animal origin was supplemented with the antioxidant Rendox (250 mg · kg^{-1}).

A 6-week feeding trial was carried out with 360 Ross broilers. Day-old chicks were randomly allotted to 9 groups in 5 replications of 8 chickens each and kept in cages with mesh floors. Body weight gains and feed utilization were calculated for the whole experimental period (1-42 days of age).

TABLE 1

Composition of diets, g · kg^{-1}

Item	Starter	Grower
Ground maize	347.1	195.2
Ground wheat	200	400
Extracted soyabean meal	350	230
Extracted rapeseed meal	-	40
Meat-and-bone meal	20	40
Animal fat[2]	-	70[1]
Rape seed oil[3]	50	
Dicalcium phosphate	15	7
Limestone	9	9
NaCl	2.5	2.5
DL-methionine	1.4	1.3
Vitamin-mineral premix (S or G)[4]	5	5
Feed enzyme[5]	+	+
Metabolizable energy, MJ · kg^{-1}	12.36	12.81
Crude protein	222	203
Crude fat	64	78.3
Crude fibre	27.6	30.8
Lys	11.7	9.8
Met	4.7	4.4
Ca	9.6	9.2
P available	4.3	4.1

[1] animal fat without or with addition of 10 or 20% rape seed oil

[2] fatty acids composition of animal fat, of total FA (%): $C_{14:0}$ - 0.88, $C_{15:0}$ - 0.5, $C_{16:0}$ - 24.4, $C_{17:0}$ - 1.31, $C_{18:0}$ - 20.47, $C_{20:0}$ - 0.73, $C_{21:0}$ - 0.32, $C_{22:0}$ - 0.22, $C_{14:1}$ - 0.45, $C_{16:1}$ - 2.84, $C_{18:1}$ - 40.97, $C_{22:1}$ - 0.34, $C_{18:2}$ - 4.19, $C_{18:3}$ - 0.94, $C_{20:2}$ - 0.52

[3] fatty acids composition of rape seed oil, in % of total FA: $C_{16:0}$ - 4.05, $C_{18:0}$ - 1.64, $C_{20:0}$ - 0.68, $C_{22:0}$ - 0.46, $C_{24:0}$ - 0.20, $C_{16:1}$ - 0.26, $C_{18:1}$ - 57.67, $C_{22:1}$ - 2.60, $C_{18:2}$ - 21.79, $C_{18:3}$ - 10.03, $C_{20:2}$ - 0.15, $C_{22:4}$ - 0.23

[4] premix S and G supplied per 1 kg of diet, respectively: (IU) vit. A 12500, 10000; vit. D_3 3000, 2000; (mg) vit. K_3 3, 2; vit. B_1 2, 1.5; vit. B_2 6, 5; B_6 3.5, 3; folic acid 1.5, 1; nicotinic acid 30, 25; D-calcium panthotenate 15, 12; choline chloride 600, 400; (μg) vit. B_{12} 20, 20; biotin 100, 100; (mg) Mn 100, 100; Zn 50, 50; Cu 8, 8; Fe 60, 60; J 0.8, 0.8; Se 0.2, 0.2; Co 0.4, 0.4

[5] Luctazyme Aviar T 1699 (with activity of xylanase and ß-glucanase), 100 mg · kg^{-1} of diet

TABLE 2

Scheme of experiment

Group	Vitamin E mg · kg^{-1}	% of fat in blend used in diets	
		animal fat	rape seed oil
I	5	100	0
II	5	90	10
III	5	80	20
IV	20	100	0
V	20	90	10
VI	20	80	20
VII	50	100	0
VIII	50	90	10
IX	50	80	20

At day 42 of age, 8 chickens (4 ♂ and 4 ♀) from each group were slaughtered by stunning and decapitation. Samples of mixed blood were taken and serum was separated by centrifugation (7500 x g for 10 min) and frozen at -20°C. The birds were plucked, eviscerated, the feet were removed and cooling was followed by determination of post-slaughter weight and weight of abdominal fat and liver. Two large breast muscles (*M. pectoralis maior*) and one thigh from each carcass were prepared. The right breast muscle and thigh were taken to test the organoleptic quality of meat. Samples of the large breast muscle, blood serum and liver were analysed for α-tocopherol content. Fatty acid composition, acid number and peroxide value (after 6-month storage) were assayed in abdominal fat.

The chemical composition of diets was analyzed using standard methods (AOAC, 1990). The amino acid content of diets was determined using a Beckman analyzer in acid hydrolysates, after initial oxidation of sulphur amino acids. Metabolizable energy, Ca and available P content in diets were calculated according to the European Table (1989) and Nutrient Requirements of Poultry (1996).

Vitamin E (α-tocopherol) was determined in blood serum, liver and breast muscle with a modified method of Manz and Philipp (1981). Tissue samples were first subjected to alkaline saponification to remove fats and to release natural tocopherols from the cells. Afterwards the added tocopherol esters were hydrolyzed into free tocopherol, and then the non-saponifying matter was ether extracted. Liquid chromatography (HPLC SpektraSYSTEM, TSP, USA) was used. Chromatographic analysis was performed on an HPLC Supelcosil LC-NH_2-Np. , 5 um, 250 x 4.6 mm column. A mixture of n-hexane 1,4-dioxan (97:3) was the mobile phase.

Detection was performed with a fluorescent probe at an excitation wavelength of 294 nm and an emission wavelength of 326 nm. Ten μg of dl-α-tocopherol/mL was used as the standard solution for internal calibration.

The composition of fatty acids in abdominal fat was determined with a GC VARIAN 3400 gas chromatograph equipped with a CP-Wax 58, 25 m and 0.53 mm column. Total lipid extracts of samples were prepared for fatty acid analysis by the method of Folch et al. (1957).

The degree of rancidity of abdominal fat based on acid number and peroxide value was tested according to a standard procedure (PN-73/A-85803) after storage of hermetically sealed samples at -20°C for 6 months.

A sensoric test of chicken meat quality was also carried out. Flavour, juiciness, tenderness and taste were evaluated by a professional panel of 5 skilled members, who judged meat (thigh and breast muscle after roasting in a microwave oven for 20 min at 650 W power) according to 5-point quality scale.

Data were subjected to statistical analysis using two-way factorial analysis of variance. The significance of differences between means was determined by Duncan's multiple range test. All procedures were carried out using Statistica 5.0 PL software.

RESULTS

The level of vitamin E supplementation did not affect body weight gains or feed utilization. The type of fat in the grower period, however, influenced the performance of broilers because the addition of 10% rape seed oil to blended fat resulted in faster growth and better feed conversion. The vitamin E level had no effect on dressing percentage and proportion of adipose fat in the carcass. The dressing percentage was highest when 10% of rape seed oil (in whole added fat) was supplemented to the grower diet ($P \leq 0.05$). Mortality rates in the experiment were 4.4% on average for all broilers (Table 3).

The content of α-tocopherol in serum, liver and breast muscle ranged from 0.36 to 8.69 $mg \cdot ml^{-1}$; 2.53 to 13.69 and 0.25 to 3.62 $mg \cdot g^{-1}$, respectively (Table 4). Increased vitamin E supplements to the diets were accompanied by increases in the content of α-tocopherol in serum, liver and breast muscle ($P \leq 0.01$). The α-tocopherol content in serum and breast muscle was lowest when 20% oil (as whole fat) was added to the grower diet, and in liver when 10% oil was added.

Vitamin E supplementation of the diets decreased the acid number and peroxide value of abdominal fat. Addition of rapeseed oil to the diet (10 or 20% in whole added fat) decreased the peroxide value, but when a 20% oil supplement in added fat was used, the acid number was found to have increased (Table 5).

Organoleptic tests of broiler meat for flavour, juiciness, tenderness and taste of breast muscle and thigh after roasting in a microwave oven demonstrated no differences relative to the level of dietary vitamin E supplement or the type of fat in the grower diet. It is worth noting, however, that the organoleptic score was fairly high in all cases, ranging from 4.17 to 4.47 on a 5-point scale.

TABLE 3

The performance of broilers and results of slaughter analysis (1-42 days of age)

Group	Body weight gain g	Feed conversion kg · kg^{-1}	Mortality no.	Slaughter yield %	Abdominal fat %
I	1676	2.03	2	70.5	2.51
II	1713	1.95	1	70.5	1.91
III	1730	2.06	3	70.6	2.68
IV	1666	1.95	1	69.6	2.33
V	1714	1.87	0	71.0	2.59
VI	1585	2.01	4	69.9	2.08
VII	1644	2.07	1	69.6	1.97
VIII	1741	1.91	1	71.3	1.93
IX	1723	1.88	3	70.2	1.86
Pooled SEM	11.6	0.016		0.205	0.094
	Source of variation			Probability	
Vitamin E	NS	NS		NS	NS
Rape seed oil	0.05	0.01		0.05	NS
Vitamin E x rape seed oil	NS	0.05		NS	NS
		Main effects means			
Vitamin E supplement, mg · kg^{-1}					
5	1707	2.02	6	70.5	2.36
20	1655	1.95	5	70.2	2.37
50	1703	1.95	4	70.4	1.92
% rape seed oil in blended fat					
0	1662^{aA}	2.02^{bB}	4	69.9^{aA}	2.27
10	1723^{bA}	1.91^{aA}	2	71.0^{bA}	2.14
20	1679^{abA}	1.98^{bAB}	10	70.3^{abA}	2.25

^{ab} P≤0.05; ^{AB} P≤0.1

Vitamin E supplementation at a rate of 20 mg · kg $^{-1}$ had a significant effect on saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), polyunsaturated fatty acid (PUFA), n-6 PUFA and EPA ($C_{20:5n3}$) contents of adipose tissue (Table 6). Higher vitamin E supplements were accompanied by increases in SFA and EPA, whereas the effects on MUFA, PUFA and n-6 PUFA were not clear. The content of all fatty acids (except DHA) in adipose tissue was influenced by the proportion of rape seed oil in the grower diet. When the rape seed oil was added to the grower diet, MUFA, PUFA, n-6 PUFA, n-3 PUFA and EPA levels increased, while the SFA and n-6/n-3 levels and SFA/UFA ratio decreased.

TABLE 4

Alpha-tocopherol content in blood serum, liver and breast muscle

Group	Alpha-tocopherol content		
	blood serum mcg · ml^{-1}	liver mcg · g^{-1}	breast muscle mcg · g^{-1}
I	1.72	3.25	1.01
II	0.36	2.53	0.25
III	2.37	4.31	1.20
IV	7.96	6.30	2.81
V	5.68	4.61	2.51
VI	2.69	4.83	1.43
VII	8.69	13.69	2.44
VIII	8.57	12.91	3.62
IX	7.52	12.15	2.79
Pooled SEM	0.373	0.509	0.124
Source of variation	Probability		
vitamin E	0.01	0.01	0.01
rape seed oil	0.01	0.01	0.01
	Main effects means		
Vitamin E supplement, mg · kg^{-1}			
5	1.48^{A}	3.36^{A}	0.82^{A}
20	5.44^{B}	5.25^{B}	2.25^{B}
50	8.26^{C}	12.9^{C}	2.95^{C}
% rapeseed oil in blended fat			
0	6.12^{C}	7.75^{B}	2.09^{B}
10	4.86^{B}	6.68^{A}	2.13^{B}
20	4.19^{A}	7.10^{AB}	1.81^{A}

^{ABC} P≤0.01

DISCUSSION

Supplementing diets with graded levels of vitamin E resulted in greater contents of α-tocopherol in the liver, serum and breast muscle. Similar observations were made by Mallorino et al. (1992) and Sell et al. (1997) for turkeys, Cherian et al. (1996) for laying hens and Soto-Salanova and Sell (1994, 1996) for chickens. α-tocopherol was not found in adipose tissues, irrespective of the vitamin E level in the feed. A small accumulation of α-tocopherol in adipose tissue was found in our previous research, where double the current level of dietary vitamin E (100 mg/kg) was used (Młodkowski et al., 2002). In contrast, Cherian et al. (1996) reported that in layers the deposition of α-tocopherol in fat was greater than in muscles.

TABLE 5

Evaluation of abdominal fat quality (acid number and peroxide value) after stored by 6 months

Group	Abdominal fat	
	acid number mg KO · g^{-1}	peroxide value ml 0,002 n $Na_2S_2O_3$ · g^{-1}
I	1.79	4.95
II	2.09	5.05
III	2.58	1.89
IV	2.04	2.65
V	1.44	2.27
VI	1.89	4.67
VII	1.83	4.35
VIII	2.16	3.02
IX	1.93	1.17
Pooled SEM	0.043	0.181
Source of variation	Probability	
vitamin E	0.01	0.01
rape seed oil	0.01	0.01
vitamin E x rape seed oil	0.01	0.01
	Main effect means	
Vitamin E supplement, mg · kg^{-1}		
5	2.15^{cB}	3.95^{bB}
20	1.79^{aA}	3.26^{aA}
50	1.97^{bA}	2.85^{aA}
% rape seed oil in blended fat		
0	1.90^{aA}	3.98^{cB}
10	1.90^{aA}	3.45^{bB}
20	2.13^{bB}	2.57^{aA}

^{abcd} $P \leq 0.05$

^{ABC} $P \leq 0.01$

Vitamin E supplementation of the diet did not affect the performance of broilers, while the minor proportion of rape seed oil in the added fat had a favourable effect on weight gain in chickens. Similar findings were reported by Soto-Salanova and Sell (1996), whereas Butcher et al. (1993) observed a positive correlation between vitamin E level and growth in egg-type pullets. A marked improvement in broiler performance during the starter and grower-finisher period was observed by Koreleski et al. (1995, 1998) after incorporation of rape seed oil as a source of unsaturated fatty acids and as an effect of better fat digestibility and energy utilization.

The level of vitamin E and level of rape seed supplementation affected abdominal fat quality. Peroxide values in adipose tissue were clearly related to the vitamin E levels. The obtained results may suggest a positive effect of vitamin E as a natural

TABLE 6

Fatty acids content in abdominal fat of broiler chickens, %

Item	Group									Pooled SEM
	I	II	III	IV	V	VI	VII	VIII	IX	
SFA	29.73	29.27	29.04	29.60	30.02	29.22	30.59	29.79	28.61	0.080
MUFA	57.27	57.48	57.36	57.26	55.99	57.47	57.65	56.69	57.10	0.082
PUFA	13.00	13.25	13.60	13.14	13.99	13.31	11.76	13.52	14.28	0.086
n-6	11.69	11.93	12.00	11.92	12.49	11.80	10.68	12.19	12.63	0.070
n-3	1.23	1.29	1.55	1.18	1.49	1.48	1.07	1.29	1.63	0.025
n-6/n-3	9.50	9.25	7.74	10.10	8.38	7.97	9.98	9.45	7.75	0.135
SFA/UFA	0.42	0.41	0.41	0.42	0.43	0.41	0.44	0.42	0.40	0.002
$C_{18:3n3}$	0.95	1.13	1.43	0.94	1.25	1.27	0.86	1.12	1.43	0.024
$C_{20:5n3}$ (EPA)	0.03	0.02	0.015	0.03	0.035	0.02	0.02	0.035	0.025	0.0001
$C_{22:6n3}$ (DHA)	0.035	0.025	0.025	0.03	0.04	0.025	0.025	0.03	0.035	0.0001

Item	Probability			Main effect means					
				vitamin E supplement, mg · kg^{-1}			% rape seed oil in blended fat		
	vit. E (V)	rape seed oil (O)	VxO	5	20	50	0	10	20
SFA	0.01	0.01	0.01	29.35^{aA}	29.61^{bAB}	29.66^{bB}	29.97^{bB}	29.69^{bB}	28.69^{aA}
MUFA	0.01	0.01	0.01	57.37^{bB}	56.91^{aA}	57.15^{abAB}	27.39^{aA}	56.72^{bB}	57.31^{bB}
PUFA	0.01	0.01	0.01	13.28^{aAB}	13.48^{bB}	13.19^{aA}	12.63^{aA}	13.59^{bB}	13.73^{bB}
n-6	0.01	0.01	0.01	11.87^{aAB}	12.07^{bB}	11.83^{aA}	11.43^{aA}	12.20^{bB}	12.14^{bB}
n-3	NS	0.01	0.01	1.36	1.38	1.33	1.16^{aA}	1.36^{bB}	1.55^{cC}
n-6/n-3	NS	0.01	0.05	8.83	8.82	9.06	9.86^{cC}	9.06^{bB}	7.82^{aA}
SFA/UFA	NS	0.01	0.01	0.41	0.42	0.42	0.425^{bB}	0.42^{bB}	0.405^{aA}
$C_{18:3n3}$	NS	0.01	0.01	1.17	1.15	1.14	0.92^{aA}	1.17^{bB}	1.38^{cC}
$C_{20:5n3}$ (EPA)	0.01	0.01	0.01	0.022^{aA}	0.028^{bB}	0.027^{bB}	0.027^{bAB}	0.030^{cB}	0.020^{aA}
$C_{22:6n3}$ (DHA)	NS	NS	0.01	0.028	0.032	0.030	0.030	0.032	0.028

$^{a, b, c}$ $P \leq 0.05$

$^{A, B, C}$ $P \leq 0.01$

antioxidant. These properties of vitamin E have been confirmed in numerous studies (Morrisey et al., 1997; Sheldon et al., 1997). As a lipophilic antioxidant, vitamin E is capable of preventing peroxidation reactions induced by free radicals in lipids of tissue subcellular membranes. It interrupts the free radicals involved at the initial stage of fat autooxidation. In a review, Sheehy et al. (1997) stated the belief that lipid

oxidation in meat is initiated in phospholipids reach in PUFA. Iron may also play a critical role by allowing generation of free radicals capable of binding hydrogen ions. In stored abdominal fat that process could be different.

A rape seed oil content in supplemented fat rising from 0 to 10% enhanced the PUFA content in abdominal fat but did not affect peroxide values in stored fat. A higher, 20%, supplement of oil even decreased the peroxide value. That effect could be attributed in part to the presence of vitamin E and selenium peroxidases. The interaction between the vitamin and oil supplements and peroxide value of the abdominal fat pad may suggest a relation between PUFA and vitamin E in tissue as factors affecting the rate of oxidation.

Organoleptic tests of broiler meat suggest that the effects of dietary vitamin E supplements and source/level of dietary fat were not significant. Only Sheldon et al. (1997) reported an improvement in the organoleptic score of turkey meat after higher vitamin E supplementation.

The fatty acid content in stored adipose tissue was clearly affected by the proportion of rape seed oil in the feed. The level of LNA ($C_{18:3\ n-3}$) in abdominal fat confirms that rape seed oil is a good source of n-3 PUFA (Borowiec and Barteczko; 2001; Mieczkowska et al., 2001; Banaszkiewicz, 2002). The health of broilers during the feeding trial and mortality rates do not suggest any direct relationship with the dietary vitamin E levels applied.

CONCLUSIONS

It can be concluded that supplementation of the diet with vitamin E (5-50 $mg \cdot kg^{-1}$ of diet) has no effect on broiler performance, but positively affects the content of α-tocopherol in the liver, blood serum and breast muscles. The quality of abdominal fat after long deep-freeze storage was positively related to the level of vitamin E. Increasing amounts of rape seed oil added to the grower diet had a beneficial effect on the fatty acid composition of adipose tissue.

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STRESZCZENIE

Wpływ dodatku witaminy E i oleju rzepakowego do paszy dla kurcząt brojlerów na wyniki produkcyjne, skład tuszki, ocenę organoleptyczną mięsa oraz trwałość tłuszczu sadełkowego

Celem badań była ocena wpływu dodatku witaminy E do mieszanek paszowych natłuszczanych mieszaniną tłuszczu utylizacyjnego i oleju rzepakowego na wskaźniki produkcyjne, zawartość alfa-tokoferolu w tkankach, jakość mięsa i tłuszczu oraz zdrowotność kurcząt.

W doświadczeniu żywieniowym przeprowadzonym na 360 kurczętach brojlerach Ross zastosowano dodatek witaminy E do paszy w ilości 5, 20 i 50 mg · kg^{-1}. Mieszanki typu grower natłuszczano tłuszczem utylizacyjnym bez lub z dodatkiem 10 bądź 20% oleju rzepakowego. Dodatek 10% oleju rzepakowego do tłuszczu utylizacyjnego zwiększał przyrosty kurcząt ($P \leq 0.05$). Wraz ze wzrostem dodatku witaminy E do paszy następowało podwyższenie poziomu alfa-tokoferolu w wątrobie, surowicy krwi i mięśniu piersiowym ($P \leq 0.01$). Zwiększony dodatek witaminy E i oleju rzepakowego do paszy miał korzystny wpływ na podatność tłuszczu sadełkowego na utlenianie, ale nie wpływał na wyniki oceny organoleptycznej mięsa brojlerów. Wraz ze wzrostem udziału oleju rzepakowego w paszy obniżał się udział SFA, a zwiększał udział PUFA, n-3 PUFA i kwasu linolenowego ($C_{18:3\ n-3}$) w tłuszczu sadełkowym.