THE USE OF LINSEED OIL IN ENRICHING THE LIPIDS OF HEN BROILER, QUAIL AND RABBIT MEAT WITH Ω-3 FATTY ACIDS

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ABSTRACT. *In the trials with hen broilers were investigated the effect of 2.5% and 3.5% of linseed oil added to mixed concentrated feed on the ω-3 fatty acid content of the total lipids of broiler meat and fat after 10 days of feeding (29.–39. day of life) and the effect of aforementioned amounts of linseed oil on the dressing percentage of broilers and the proportion of haunch and breast muscle in carcass, also the taste characteristics of meat.*

It was concluded that for enriching broilermeat with ω-3 fatty acids, it would be suitable, based on the data of the current trial, to feed the chicken broilers 2.5% linseed oil with mixed concentrated feed during 10 days prior to slaughtering. Feeding 3.5% linseed oil would be more expensive, furthermore, the amount of ω-3 fatty acids in tissues will be sufficient also in case of 2.5% linseed oil and most probably the tasting figures of meat will improve as well.

For the enhancement of ω-3 fatty acids content in quail meat and quail fat with the help of local feeds rich in ω-3 fatty acids, two trials were carried out on Matjama quail farm of Järveotsa farmstead in September-October 2004.

In the first experiment the trial group quail broilers (from 21. to 42. day of life) were fed 8% linseeds or 10% linseed cake in the basal ration. The best results appeared in using the ration which contained 8% linseeds.

Based on the results of the first trial, the amounts of diets rich in ω-3 fatty acids were adjusted in the second trial: now 6% linseeds and 12% linseed cake were included in the rations of different trial groups. These rations were used during the last two feeding weeks of the quail.

In the second trial, feeding the quail rations which had been adjusted according to the digestibility of nutrients, a wholly satisfactory ω-3 fatty acids content (8.1%–13.8%) in total lipids of different tissues of quail carcasses was achieved. Rations containing either 6% linseeds or 12% linseed cake during the two weeks prior to killing can be recommended for the production of the so-called health quail meat enriched with ω-3 fatty acids.

From linseed oil fed to young rabbits in order to enrich their meat and internal fat with ω-3 fatty acids in two trials, the trial animals assimilated ω-3 fatty acids very successfully, by 70%. Young bucks and does converted ω-3 fatty acids from linseed oil to almost the same degree.

As far as saturated fatty acids are concerned, feeding linseed oil decreased their content in meat lipids and internal fat proportionally with the duration of feeding linseed oil.

In enriching rabbit meat and internal fat, better results were obtained by feeding 2 g linseed oil per day to young rabbits in the course of one month. 100 g of the meat of a rabbit who had been fed in this manner contained 0.4 g and 100 g of internal fat contained 16.4 g ω-3 fatty acids which make up 0.5% and 20.5%, respectively of the daily need of a grown-up human for ω-3 fatty acids.

Keywords: *ω-3 fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids, linseed oil, fatty acid composition of meat lipids.*

Introduction

During the last decade, the right proportion of ω-6 and ω-3 fatty acids has been subject to frequent discussion among nutritionists. Nowadays in the western world the main source of fat has been vegetable fat which ratio of ω-6/ω-3-fatty acids in human diet has been 15 or more. Moreover, the suggestion of organizations responsible for public health has been that α-linolenic acid (ALA, C18:3ω-3) should make up 1% and eicosapentaenoic acid (EPA, C20:5 ω-3) together with docosahexaenoic acid (DHA, C22:6 ω-3) 3% of the daily dosis of humans.

Such a recommended dietary dosis of EPA+DHA is much higher than that of the regular daily intake of Europeans and North-Americans. According to a research conducted in Belgium, EPA+DHA made up only 0.12% (290 mg) of the total energy of the daily human allowance, 45% of which came from fish (Arnouts, 2005). The research concludes that the concentration of ω-3 fatty acids in eggs, milk and meat should be increased, enriching them to the level which will satisfy their standard need in human diet.

The role of and ratio of ω-6- and ω-3 fatty acids in fighting cardiovascular diseases have been studied extensively by many scientists. Take for instance the publications of M. L. Burr *et al.* (1989), A. P. Simopoulos (1991) and W. E. Connor *et al.* (1994). E. Siguel (1996) discovered that due to the effect of polyunsaturated fatty acids, the ratio cholesterol/HDL-cholesterol (high density lipoproteins) in blood decreases.

ω-3 fatty acids belong to polyunsaturated monobasic carboxylic acids and display an important role in the life of a human organism, for example in the synthesis of prostaglandins in the organism. The substances to be synthesized regulate the coagulation of blood as well as stricturing and expansion of arteries, decrease the content of blood cholesterol, having, furthermore, an impact on the metabolic processes of cells (Sardesai, Detroit, 1992; Salem, 1989; Cave, 1991; Ferretti *et al*., 1991; Simopoulus, Salem, 1992). The daily need for ω-3 fatty acids in human consumption is 0.4–0.8 g on average (Leskanich, Noble, 1997; Farrell, 1997; The importance…, 1998). While using regular foodstuffs, humans develop a deficiency in ω-3 fatty acids. The richest source of ω-3 fatty acids is in the fat of cold-water fish and several plant oils, but most people do not like to consume such oil. Oil capsules rich in ω-3 fatty acids produced by many companies are too expensive. As a result, worldwide attempts are being made to enrich regular foodstuffs with ω-3 fatty acids.

1. Results of influencing fatty acids content in broiler meat and fat in Estonia so far

Since the last years of the previous century, the Institute of Animal Sciences of the Estonian Agricultural University has initiated investigations into enriching poultry meat. It was discovered that quail are successfully capable of assimilating ω-3 fatty acids from the feed. Adding 3% and 4% of linseed oil, respectively, to the feed of quail, the content of ω-3 fatty acids in quail meat increased substantially (H. Tikk *et al.,* 1999). An addition of 3% linseed oil to the feed of quail increased the content of ω-3 fatty acids (in total lipids) in breast muscle 4.6%, haunch muscle respectively from 8.7% to 14.0%, in skin even from 1.8% to 9.7%. A number of experiments have been carried out since 1999 at the Department of Small Farm Animal and Poultry Husbandry of Estonian University of Life Sciences for enriching hen broiler meat or rather its fat (including internal fat) with ω-3 fatty acids (Hämmal, V. Tikk, 1999; H. Tikk *et al.*, 1999; Hämmal *et al.*, 2000; Hämmal *et al.*, 2001; Х. Тикк, Лембер, 2003; Hämmal, 2004), in the course of which broilers were fed linseed oil, rapeseed oil and mixtures of linseed and rapeseed oil.

A 4% rapeseed oil content in the regular broiler feed during two months resulted in the ω-3 fatty acid content in total lipids of certain broiler tissues as follows (V. Tikk *et al.*, 2000): breast meat – 8.5%; haunch meat – 6.1%; skin – 4.5%; internal fat – 4.3%. Thus 100 g broiler haunch meat contains an average 0.15 g ω-3 fatty acids, 100 g skin contains ca 1.7 g ω-3 fatty acids. During the same experiment, the ω-3 fatty acids content in imported broilers was measured as well and, in contrast, it turned up to be practically nonexistent – 0.8% of total lipids.

The use of mixtures containing rapeseed oil and a small amount of linseed oil in broiler feed and their impact on the ω-3 fatty acids content has been studied as well in Estonia (Hämmal *et al.*, 2000). The results of experiments revealed that in the event of using mostly rapeseed oil, the ω-3 fatty acid content of broiler fat could not be increased to more than 4–7% of the amount of total lipids. This cannot be considered sufficient for recommending consumers to use hen broiler skin and fat without hesitation.

In an experiment of feeding linseed oil to broilers in 2003 it was found out:

1. A 2–3% linseed oil supplement in hen broiler feed does not influence the anatomical composition of broiler bodies significantly.
2. A 2% linseed oil supplement in broiler feed almost doubles the content of ω-3 fatty acids in broiler fat; however, this cannot be regarded sufficient for producing the so-called broiler health meat;
3. A 3% linseed oil supplement in broiler feed increased the content of ω-3 fatty acids in broiler fat five-fold on average already after two weeks of feeding.
4. As a result of feeding 2% and 3% of linseed oil, the ratio of ω-6 and ω-3 fatty acids became very favourable from the point of view of human consumption: in case of 2% it became 3.2 and in case of adding 3% linseed oil it became 1.7 (H. Tikk, Lember, 2004).

1.1. Increasing ω-3 fatty acids content in the meat and fat of hen broilers by feeding 2.5% and 3.5% linseed oil

1.1.1. Motivation and aim of trial

In the trials carried out so far, mixed concentrated feed enriched with linseed and rapeseed oil was fed to broilers during the whole growing period (up to 56 days) or starting from their second growing period, from their 29. day of life until slaughtering. As new broiler crosses are ready for slaughter sooner, at the age of 37–39 days, a greater amount of oil should evidently be used in their ration during the second shortened growing period.

Proceeding from the latter, it was planned during the current trial with hen broilers to study

- the effect of 2.5% and 3.5% linseed oil added to mixed concentrated feed on the ω-3 fatty acid content of the total lipids of broiler meat and fat after 10 days of feeding (29.–39. day of life);
- the effect of the aforementioned amounts of linseed oil on the dressing percentage of broilers and the proportion of haunch and breast muscle in carcass;
- the taste characteristics of broilers fed with linseed oil.

1.1.2. Trial methodology

The trial was established at A/S Tallegg and two private farms in Tartu county, Roiu and Lasva between November 8–18, 2004. On November 8, 40 28-day-old hen broilers were bought from Tallegg and two test groups were formed on private farms, each with 20 broilers.

The basal feed for broilers of the I test group was granulated mixed concentrated feed with a 2.5% linseed oil additive.

The basal feed for broilers of the II test group was the same granulated mixed concentrated feed with a 3.5% linseed oil additive.

The mixed concentrated feed as the basal feed for the second growing period of hen broilers contained 21.2% raw protein and 13.2 MJ/kg metabolizable energy.

The hens of the test group were raised ready for slaughter on the same Tallegg poultry farm where the birds of the I and II test group came from. Their diet was the same granulated mixed concentrated feed as that of the I and II test group, however, without the oil additive. The test slaughtering of the birds of the I and II test group and the control group took place on the same day, November 18, 2004. On slaughtering, a blood sample was taken from each bird.

10 birds (5 hens, 5 cocks) from each group were weighed, picked out and slaughted and the carcasses and edible internal organs were weighed and the carcasses were chilled. Breast and leg muscles were separated from the carcass, they were weighed and samples were taken for zootechnical analysis (dry matter, crude protein, crude ash and crude fat) and for fatty acid analysis. Samples for determining fatty acids were taken from leg muscle, internal fat and skin with subcutaneous fat. Each sample was taken in two replications: for meat analysis and fatty acid analysis of fat.

At the end of the experiment boiled breast meat (smell, consistence, chewing residue, taste), broth made of breast meat and bone broth (colour, transparency, fat condition, smell, taste) of the slaughtered hen broilers of the control group and of those fed 3.5% linseed oil (II trial group) were subjected to organoleptic tasting.

1.1.3. Trial results

The results presented in Table 1.1. of the effect of feeding linseed oil to the anatomical-morphological characteristics of the body and carcass of broilers reveal a somewhat greater body mass in case of female and male broilers on slaughter as well as a higher dressing percentage of the birds of the trial groups compared to those of the control group.

At the statistical processing of the material only the difference ($P<0.05$) in dressing percentage of birds from trial group I and the control group were significant. The other differences in figures presented in Table 1.1. were significant ($P<0.05$) due to variation within the group and a small number (5 individuals).

Table 1.1. Effect of linseed oil content in the diet on the carcass composition of chicken

Item		2.5% linseed oil I group		3.5% linseed oil II group		Control group	
		♀♀	♂♂	♀♀	♂♂	♀♀	♂♂
Body mass kg		1.99	2.31	1.73	2.14	1.79	2.06
Carcass mass kg		1.50	1.74	1.28	1.57	1.28	1.48
Dressing %		75.38	75.32	73.99	73.36	71.49	72.02
Eatable offals in carcass:							
neck	g	66.40	73.20	47.00	60.86	36.42	49.46
	%	4.45	4.20	3.68	3.87	2.85	3.34
heart	g	10.40	14.00	10.04	12.30	9.58	11.04
	%	0.70	0.81	0.79	0.78	0.75	0.75
liver	g	52.40	64.00	50.94	57.60	40.62	41.60
	%	3.49	3.67	3.99	3.67	3.17	2.81
gizzard	g	32.80	43.00	40.02	35.66	29.90	30.00
	%	2.22	2.47	3.17	2.27	2.34	2.02
breast muscles	g	367.20	378.80	340.96	397.84	343.29	368.22
	%	24.58	21.77	26.45	25.34	26.82	24.88
leg muscles	g	322.80	336.00	284.20	355.61	297.98	330.78
	%	21.56	19.29	22.27	22.65	23.28	22.35

The results of the chemical analysis of breast and leg muscles of broilers presented in Table 1.2. do not enable to draw conclusions about the effect of linseed oil diet supplement on the chemical composition of broilers' breast and leg muscles as differences between groups regarding both fat and protein content were too inconspicuous.

Table 1.2. Effect of linseed oil content in the diet on the chemical composition of chicken muscles

Item	2.5% linseed oil I group		3.5% linseed oil II group		Control group	
	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂
Breast muscles:						
water %	75.7	75.3	75.6	75.9	75.0	75.5
protein %	22.0	22.5	22.5	22.3	23.1	22.8
ash %	1.14	1.09	1.18	1.12	1.17	1.12
fat %	1.6	1.4	1.2	1.2	1.4	1.1
Leg muscles:						
water %	78.2	77.9	77.8	77.7	78.0	77.5
protein %	18.4	19.3	18.7	18.7	18.6	18.3
ash %	1.02	1.04	1.03	0.99	0.95	0.96
fat %	2.8	2.5	2.8	3.2	2.9	3.2

The fatty acid composition (in lipid percentages) of different tissues of female and male broilers from trial and control groups are presented in Tables 1.3.–1.9. Based on the mean of analysis data (n=5) given in the above tables, the following generalizations can be made.

1. Feeding 2.5% linseed oil (I trial group) in the course of 10 days increased the amount of ω-3 fatty acids in the skin and subcutaneous fat, internal fat and leg fat of hen broilers from I trial group by 3.8, 4.1 and 3.6 times. The respective figures for male broilers were by 3.3, 4.3 and 4.2 times. In terms of absolute value, the ω-3 fatty acids content in hen broilers increased to 5.43%, 7.16% and 6.31% and of male broilers to 6.01%, 7.31% and 6.46%, respectively of the lipids of the above tissues. The respective figures about the female broilers of the control group were 1.67%, 1.74% and 1.76% and the figures about the male broilers 1.80%, 1.72% and 1.55%. On average (♀♀+♂♂), the ω-3 fatty acids content in skin and subcutaneous fat, internal tissue and leg mucle tissue of the broilers of the I trial group increased by 3.1, 4.2 and 3.9 times, respectively.

Table 1.3. Fatty acid content (%) of different tissues of the 1st group female chicken broilers

Fatty acid			Skin with sub-cutaneous fat		Inner fat		Fat in leg muscules	
	systematic name	common name	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
14:0	tetradecanoic acid	myristic acid	0.60	0.04	0.67	0.03	0.78	0.14
15:0	pentadecanoic acid		0.08	0.02	0.09	0.02	0.08	0.03
16:0	hexadecanoic acid	palmitic acid	19.71	1.08	20.28	1.16	20.99	1.44
16:1	hexadecenoic	palmitoleic acid	3.84	0.72	3.70	0.73	3.08	0.72
17:0	heptadecanoic acid	margaric acid	0.18	0.07	0.12	0.02	0.15	0.07
17:1	heptadecenoic acid		0.05	0.03	0.03	0.02	0.10	0.04
18:0	octadecanoic acid	stearic acid	5.39	0.69	5.84	0.48	6.41	1.02
18:1	octadecenoic acid	oleic acid	39.06	0.82	36.12	1.19	35.71	2.00
18:2n6	octadecadienoic acid	linoleic acid	24.66	1.01	25.07	1.09	23.99	0.88
18:3n3	octadecatrienoic acid	α-linoleic acid	5.23	0.48	6.88	0.92	5.38	0.61
20:0	eicosanoic acid	arachidic acid	0.08	0.02	0.04	0.02	0.09	0.02
20:1	eicosenoic acid	gadoleic acid	0.37	0.06	0.33	0.04	0.32	0.03
20:2n6	eicosadienoic acid		0.16	0.05	0.17	0.02	0.41	0.20
20:4n6	eicosatetraenoic acid	arachidonic acid	0.22	0.01	0.20	0.07	1.33	0.74
20:5n3	eicosapentaenoic acid (EPA)	timnodonic acid	0.04	0.03	0.12	0.03	0.21	0.07
22:4n6	docosatetraenoic acid		0.17	0.02	0.18	0.02	0.25	0.12
22:5n3	docosapentaenoic acid (DPA)	clupanodonic acid	0.10	0.01	0.11	0.03	0.48	0.26
22:6n3	docosahexaenoic acid (DHA)		0.06	0.01	0.05	0.01	0.24	0.21
Saturated fatty acids			26.06	1.12	27.04	1.24	28.50	2.23
Monounsaturated fatty acids			43.79	0.78	40.81	1.44	39.30	2.52
n6 polyunsaturated fatty acids			25.21	1.00	25.62	1.12	25.98	1.23
n3 polyunsaturated fatty acids			5.43	0.50	7.16	0.92	6.31	0.40
n6/n3			4.64	0.61	5.58	0.53	4.13	0.33
n6 long chain polyunsaturated fatty acids			0.38	0.01	0.55	0.04	1.98	1.05
n3 long chain polyunsaturated fatty acids			0.20	0.03	0.28	0.04	0.93	0.51

2. Feeding 3.5% linseed oil (II trial group) during 10 days resulted in an even bigger effect of transforming ω-3 fatty acids into the lipids of the studied tissues. The amount of ω-3 fatty acids in the skin and subcutaneous fat, internal fat and fat of leg muscles of the hen broilers increased by 4.2, 4.1 and 4.5 times, of the

male broilers by 4.1, 5.1 and 5.0 times, respectively. In terms of absolute value, the ω-3 fatty acids content in hen broilers increased to 6.95%, 7.19% and 7.98% and in case of male broilers to 7.39%, 8.79% and 7.74%, respectively of the lipids of the above tissues. On average (♀♀+♂♂), the ω-3 fatty acids content in the above tissues of the broilers of the II trial group increased 3.8, 4.6 and 4.8 fold which is significantly more than in the respective tissues of the birds of the I trial group.

3. A more significant part of the determined ω-3 fatty acids was made up of α-linolenic acid (18:3n3). In skin and subcutaneous fat as well as in internal fat the amount of long-chained ω-3 fatty acids (20:5n3; 22:5n3 and 22:6n3) was only 0.20–0.76%, in leg fat 1.90%, on average.

4. The total increment in ω-3 fatty acids occurred mainly at the cost of α-linolenic acid (18:3n3), to a lesser degree owing to the decrease in palmitic (16:0) and oleic acid (18:1) content in the lipids of the studied tissues.

5. The ω-3 fatty acids content in the lipids of the studied tissues in the trial and control group did not differ significantly.

6. A 2.5% and 3.5% linseed oil additive in diet decreased the content of saturated and monounsaturated fatty acids, haunch meat lipids excluded, as in case of hen broilers this figure was uniform in all groups but increased, however, the respective figure of male broilers.

7. On feeding linseed oil, ω-3 fatty acids content was increased manyfold in the studied tissues, however, the ω-6 fatty acids level remained relatively stable. This is why the ω-6 ja ω-3 ratio presented in tables 1.3.–1.9. of the studied tissues of the broilers from the I trial group had diminished in comparison with the control group 3.3–4.1 fold. 4.2–5.0 fold in the II trial group. In the trial groups the ratio was 3.42–4.64 in skin and subcutaneous fat, in internal fat 2.87–5.58, in leg fat 3.65–4.31. In the birds of the control group the figure was 14.50–14.64, 15.34–16.60 and 15.78–18.75, respectively.

8. The data on the fatty acid analysis of different tissues of the control group broilers are in perfect correlation with the data presented in Table 1.9. A somewhat higher ω-3 fatty acids content at the analysis presented in Table 1.9. refers to a 3–5% corn or rapeseed oil content in the final ration of the broilers.

9. The presented amounts of ω-3 fatty acids in 100 g of male broilers of I trial group can guarantee a grown up person consuming skin with subcutaneous fat (contains 64.0% fat), internal fat (contains 90% fat) and leg muscles (contain 8.5% fat) a 4.8, 8.2 ja 0.7 fold daily dosis (0.8 g) of ω-3 fatty acids. In case of hen broilers from the same group the respective figures would be 4.4, 8.0 and 0.6 of daily dosis of ω-3 fatty acids. The above figures would be even higher if broilers were fed with a blend of 3.5% linseed oil and mixed concentrated feed.

Table 1.4. Fatty acid content (%) of different tissues of the 1st group male chicken broilers

Fatty acid	Skin with subcutaneous fat		Inner fat		Fat in leg muscules	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
14:0	0.61	0.06	0.66	0.04	0.77	0.08
15:0	0.07	0.02	0.07	0.01	0.11	0.01
16:0	19.53	1.59	19.70	0.90	20.68	0.88
16:1	4.35	0.72	3.99	0.75	2.76	0.63
17:0	0.17	0.03	0.12	0.02	0.15	0.05
17:1	0.06	0.04	0.03	0.03	0.14	0.12
18:0	5.09	0.42	5.16	0.70	6.96	0.72
18:1	38.40	1.51	36.63	1.51	33.74	2.57
18:2n6	24.73	2.97	25.39	1.89	24.10	1.91
18:3n3	5.60	0.58	6.63	0.31	4.58	0.80
20:0	0.07	0.02	0.05	0.01	0.11	0.08
20:1	0.33	0.04	0.28	0.09	0.32	0.07
20:2n6	0.18	0.03	0.21	0.05	0.62	0.25
20:4n6	0.32	0.06	0.14	0.05	2.65	1.10
20:5n3	0.09	0.02	0.14	0.03	0.45	0.19
22:4n6	0.09	0.03	0.26	0.08	0.43	0.19
22:5n3	0.21	0.08	0.38	0.13	1.01	0.43
22:6n3	0.10	0.02	0.16	0.04	0.42	0.19
Saturated fatty acids	25.54	1.95	26.23	0.69	28.79	1.22
Monounsaturated fatty acids	43.80	2.09	41.77	2.46	37.06	3.09
n6 polyunsaturated fatty acids	25.32	3.00	25.71	2.07	27.80	2.77
n3 polyunsaturated fatty acids	6.01	0.57	7.31	0.13	6.46	0.41
n6/n3	4.21	0.44	3.52	0.33	4.31	0.45
n6 long chain polyunsaturated fatty acids	0.59	0.06	0.40	0.14	3.70	1.49
n3 long chain polyunsaturated fatty acids	0.40	0.012	0.70	0.21	1.88	0.79

Table 1.5. Fatty acid content (%) of different tissues of the 2nd group female chicken broilers

Fatty acid	Skin with subcutaneous fat		Inner fat		Fat in leg muscules	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
14:0	0.61	0.05	0.56	0.05	0.72	0.15
15:0	0.07	0.01	0.06	0.01	0.10	0.02
16:0	19.58	1.61	19.44	1.56	20.82	2.20
16:1	4.06	0.81	3.95	0.97	2.50	0.76
17:0	0.16	0.04	0.11	0.02	0.19	0.06
17:1	0.03	0.01	0.08	0.03	0.18	0.20
18:0	5.18	0.43	4.98	0.69	6.95	1.49
18:1	38.10	1.06	38.43	1.56	30.70	3.73
18:2n6	24.25	1.41	24.22	1.28	24.70	1.23
18:3n3	6.38	0.75	6.43	0.60	5.26	1.83
20:0	0.05	0.03	0.03	0.01	0.14	0.03
20:1	0.37	0.11	0.33	0.06	0.30	0.13
20:2n6	0.24	0.07	0.21	0.04	0.90	0.41
20:4n6	0.23	0.05	0.12	0.02	3.24	1.53
20:5n3	0.05	0.05	0.04	0.01	0.69	0.31
22:4n6	0.12	0.04	0.29	0.06	0.58	0.38
22:5n3	0.31	0.11	0.43	0.19	1.36	0.62
22:6n3	0.21	0.04	0.29	0.08	0.67	0.37
Saturated fatty acids	25.64	1.57	25.18	1.58	28.91	3.55
Monounsaturated fatty acids	43.44	1.16	44.01	1.81	33.82	4.28
n6 polyunsaturated fatty acids	24.60	1.45	24.94	1.29	29.43	1.54
n3 polyunsaturated fatty acids	6.95	0.72	7.19	0.60	7.98	0.83
n6/n3	3.54	0.29	3.47	0.29	3.72	0.41
n6 long chain polyunsaturated fatty acids	0.59	0.07	0.62	0.10	4.73	2.24
n3 long chain polyunsaturated fatty acids	0.57	0.08	0.76	0.26	2.72	1.25

Table 1.6. Fatty acid content (%) of different tissues of the 2nd group male chicken broilers

Fatty acid	Skin with subcutaneous fat		Inner fat		Fat in leg muscules	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
14:0	0.61	0.05	0.66	0.04	0.72	0.13
15:0	0.05	0.01	0.07	0.01	0.12	0.10
16:0	19.49	1.30	20.04	1.11	20.35	1.17
16:1	3.81	0.57	3.54	0.69	2.48	0.57
17:0	0.12	0.04	0.10	0.03	0.22	0.17
17:1	0.07	0.04	0.07	0.03	0.17	0.16
18:0	5.24	0.69	5.66	0.62	6.76	1.80
18:1	37.56	1.52	35.46	1.43	32.87	4.74
18:2n6	24.68	1.70	24.70	1.29	24.51	1.72
18:3n3	6.86	1.51	8.19	1.53	5.68	1.47
20:0	0.05	0.01	0.04	0.03	0.09	0.02
20:1	0.33	0.04	0.34	0.06	0.31	0.07
20:2n6	0.19	0.03	0.21	0.04	0.63	0.34
20:4n6	0.24	0.07	0.15	0.04	2.52	1.82
20:5n3	0.07	0.04	0.05	0.02	0.45	0.27
22:4n6	0.16	0.03	0.17	0.04	0.51	0.41
22:5n3	0.28	0.08	0.21	0.07	1.11	0.79
22:6n3	0.19	0.06	0.34	0.11	0.50	0.35
Saturated fatty acids	25.57	1.81	26.57	1.22	28.25	2.85
Monounsaturated fatty acids	42.58	1.93	40.34	1.92	35.93	5.24
n6 polyunsaturated fatty acids	25.27	1.75	25.23	1.31	28.16	3.03
n3 polyunsaturated fatty acids	7.39	1.54	8.79	1.54	7.74	0.85
n6/n3	3.42	0.67	2.87	0.53	3.65	0.28
n6 long chain polyunsaturated fatty acids	0.59	0.21	0.53	0.18	3.66	2.51
n3 long chain polyunsaturated fatty acids	0.54	0.20	0.60	0.21	2.06	1.40

Table 1.7. Fatty acid content (%) of different tissues of female chickens in the control group

Fatty acid	Skin with subcutaneous fat		Inner fat		Fat in leg muscules	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
14:0	0.59	0.04	0.58	0.05	0.69	0.17
15:0	0.08	0.02	0.08	0.01	0.11	0.05
16:0	22.38	0.88	21.64	0.54	21.11	0.66
16:1	4.89	0.67	4.75	0.51	4.16	0.63
17:0	0.09	0.03	0.13	0.02	0.17	0.04
17:1	0.04	0.02	0.08	0.05	0.24	0.23
18:0	5.14	0.44	4.99	0.27	6.21	1.16
18:1	40.41	1.60	40.71	1.61	37.69	3.71
18:2n6	23.43	0.73	24.05	1.62	24.27	1.47
18:3n3	1.38	0.16	1.36	0.15	1.27	0.15
20:0	0.04	0.01	0.04	0.01	0.06	0.02
20:1	0.46	0.09	0.40	0.07	0.36	0.07
20:2n6	0.31	0.08	0.43	0.07	0.97	0.58
20:4n6	0.29	0.09	0.16	0.04	1.78	1.09
20:5n3	0.02	0.01	0.09	0.02	0.14	0.17
22:4n6	0.18	0.04	0.22	0.05	0.41	0.26
22:5n3	0.15	0.03	0.16	0.03	0.26	0.17
22:6n3	0.12	0.03	0.13	0.02	0.10	0.14
Saturated fatty acids	28.32	1.26	27.45	0.66	28.36	1.86
Monounsaturated fatty acids	46.57	1.93	46.97	1.84	42.51	4.05
n6 polyunsaturated fatty acids	24.21	0.70	24.87	1.64	27.43	2.06
n3 polyunsaturated fatty acids	1.67	0.16	1.74	0.15	1.76	0.31
n6/n3	14.50	1.41	16.60	1.44	15.78	1.82
n6 long chain polyunsaturated fatty acids	0.78	0.17	0.81	0.19	3.16	1.90
n3 long chain polyunsaturated fatty acids	0.29	0.06	0.38	0.11	0.50	0.45

Table 1.8. Fatty acid content (%) of different tissues of mail chickens in the control group

Fatty acid	Skin with subcutaneous fat		Inner fat		Fat in leg muscules	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
14:0	0.61	0.04	0.59	0.08	0.69	0.09
15:0	0.09	0.01	0.09	0.04	0.13	0.08
16:0	21.40	0.97	20.92	1.40	21.03	0.87
16:1	4.69	1.12	4.67	0.85	4.08	0.64
17:0	0.11	0.02	0.15	0.05	0.16	0.05
17:1	0.04	0.02	0.06	0.04	0.15	0.07
18:0	4.92	0.77	4.54	0.59	5.69	1.13
18:1	39.33	1.03	40.42	1.21	37.89	2.75
18:2n6	25.71	2.61	25.66	2.10	25.22	2.51
18:3n3	1.45	0.06	1.33	0.11	1.13	0.18
20:0	0.06	0.03	0.06	0.02	0.05	0.01
20:1	0.40	0.03	0.39	0.06	0.38	0.14
20:2n6	0.28	0.04	0.32	0.05	0.78	0.47
20:4n6	0.40	0.07	0.21	0.07	1.80	0.79
20:5n3	0.03	0.02	0.08	0.03	0.08	0.04
22:4n6	0.16	0.04	0.20	0.06	0.41	0.19
22:5n3	0.17	0.03	0.18	0.06	0.23	0.11
22:6n3	0.15	0.03	0.13	0.02	0.10	0.08
Saturated fatty acids	27.18	1.22	26.35	1.53	27.76	1.97
Monounsaturated fatty acids	45.23	1.99	46.46	1.36	42.53	2.76
n6 polyunsaturated fatty acids	26.55	2.58	26.39	2.15	28.21	2.28
n3 polyunsaturated fatty acids	1.80	0.08	1.72	0.11	1.55	0.28
n6/n3	14.64	1.64	15.34	0.59	18.75	3.89
n6 long chain polyunsaturated fatty acids	0.84	0.18	0.73	0.27	2.99	1.32
n3 long chain polyunsaturated fatty acids	0.35	0.11	0.39	0.12	0.41	0.21

Table 1.9. Fatty acid content (%) of different tissues in imported broiler legs

Fatty acid	Skin	Fat	Meat
14:0	0.49	0.46	0.57
15:0	0.06	0.05	0.07
16:0	24.00	24.14	23.49
16:1	5.54	5.53	4.88
17:0	0.14	0.15	0.18
17:1	0.12	0.08	0.26
18:0	4.54	4.34	6.93
18:1	41.18	41.89	36.55
18:2n6	20.41	20.26	21.25
18:3n3	2.08	2.09	1.80
20:0	0.02	0.01	0.04
20:1	0.32	0.33	0.20
20:2n6	0.12	0.04	0.66
20:4n6	0.23	0.12	2.23
20:5n3	0.05	0.04	0.10
22:4n6	0.52	0.36	0.44
22:5n3	0.11	0.06	0.24
22:6n3	0.07	0.05	0.11
Saturated fatty acids	29.25	29.15	31.28
Monounsaturated fatty acids	47.84	48.30	42.04
n6 polyunsaturated fatty acids	21.28	20.78	24.58
n3 polyunsaturated fatty acids	2.31	2.24	2.25
n6/n3	9.21	9.28	10.92
n6 long chain polyunsaturated fatty acids	0.87	0.52	3.33
n3 long chain polyunsaturated fatty acids	0.23	0.15	0.45

10. Tasting results of broilers' breast meat, breast meat broth and bone broth of control group and II trial group (3.5% linseed oil in feed) were better in the control group. On a five-point evaluation scale (34 tasters), the smell of boiled breast meat of the control group broilers was better by 0.38 (4.49 in absolute value) and taste by 0.30 (absolute value 4.47) points. As regards breast muscle broth, the tasting results were with the same orientation, 0.41 (4.35) and 0.14 (4.38) and 0.03 (3.56) and 0.30 (3.71) evaluation points, respectively.

As the established absolute figures of smell and taste were high, feeding broilers with 3.5% linseed oil has not influenced the taste characteristics of broiler meat significantly, whereas the effect is even smaller in case of feeding with 2.5% linseed oil.

1.1.4. Summary and conclusions

The aim of the trial is by adding 2.5% and 3.5% linseed oil to broilers' diet and feeding it for 10 days to increase ω-3 fatty acids in the lipids of different tissues to such an amount which would enable to use the skin and subcutaneous fat and internal fat of broilers as a nutrient for prophylaxis of heart and coronary diseases as well as other diseases and for treatment purposes. In addition to this, investigation was carried out to find out the effect of linseed oil on the morphology of broilers' body and carcass and on the chemical composition and taste qualities of broiler meat.

The above trial proved the following:

- Adding 2.5 ja 3.5% linseed oil to broiler feed influenced significantly, considering all the groups, only the dressing percentage of the female and male broilers of the I trial group. As for the other figures, no significant differences could be found.
- Adding linseed oil to broiler feed did not have any effect on the chemical composition of the breast and leg muscles of the birds.
- Adding 2.5% linseed oil during 10 days increased the amount of ω-3 fatty acids in broilers' skin and subcutaneous fat, internal fat and leg muscle fat in case of female broilers 3.8, 5.1 ja 3.0 fold, respectively, in case of male broilers 3.8, 5.1 ja 4.2 fold, respectively. On adding 3.5% linseed oil, the new figures were (♀♀) 4.6, 4.8 ja 4.5 fold and (♂♂) 4.7, 6.2 and 5.0 fold, respectively.
- Feeding broilers with 2.5% ja 3.5% linseed oil together with mixed concentrated feed enhanced the amount of ω-3 fatty acids in the studied tissues to a level which enables to consider broilers' skin with fat layer and internal fat enriched with ω-3 fatty acids as valuable nutrients.

- At the same time with the increment of ω-3 fatty acids in the studied tissues the ratio of ω-6 and ω-3 fatty acids diminished manyfold, enhancing considerably the value of enriched tissues, according to the viewpoints of dietology.
- Tasting revealed somewhat better figures concerning the meat of the control group birds compared to the meat of birds who had receiced 3.5% linseed oil additive.
- For enriching broiler meat with ω-3 fatty acids, it would be suitable, based on the data of the current trial, to feed the birds 2.5% linseed oil together with mixed concentrated feed during 10 days prior to realization. Feeding 3.5% linseed oil would be slightly more expensive, furthermore, the amount of ω-3 fatty acids in tissues will be sufficient also in case of 2.5% linseed oil and most probably the tasting figures of meat will improve as well.

2. Increasing the quality of quail broiler meat by enriching it with ω-3 fatty acids

2.1. Motivation and objective of experiments

The enrichment of regular foodstuffs with ω-3 fatty acids, agents which can prevent coronary diseases, cancer and many other illnesses has gained high priority in many countries nowadays.

Quail meat is generally approved dietary food. Of its total lipids, ω-3 fatty acids make up an average of 1.4% (Decker, Cantor, 1992).

There are no data available in professional literature regarding the enrichment of quail meat with ω-3 fatty acids, except for the researches carried out by the Department of Small Farm Animal and Poultry Husbandry at the Institute of Veterinary Medicine and Animal Sciences of Estonian University of Life Sciences.

In 1998 on Järveotsa quail farm 21–42-day-old quail broilers were fed 4% linseed oil added to mixed concentrated feed. Analyses of breast and haunch meat revealed that the enrichment of ration with 4% linseed oil almost doubled the content of ω-3 fatty acids in the breast and haunch muscles of quail compared to the figures of the control group and increased it 3.4-fold in fat. Comparing the content of α-linolenic acid in the breast and haunch muscles and fat of the birds from control group with the respective figures of the birds from the trial group, it turned out that the content of α-linolenic acid (18:3n3) of the latter had risen from 2.6% to 7.8%, from 2.3% to 5.7% and from 3.0% to 10.2%, respectively. At the same time, the content of docosahexaenoic acid (22:6n3) increased in haunch and breast muscles from 1.2% to 2.2% and from 1.5% to 2.3%, respectively. The amount of eicosapentaenoic acid (20:5n3) in fat was very little in the samples of both control group and trial group, below 0.05% (H. Tikk *et al.*, 1999; Хяммал и др., 1999).

A trial executed on Järveotsa quail farm in the year 2000 for the enrichment of quail meat with ω-3 fatty acids was analogous to the aforementioned, although in mixed concentrated feed 3% linseed oil was fed the quail of the trial group and, in addition, fatty acid content in skin (together with subcutaneous fat) was studied as well, as it turned up that the skin of a quail carcass contains up to 40% fat. Compared to the figures of the control group, including 3% linseed oil in the ration increased ω-3 fatty acids content in the lipids of breast muscles 2.4-fold, in haunch muscles 1.6-fold, in skin with subcutaneous fat 5.4-fold and in fat 5.9-fold. The above mentioned enriched quail meat must be considered very promising foodstuff. 100 g quail fat would thus correspond to 65 quail eggs enriched with ω-3 fatty acids, regarding ω-3 fatty acids content. One gram of yolk of an enriched quail egg contains 30 mg of ω-3 fatty acids, 1 g of skin with subcutaneous fat contains 39 mg and internal fat 75 mg of ω-3 fatty acids (Hämmal *et al*., 2001; H. Tikk *et al.*, 2002; Hämmal, 2004).

The results of these two trials presented here revealed that quail are capable of storing larger amounts of ω-3 fatty acids in the lipids of their muscles, skin and internal fat than in the lipids of their egg yolk. 3% linseed oil can be considered sufficient in mixed concentrated feed for quail broilers in order to raise quail meat to the level of very healthy foodstuff.

As linseed oil is rather expensive and feeding it would increase the cost price of quail meat, an attempt was made with the help of two trials to replace linseed oil in quail broilers' ration with cheaper feeds of local origin, linseed cake and linseeds.

2.2. Trial methodology

2.2.1. Increasing ω-3 fatty acids content in quail meat and fat with the help of local feeds rich in ω-3 fatty acids (I trial)

During the first trial in September 2004, young meat quail of French origin on Järveotsa quail farm were fed from their 21. day of age until 42. day of age in addition to mixed concentrated quail chick feed the following additives: in I trial group 8% linseeds; in II trial group 10% linseed cake. In the control group only mixed concentrated feed was used.

Mixed concentrated quail chick feed contained 22.6% crude protein and 12.85 MJ/kg metabolizable energy. Mixed concentrated feed contained 4% rapeseed oil as well.

Linseeds and linseed cake were involved in the trial in order to replace expensive linseed oil which had so far given good results in increasing the level of ω-3 fatty acids in poultry products.

The trial and control groups were kept in similar conditions on deep litter with the density of 50 birds on 1 m^2. The birds were fed on an *ad libitum* basis.

At the age of 42 days 5 hen quail from each trial group were killed. Birds were weighed individually prior to killing and after killing their carcasses, necks, hearts, livers, gizzards, breast and leg muscles were weighed as well.

Mixed concentrated feeds, quail excrements, breast and leg muscles were subjected to chemical analysis. Fatty acid content was analysed in feeds, linseeds, linseed cake, breast and leg muscles of the trial birds, skin and internal fat. The chemical analysis was carried out at the laboratory of the Department of Nutrition of the Institute of Veterinary Medicine of Estonian University of Life Sciences, measurements of fatty acids were carried out at the Laboratory of Ecochemistry.

2.2.2. Specification of the amounts of local feeds to be used for enhancing ω-3 fatty acids content in quail meat (II trial)

The second trial carried out was based on the results of the previous trial with quail broilers of Estonian breed. The trial took place in October-November 2004 on Järveotsa quail farm. The quail chicks hatched out on October 5 were raised from 1. to 28. day of age on deep litter in equal conditions and on similar feed. Three trial groups were formed of 28-day-old quail chicks, 200 chicks in each, and placed in separate pens in chicken house. The further feeding of trial quail varied: I group – granulated basal feed + 6% linseeds; II group – granulated basal feed + 12% linseed cake. III group (control group) was fed granulated basal feed which contained 22.8% crude protein and 12.68 MJ/kg metabolizable energy.

Test feeding commenced on November 3. Trial quail were kept in equal conditions and fed on an *ad libitum* basis. On November 17, at the age of 42 days, 5 male and female quail of average body weight were killed from each group. For specific investigation, blood samples were taken individually. The quail were weighed prior to killing. Quail carcasses, edible internal organs (heart, liver, gizzard), breast muscles and leg muscles were weighed individually. Samples from breast muscles, leg muscles, skin and internal fat were taken for chemical analysis. In the samples taken, dry matter was determined plus chemically the content of mineral matter, crude protein and crude fat and, furthermore, the fatty acid content of fat in the samples was found out. The chemical analyses were carried out in the same laboratories as in case of previous trial.

2.2.3. The chemical composition of feeds used

In order to avoid repetition, the chemical composition of rations used in the trial has been presented in the part discussing trial results (Table 2.4), where they are vital in explaining the assimilation of nutrients. The raw fat and ω-3 fatty acids content in trial feeds is presented in Table 2.1.

Table 2.1. Content of crude fat and ω-3 fatty acids in the diet

Feeds	Crude fat content %	ω-3 fatty acids in crude fat %	ω-3 fatty acids content in 1 g of feed mg	ω-3 fatty acids content in daily (30 g) diet mg
Linseed	32.77	47.77	157	–
Linseed cake	13.46	48.50	65	–
Mixed feed with linseed (8%)	9.72	13.50	13	390
Mixed feed with linseed cake (10%)	5.94	23.71	14	420
Mixed feed	4.73	10.77	5	150
Linseed oil	96.00	52.97	509	–

2.3. Trial results

2.3.1. Enhancing ω-3 fatty acids content in quail meat and fat by means of local feeds rich in ω-3 fatty acids

2.3.1.1. The anatomical-morphological composition of the body and carcass of trial quail

The mean results of trial killing followed by the anatomical-morphological analysis of body and carcass are presented in Table 2.2.

Table 2.2. Influence of linseed and linseed cake on the carcass composition of 42 day old femail quails (n=5)

Items	Trial group		
	1st (8% linseed)	2nd (10% linseed)	control
Live weight g	284.4	285.2	280.8
carcass g	186.0	184.8	182.0
dressing %	65.4	64.8	64.8
liver %	1.9	2.0	1.8
heart %	1.1	0.7	0.7
gizzard %	2.1	1.5	1.3
neck %	2.7	2.8	3.4
In carcass %			
breast muscles	31.4	29.5	28.9
leg muscles	19.4	20.3	17.9

The data in Table 2.2 reveal that relevant differences in basic figures, dressing percentage and breast and leg muscles of the quail broilers from the trial groups did not occur. The dressing percentage and proportion of breast muscles in the carcasses of quail from the linseed group were slightly higher, compared to the figures of the birds from the linseed group and the linseed cake group. Thus, based on dressing percentage and proportion of breast muscle, the linseed-group feeding type should be preferred.

2.3.1.2. The chemical composition of meat, skin and fat of the trial quail and the digestibility of feeds

The chemical composition of the trial quail is presented in Table 2.3 which reveals that quail meat was rather fatty. Based on the given data, breast muscles contained 5.7%–7.7% and leg muscles 14.7%–17.2% crude fat.

Table 2.3. Chemical composition of quail meat in different groups (%)

Trial group muscle	Dry matter	Crude protein	Crude ash	Crude fat
8% linseed in the diet				
breast muscles	29.85	22.88	1.28	5.69
leg muscles	34.46	18.26	1.19	15.01
10% linseed cake				
breast muscles	31.22	22.21	1.29	7.72
leg muscles	36.18	17.64	0.92	17.62
Control group				
breast muscles	31.26	23.69	1.11	6.46
leg muscles	34.79	19.08	1.02	14.69

The highest crude fat content could be observed in the breast and leg muscles of the quail from the linseed cake trial group, 7.72% and 17.62%, respectively. On the other hand, the linseed cake trial group presented the lowest crude protein content in muscles. On the basis of analysis of the chemical composition of meat, the linseed cake feeding group should be preferred.

On the basis of analyses performed on feeds prescribed and excrements rejected during the trial period, the digestibility of nutrients in rations was determined in a simplified manner (Table 2.4).

Table 2.4. Nutrient digestibility of different diets

Items %	Trial groups		
	1st, 8% linseed	2nd, 10% linseed cake	control
Crude protein			
in diet	21.56	24.06	22.62
in feces	9.86	9.82	7.84
digestibility	54.27	59.19	65.34
Crude fat			
in diet	9.72	5.94	4.73
in feces	1.13	0.26	0.25
digestibility	88.38	95.62	94.42
Crude ash			
in diet	12.49	11.81	18.33
in feces	9.59	7.77	7.39
digestibility	23.22	34.21	41.32
Crude fibre			
in diet	8.05	8.98	8.75
in feces	7.27	5.74	4.74
digestibility	9.69	36.08	48.46

Table 2.4 confirms that the lowest digestibility of all analysed nutrients could be observed in the linseed group, especially in case of crude fiber. This was followed by digestibility figures of birds from the linseed cake group and the control group. Probably the highest crude fat content (9.72%) in the ration of birds from the linseed group (see Table 2.1) inhibits to some extent the assimilation of nutrients during the digestive process. Based on Table 2.4, the linseed group's type of feeding should be preferred.

2.3.1.3. Fatty acid composition of the meat, skin and fat of the trial quail

Fatty acid composition of breast and leg muscles, skin and internal fat separated from the carcasses of trial quail is presented in Tables 2.5, 2.6 and 2.7.

Table 2.5. Influence of linseed (8%) in the diet on the fatty acid composition of different tissues

Fatty acid	Breast muscles	Leg muscles	Skin	Inner fat
C14:0	0.79	0.87	0.80	0.73
C16:0	14.92	14.18	14.37	13.20
C16:1	3.65	4.42	4.35	3.54
C18:0	5.07	3.59	4.00	3.49
C18:1	34.07	36.87	42.35	38.28
C18:2n6	30.62	30.89	27.32	32.68
C18:3n3	7.24	7.55	5.86	7.22
C20:0	0.12	0.09	0.11	0.10
C20:1	0.66	0.68	0.63	0.63
C20:4n6	1.11	0.25	0.09	0.05
C20:5n3	0.47	0.20	0.05	0.06
C22:5n3	0.12	0.10	×	×
C22:6n3	1.17	0.30	0.06	0.01
∑ Saturated fatty acids	20.90	18.73	19.28	17.52
∑ Polyunsaturated fatty acids	38.38	41.97	47.33	42.45
∑ n6 polyunsaturated fatty acids	31.73	31.14	27.41	32.73
∑ n3 polyunsaturated fatty acids	9.00	8.15	5.97	7.29
n6/n3	3.53	3.82	4.59	4.49

Comparing the data of these tables, it comes out that most ω-3 fatty acids present in the fat of quail are made up by α-linolenic acid (C18:3n3), even up to 98%. Comparing all three tables, it also comes out that the greatest ω-3 fatty acids content can be found in the fat of breast muscles. This is followed by ω-3 fatty acids content in leg muscles, internal fat and subcutaneous fat. The data of the tables reveal that more ω-3 fatty acids were stored in internal fat and subcutaneous fat by the quail of the linseed group (7.29% and 5.97%), slightly less by the linseed cake group (6.96% and 5.12%). Compared to the birds from the control group, internal fat of quail from the linseed group contained 2.6 and fat in skin 2.4 times more ω-3 fatty acids. Corresponding figures in the linseed cake group were 2.5 and 2.0 times higher.

Table 2.6. Influence of linseed cake (10%) in the diet on the fatty acid composition of different tissues

Fatty acid	Breast muscles	Leg muscles	Skin	Inner fat
C14:0	0.76	0.78	0.72	0.77
C16:0	15.37	15.02	14.60	13.25
C16:1	3.28	3.59	4.03	3.50
C18:0	5.43	4.67	3.82	3.77
C18:1	33.27	36.92	42.52	38.21
C18:2n6	32.02	30.49	28.46	32.73
C18:3n3	6.90	6.62	5.06	6.92
C20:0	0.12	0.09	0.07	0.12
C20:1	0.57	0.53	0.58	0.66
C20:4n6	0.97	0.43	0.07	0.04
C20:5n3	0.32	0.18	0.03	0.03
C22:5n3	0.09	0.08	×	×
C22:6n3	0.90	0.60	0.03	0.01
∑ Saturated fatty acids	21.68	20.56	19.21	17.91
∑ Polyunsaturated fatty acids	37.12	41.04	47.13	42.37
∑ n6 polyunsaturated fatty acids	32.99	30.92	28.53	32.77
∑ n3 polyunsaturated fatty acids	8.21	7.48	5.12	6.96
n6/n3	4.02	4.13	5.57	4.71

Table 2.7. Fatty acid content of quail meat fed control diet

Fatty acid	Breast muscles	Leg muscles	Skin	Inner fat
C14:0	0.71	0.77	0.79	0.87
C16:0	15.55	14.37	14.81	14.88
C16:1	4.07	3.71	4.59	4.41
C18:0	4.78	3.30	4.16	4.35
C18:1	36.88	38.77	43.37	39.31
C18:2n6	32.15	34.57	29.04	32.59
C18:3n3	3.28	3.32	2.47	2.78
C20:0	0.07	0.10	0.10	0.08
C20:1	0.47	0.52	0.53	0.65
C20:4n6	1.01	0.18	0.08	0.05
C20:5n3	0.34	0.10	0.04	0.03
C22:5n3	0.03	0.03	×	×
C22:6n3	0.65	0.26	0.02	0.00
∑ Saturated fatty acids	21.11	18.54	19.86	20.18
∑ Polyunsaturated fatty acids	41.42	43.00	48.49	44.37
∑ n6 polyunsaturated fatty acids	33.16	34.75	29.12	32.64
∑ n3 polyunsaturated fatty acids	4.30	3.71	2.53	2.81
n6/n3	7.71	9.37	11.51	11.62

2.3.1.4. Summary of I trial

1. The body mass of quails raised on different rations did not differ significantly. On the basis of dressing percentage and proportion of breast muscle in carcass the linseed group's feeding type should be preferred.

2. On the basis of digestibility of nutrients in ration and chemical composition of meat the linseed group's feeding type should be preferred as well.

3. ω-3 fatty acids content in internal fat, subcutaneous fat and fat in breast and leg muscles was greatest also in case of linseed group's feeding type. The fat of different parts of body in this group contained ω-3 fatty acids in amounts (7–8% of total lipids) which are characteristic of the so-called health meat.

In summary, the trials conducted on Matjama quail farm of Järveotsa farmstead in September-October 2004 proved that feed containing 4% rapeseed oil (control group in the trial) is not sufficient for ensuring an increased ω-3 fatty acids content in quail meat (2.8% ω-3 fatty acids in internal fat). A 10% linseed cake additive to the ration (linseed cake group in the trial) enhanced the amount of ω-3 fatty acids in internal fat to 6.96%, an 8% linseed additive (the linseed group) to 7.29%.

Regarding the aforementioned results, the objectives planned for the II trial were as follows:

- to shorten the feeding period of additives rich in ω-3 fatty acids from 3 weeks to 2 weeks since 28. day of life;
- to diminish the amount of linseeds and increase the amount of linseed cake in trial groups. The analyses have so far indicated that 8% linseeds added 2,6% linseed oil to the ration as 10% linseed cake added only 1.3% linseed oil;
- to study the assimilation of ω-3 fatty acids from different feeds by 42-day-old quail broilers.

2.3.2. Enhancing ω-3 fatty acids content in quail meat and fat with local feeds rich in ω-3 fatty acids according to adjusted amounts and shorter feeding period based on the results of the previous trial (II trial)

Compared to the previous trial, the amount of linseed in the dietary rations of quail was diminished to 6% and the amount of linseed cake was raised to 12% and the feeding of trial diets was shortened to 2 weeks.

2.3.2.1. The anatomical-morphological composition of the meat and carcass of the trial quail

The anatomical-morphological composition of the body and carcass of quail broilers is presented in Table 2.8, indicating that no significant difference resides between the body mass of quail belonging to separate groups, with an exception of slightly bigger body mass regarding both male and female broilers of the linseed group. Also the quail of the linseed cake group exceeded the body mass of the control group nonsignificantly. The dressing percentage was highest in the linseed group as well. As regards the proportion of breast and leg muscle in carcass, the trial groups did not present significant differences, although, in a nutshell, the mean data about the birds from the linseed group were a bit better than those concerning the other trial groups.

Table 2.8. Influence of ω-3 rich feed sources on the anatomical-morphological composition of the body and carcass of quails (n=5)

Items	I diet 6% linseed		II diet 12% linseed cake		Control group	
	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂
Body mass g	256.80	226.80	242.80	227.60	241.60	219.20
Carcass mass g	170.60	155.00	152.80	150.80	159.60	149.00
Dressing %	66.44	68.41	63.00	66.22	66.19	67.98
Eatable offals in carcass:						
neck g	8.84	8.34	11.38	9.80	9.72	9.40
%	3.47	3.67	4.69	4.34	4.03	4.32
hearth g	2.46	2.15	2.22	2.18	2.36	2.04
%	0.95	0.93	0.92	0.96	0.98	0.93
liver g	7.10	4.86	7.06	6.32	5.72	4.92
%	2.76	2.15	2.89	2.77	2.37	2.23
gizzard g	5.00	3.53	3.82	4.90	4.12	2.98
%	1.94	1.54	1.56	2.14	1.70	1.37
Breast muscles g	49.60	46.40	42.00	45.60	46.80	44.00
from carcass %	29.11	29.86	27.48	30.20	29.34	29.44
Jalalihased g	33.60	30.80	28.80	30.00	31.60	29.60
from carcass %	19.70	19.88	18.85	19.95	19.78	19.88

2.3.2.2. Chemical composition of the breast and leg muscles of the trial birds

The chemical composition of the breast and leg muscles of the trial quail is presented in Table 2.9. On the basis of Table 2.9 it can be concluded that the mean chemical composition of breast muscles did not differ significantly group wise. However, a somewhat higher fat content in breast muscles could be observed in the linseed cake group. As well as this, the chemical analysis of leg muscles indicated a slightly higher crude fat and crude protein content in the leg muscles of the linseed cake group of quail.

Table 2.9. Influence of different oil source on the composition of quail muscles

Chemical composition	I diet 6% linseed		II diet 12% linseed cake		Control group	
	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂
Breast muscles:						
water %	74.5	74.8	74.0	74.5	74.3	74.6
crude protein %	22.2	22.4	22.0	22.0	22.0	22.1
crude ash %	1.22	1.23	1.23	1.24	1.26	1.25
crude ash %	2.8	2.7	3.7	2.9	2.7	2.5
Leg muscles:						
water %	77.3	75.7	75.5	75.6	76.2	76.0
crude protein %	18.6	18.9	19.5	19.5	19.5	19.9
crude ash %	1.01	1.05	1.08	1.10	1.07	1.16
crude ash %	3.1	4.3	3.9	4.2	3.5	3.3

2.3.2.3. Fatty acid composition of the breast muscles, skin and internal fat of the trial quail

The fatty acid composition of breast muscles, skin and internal fat of the trial quail has been presented trial group wise in Tables 2.10, 2.11 and 2.12. The tables indicate the greatest ω-3 fatty acids content in the total lipids of the breast muscles, skin and internal fat of the quail from the linseed group: 11.27 % of total lipids of breast muscles, 12.36% of total lipids of skin and 13.63% of total lipids of internal fat. In the linseed cake group, the aforegiven figures were 9.12%, 9.34% and 8.95% and in the control group 4.95%, 3.88% and 3.53%, respectively. Consequently, the aforegiven figures of the linseed group exceed the corresponding figures of the control group by 2.3, 3.2 and 3.9 times. In the linseed cake group, these figures were, compared to those of the control group, 1.8, 2.4 and 2.5 times higher. In the calculations, mean data of the female and male quail have been used as gender and group wise they did not differ significantly.

Table 2.10. The fatty acid composition of breast muscles, skin and internal fat of the quails fed 6% linseed

Fatty acid	Breast muscles		Skin		Internal fat	
	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂
C14:0	0.55	0.56	0.96	0.97	0.84	0.87
C15:0	0.09	0.12	0.15	0.14	0.12	0.13
C16:0	20.22	19.76	18.06	17.82	18.88	18.37
C16:1	2.93	2.46	3.41	3.07	3.68	2.59
C17:0	0.14	0.13	0.22	0.21	0.17	0.16
C17:1	0.07	0.28	0.06	0.06	0.05	0.03
C18:0	10.35	11.43	6.04	6.32	5.42	6.58
C18:1	25.41	23.73	35.04	34.33	36.15	35.13
C18:2n6	19.70	20.05	22.39	23.49	19.90	21.67
C18:3n3	7.63	7.03	11.56	11.50	12.87	12.74
C20:0	0.08	0.05	0.09	0.07	0.06	0.07
C20:1	0.32	0.57	0.91	1.10	0.78	0.86
C20:4n6	3.17	3.55	0.21	0.18	0.16	0.12
C20:5n3	2.32	2.54	0.31	0.21	0.30	0.21
C22:5n3	0.91	0.83	0.18	0.18	0.20	0.16
C22:6n3	0.61	0.69	0.42	0.35	0.45	0.34
∑ Saturated fatty acids	31.43	32.05	25.51	25.53	25.48	26.16
∑ Monounsaturated fatty acids	28.73	27.04	39.42	38.56	40.65	38.61
∑ n6 polyunsaturated fatty acids	22.87	23.60	22.60	23.67	20.06	21.79
∑ n3 polyunsaturated fatty acids	11.47	11.07	12.47	12.24	13.82	13.44
n6/n3	2.0	2.1	1.87	1.97	1.51	1.70

Table 2.11. The fatty acid composition of breast muscles, skin and internal fat of the quails fed 12% linseed cake

Fatty acid	Breast muscles		Skin		Internal fat	
	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂
C14:0	0.50	0.68	1.02	1.05	0.88	0.93
C15:0	0.11	0.09	0.16	0.13	0.09	0.11
C16:0	19.53	20.48	17.87	18.91	20.84	20.58
C16:1	3.84	3.65	4.44	4.80	5.33	4.36
C17:0	0.08	0.18	0.15	0.18	0.12	0.13
C17:1	0.17	0.18	0.05	0.06	0.04	0.03
C18:0	8.89	9.01	5.51	5.40	5.13	5.43
C18:1	29.88	29.81	37.37	37.97	40.40	38.25
C18:2n6	20.55	19.59	22.33	20.98	18.12	19.28
C18:3n3	6.24	6.38	8.86	8.38	7.42	9.24
C20:0	0.10	0.10	0.10	0.10	0.06	0.06
C20:1	0.79	0.63	1.24	1.17	0.83	0.87
C20:4n6	2.71	2.55	0.17	0.16	0.10	0.11
C20:5n3	1.77	1.90	0.23	0.24	0.20	0.23
C22:5n3	0.61	0.48	0.13	0.12	0.09	0.10
C22:6n3	0.42	0.43	0.36	0.35	0.34	0.30
∑ Saturated fatty acids	29.21	30.54	24.81	25.77	27.13	27.24
∑ Monounsaturated fatty acids	34.68	34.27	43.10	44.00	46.60	43.51
∑ n6 polyunsaturated fatty acids	23.26	22.14	22.50	21.14	18.22	19.38
∑ n3 polyunsaturated fatty acids	9.04	9.19	9.59	9.09	8.05	9.87
n6/n3	2.6	2.4	2.36	2.53	2.71	2.11

Summing up, the present trial on the fatty acid analysis of total lipids of different body tissues proved the following.

The lipids of the breast muscles contained up to 11.47% of ω-3 fatty acids in the trial groups. Whereas more than half of the amount of ω-3 fatty acids was made up of α-linolenic acid (C18:3n3).

Of the total lipids of internal fat and skin, ω-3 fatty acids content turned out to be higher than expected – 8.95% in internal fat as mean of genders in the linseed group, 12.36% of total lipids in skin in the linseed group and 9.34% in the linseed cake group.

Table 2.12. The fatty acid composition of breast muscles, skin and internal fat of the quails fed control diet

Fatty acid	Breast muscles		Skin		Internal fat	
	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂
C14:0	0.61	0.57	1.12	1.14	0.98	1.04
C15:0	0.08	0.08	0.15	0.13	0.10	0.10
C16:0	21.17	22.81	21.66	22.75	21.71	23.79
C16:1	4.95	3.96	6.35	5.72	6.03	5.87
C17:0	0.12	0.17	0.18	0.13	0.16	0.14
C17:1	0.23	0.07	0.10	0.07	0.06	0.05
C18:0	9.03	10.07	5.62	5.92	4.67	5.59
C18:1	31.90	28.90	41.05	40.68	43.96	42.50
C18:2n6	18.12	17.73	18.46	18.27	17.31	16.59
C18:3n3	2.12	1.73	3.20	2.90	2.88	2.56
C20:0	0.09	0.10	0.07	0.10	0.05	0.06
C20:1	0.62	0.57	1.07	1.19	0.96	0.98
C20:4n6	2.97	3.68	0.18	0.17	0.15	0.10
C20:5n3	1.62	1.97	0.21	0.20	0.28	0.18
C22:5n3	0.53	0.65	0.12	0.19	0.13	0.12
C22:6n3	0.58	0.69	0.48	0.44	0.55	0.35
∑ Saturated fatty acids	31.10	33.80	28.78	30.16	27.67	30.71
∑ Monounsaturated fatty acids	37.70	33.50	48.57	47.66	51.01	49.40
∑ n6 polyunsaturated fatty acids	21.09	21.41	18.64	18.44	17.46	16.68
∑ n3 polyunsaturated fatty acids	4.85	5.04	4.01	3.74	3.85	3.20
n6/n3	4.3	4.2	4.65	4.99	4.59	5.30

Owing to the use of adjusted rations based on the digestibility of nutrients and the chemical composition of different tissues of carcass, a high level of ω-3 fatty acids was obtained in the total lipids of the breast muscles, skin and internal fat of the trial quail. Both in the linseed group and the linseed cake group the proportion of ω-3 fatty acids of total lipids made up 9.0%–13.6%. These figures exceed considerably the intended 7%–8% and on consuming 100 g of such quail meat (contains an average 5% of fat) ensures humans with 0.6–0.8 g ω-3 fatty acids. This amount corresponds to 75%–100% of the daily dosis of ω-3 fatty acids necessary for an adult.

2.3.3. Summary

For the enhancement of ω-3 fatty acids content in quail meat and quail fat with the help of local feeds rich in ω-3 fatty acids, two trials were carried out on Matjama quail farm of Järveotsa farmstead in September-October 2004.

In the first experiment the trial group quail broilers (from 21. to 42. day of life) were fed 8% linseeds or 10% linseed cake in the basal ration. The best results appeared in using the ration which contained 8% linseeds.

Based on the results of the first trial, the amounts of diets rich in ω-3 fatty acids were adjusted in the second trial: now 6% linseeds and 12% linseed cake were included in the rations of different trial groups. These rations were used during the last two feeding weeks of the quail.

In the second trial, feeding the quail rations which had been adjusted according to the digestibility of nutrients, a wholly satisfactory ω-3 fatty acids content (8.1%–13.8%) in total lipids of different tissues of quail carcasses was achieved. Rations containing either 6% linseeds or 12% linseed cake during the two weeks prior to killing can be recommended for the production of the so-called health quail meat enriched with ω-3 fatty acids.

3. The enrichment of rabbit meat with ω-3 fatty acids

Investigations into the feeding of rabbits during the last 30 years can be summed up (until the year 2003) by tables compiled by F. Lebas (2003) on feeding experiments with rabbits. There are only four researches which tackle the use of linseeds and linseed cake. In case of feeding angora rabbits, 60% of the protein of peanut cake was successfully substituted with linseed meal (Singh, Negi, 1987); linseed meal did not suit for substituting 11 % of soya meal in the rabbit growth ration (Gippert, 1980); feeding 8% linseeds did not cause significant quality deterioration in rabbit meat (Cavani *et al*., 2003); linseed cake can be successfully used in rabbit growth rations (Johnston, Berrio, 1984). No data were available in the above mentioned article on feeding trial rabbits with linseed oil.

Rabbit meat is low in fat. With regard to cholesterol level (164 mg/100 g), as nutient it is significantly more preferred to hen broiler meat (220 mg/100 g) or beef (230 mg/100 g). On the other hand, it has been pointed out that rabbit meat contains many unsaturated and polyunsaturated fatty acids, the origin of which is not

always endogenous (Ouhayoun *et al*., 1987) but a result of feeding. In professional literature statements can be found that on blending rabbit ration with linseed oil or soya oil, rabbit meat will acquire an unpleasant taste and smell as the above oils contain abundantly polyunsaturated fatty acids, especially linoleic acid which gets ranced rapidly. But if the fat additive is cocoa fat (rich in stearic acid), the rabbit meat produced will have high organoleptic qualities (Ouhayoun *et al*., 1987).

At the end of the previous century, a campaign was launched to enhance the proportion of ω-3 fatty acids in nutrients and lower at the same time ω-6/ω-3-fatty acid ratio in food, preferably 5:1–6:1 (British…, 1993). ω-6/ω-3-fatty acid ratio in the lipids of rabbits' leg meat is 11:1, in the lipids of rabbits' internal fat 8.5:1 (Ramirez *et al*., in press). For this reason, alteration of the ratio would be interesting from the point of view of human consumption.

There is little trial material available on attempts to influence with the help of ω-3 fatty acids in feeds the content of polyunsaturated fatty acids in rabbit meat and the ω-6/ω-3-fatty acid ratio: the effect of feeding ω-3 fatty acids on the ω-3 fatty acids content of doe milk and the body tissues of the young was positive (Castellini *et al*., 2003); with fish oil and several other feed additives containing linolenic acid a rise was achieved in the content of polysaturated fatty acids in rabbit meat (Bernardini *et al*., 1999; Dal Bosco *et al.*, 2004; Tassinari *et al.*, 2001). There is no reference in the sources to the use of linseed oil for increasing ω-3 fatty acids content in the lipids of rabbits' body tissues.

The ability of agricultural animals to assimilate ω-3 fatty acids from feeds rich in ω-3 fatty acids is considered to be low. It has also been found out that the higher the ω-3/ω-6 ratio in an animal's lipids is, the lower is its conversion of ω-3 fatty acids into lipids (Huang *et al*., 1990).

The above viewpoints need experimental control which will follow hereinafter based on feeding tests with linseed oil to young rabbits.

3.1. Methods of trials

There is very little material available in professional literature on the fatty acid composition of rabbit meat and rabbit fat. So far data was missing on the enrichment of rabbit meat with ω-3 fatty acids. The following two trials have been established in order to enrich rabbit meat and rabbit fat with ω-3 fatty acids.

The first (I) trial was established to solve the following questions:

1) are young rabbits capable of converting linseed oil into polyunsaturated fatty acids, including ω-3 fatty acids into the lipids of muscles and internal fat?
2) does the daily ration of linseed oil fed to young rabbits (3.7 g) and the duration of feeding linseed oil (30 days) guarantee the preliminary planned results (doubling of ω-3 fatty acids content in lipids)?
3) do young does and bucks convert ω-3 fatty acids from linseed oil differently?

Trial I (September 24, 2004–October 24, 2004) involved two litters of French Lop rabbits. The trial group was formed of 3 young bucks and 3 young does, the animals of the control group were analogous to those of the trial group. The young rabbits were 4 months old at the beginning of the trial. Young bucks and does were kept in separate cages.

The trial animals were fed as follows. The young rabbits of the control group received daily 100 g mixed concentrated rabbit feed, 80 g barley (in grain) and good hay on an *ad libitum* basis. Mixed concentrated rabbit feed contained 11.6 MJ/kg metabolizable energy and 16% crude protein. The trial group rabbits were fed with 3.7 g linseed oil added to their daily dosis of mixed concentrated feed, *i.e.* 3.7 g per trial group animal per day. At the end of the 30-day-long trial period all the rabbits involved in the trial were killed, their carcass mass, dressing percentage and fatty acid composition in meat and internal fat were determined.

The task of the II trial was to find out:

1) if the duration of feeding linseed oil can be shortened;
2) if it is possible to diminish the daily dosis of linseed oil fed to young rabbits during the 30 trial days.

The trial (November 13, 2005 – December 14, 2005) involved 3 groups each consisting of 5 female crosses of Californian and Silver Rabbits who were 4 months old at the beginning of the trial. The daily basal ration of the young rabbits was as follows: 50 g mixed concentrated feed, 50 g barly grains and hay which was liberally provided. The animals of the I trial group received in addition to basal ration 4 g linseed oil a day during 14 days. The animals of the II group received 2 g linseed oil a day during 30 days. The III group – the control group – was kept on basal ration. The trials were established on the rabbit farm of Andressaare farmstead in Kõo parish, Viljandi county.

At the end of the trial the young rabbits were killed, their carcass mass, dressing percentage and fatty acid composition in meat and internal fat were determined. The fatty acid content in meat lipids and internal fat was determined by S. Kuusik from the Laboratory of Ecochemistry at Estonian University of Life Sciences.

3.2. Results of trials

The growth, carcass mass and dressing percentage of young rabbits in trial I is characterized by Table 3.1 which indicates that body masses of young rabbits as well as carcass masses and dressing percentages both in the trial and the control group did not differ significantly (P>0.05).

Table 3.1. The growth, carcass mass and the dressing % of young rabbits in 1st trial

Sex	Body mass at the beginning kg	Body mass at the end kg	Carcass mass kg	Dressing %
		Trial group		
♂♂	3.40	3.50	1.80	51.4
	3.50	3.70	2.00	54.1
	3.80	3.90	2.00	51.3
Average	3.30	3.70	1.93	52.3
♀♀	3.70	3.80	2.00	52.6
	3.50	4.00	2.10	52.5
	3.60	4.00	2.07	51.8
Average	3.60	3.90	2.06	52.3
		Control group		
♂♂	3.20	3.50	1.60	45.7
	3.50	3.70	1.90	51.3
	3.60	3.90	2.00	51.3
Average	3.40	3.70	1.83	49.4
♀♀	3.60	4.10	2.03	49.5
	3.70	4.00	1.80	45.0
	3.60	4.00	1.90	47.5
Average	3.60	4.00	1.92	47.3

The greatest arithmetic difference was found between the dressing percentages of the trial and the control group. Here the dressing percentages of does and bucks from the trial group exceeded considerably the corresponding figures of the control group rabbits.

Based on the data of Table 3.1, it can be said that feeding linseed oil to young does and bucks did not have a negative effect on their growth and dressing percentage.

The fatty acid composition of lipids and internal fat in the meat of trial rabbits is presented in Table 3.2.

Analysing Table 3.2, the following could be brought out.

1. Feeding 3.7 g linseed oil daily in the course of 30 days per trial rabbit increased the amount of ω-3 fatty acids in the muscular tissue lipids of bucks from 4.49% to 7.72%, *i.e.* by 1.72 times. In case of does, from 3.86% to 7.83%, *i.e.* by 2.03 times, respectively.

In internal fat of bucks, the ω-3 fatty acids content increased from 3.76% to 8.82%, *i.e.* by 2.35 times. In case of does, from 3.74% to 9.53%, *i.e.* by 2.55 times.

2. Does increased (in absolute value the trial group figure minus the control group figure) ω-3 fatty acids content into the lipids of muscular tissue 3.7%, bucks 3.23%. As regards internal fat, the figures were 5.79% and 5.06%, respectively. Thus does have a somewhat better capacity of converting ω-3 fatty acids into meat lipids and internal fat than bucks.

3. A substantially greater amount of ω-3 fatty acids is being converted into internal fat than into meat lipids.

4. An overwhelming part of ω-3 fatty acids in meat lipids and internal fat was taken up by α-linolenic acid (C18:3n3), 4.29% in meat lipids, 8.65% in internal fat of bucks of the trial group. In case of trial group does, 6.33% and 9.32%, respectively.

5. Eicosapentaenoic acid (C20:5n3), docosapentaenoic acid (C22:5n3) and docosahexaenoic acid (C22:6n3) accounted for the total of 44.3% of the sum of ω-3 fatty acids in the meat lipids of the trial group bucks, for 1.9% in internal fat, for 19.2% in the meat lipids of does and for 2.1% in internal fat. Consequently, few polyunsaturated long-chained fatty acids (LC PUFA) can be found in internal fat.

6. ω-3/ω-6 fatty acid ratio improved considerably in the meat lipids and internal fat of the trial rabbits who had been fed linseed oil. In case of bucks the ratio in meat lipids diminished from 6.37 to 3.52, in case of does from 8.07 to 3.09 respectively. In internal fat of bucks the aforementioned ratio diminished from 6.23 to 2.14, in does from 6.21 to 2.22, respectively.

7. Based on Table 3.2, 100 g rabbit meat fed on linseed oil (fat content 5.1%) and 100 g internal fat contains ω-3 fatty acids as follows: in bucks 0.4 g and 8.8 g respectively, in does 0.4 g and 9.5 g. Thus a rather considerable amount of ω-3 fatty acids can be found in internal fat. Consequently, on the basis of calculations, the daily need for ω-3 fatty acids (0.8 g) of a grown-up human will be covered by 200 g rabbit meat enriched with ω-3 fatty acids or 10 g internal rabbit fat.

Table 3.2. The fatty acid composition of meat lipids and internal fat of trial rabbits

Fatty acid	Trial group				Control group			
	meat lipids		internal fat		meat lipids		internal fat	
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
10:0	0.07	0	0.37	0.15	0.01	0.10	0.11	0.06
12:0	0.09	0.04	0.26	0.17	0.04	0.07	0.16	0.14
14:0	2.11	2.66	2.93	3.46	2.25	2.03	2.95	3.87
15:0	0.40	0.44	0.32	0.44	0.53	0.40	0.58	0.57
16:0	28.88	28.54	28.95	27.40	31.21	30.20	33.58	33.70
16:1	2.19	3.49	2.62	2.93	1.72	1.70	1.92	2.32
17:0	0.40	0.46	0.58	0.56	0.59	0.42	0.75	0.54
17:1	0.36	0.27	0.23	0.24	0.38	0.23	0.23	0.27
18:0	6.95	6.76	9.53	8.39	7.03	8.10	7.66	7.31
18:1	22.91	24.96	25.80	25.05	22.48	21.12	24.11	23.64
18:2n6	19.95	19.64	18.53	20.69	22.31	22.65	22.90	22.81
18:3n3	4.29	6.33	8.65	9.32	2.57	2.08	3.59	3.62
20:0	0.13	0.04	0.11	0.12	0.11	0.05	0.16	0.10
20:1	0.22	0.26	0.45	0.38	0.39	0.43	0.49	0.40
20:2n6	0.21	0.08	0.12	0.11	0.21	0.19	0.11	0.10
20:4n6	5.65	3.59	0.18	0.21	4.71	6.50	0.18	0.21
20:5n3	0.44	0.28	0.02	0.05	0.36	0.34	0.04	0.02
22:1	0.39	0.10	0.12	0.04	0.15	0.14	0.14	0.07
22:4n6	0.97	0.50	0.06	0.11	1.01	1.20	0.17	0.08
22:5n6	0.40	0.34	0.02	0.03	0.39	0.63	0.04	0.03
22:5n3	2.41	1.03	0.13	0.14	1.30	1.16	0.11	0.09
22:6n3	0.57	0.19	0.02	0.01	0.26	0.29	0.03	0.02
Saturated fatty acids	39.03	38.95	43.05	40.69	41.77	41.36	45.95	46.30
Monounsaturated fatty acids	26.07	29.08	29.22	28.64	25.12	23.61	26.88	26.71
n6 polyunsaturated fatty acids	27.18	24.15	18.91	21.16	28.63	31.17	23.40	23.24
n3 polyunsaturated fatty acids	7.72	7.83	8.82	9.53	4.49	3.86	3.76	3.74
n6/n3	3.52	3.09	2.14	2.22	6.37	8.07	6.23	6.21
n6 long chain polyunsaturated fatty acids	7.23	4.51	0.38	0.47	6.31	8.52	0.51	0.43
n3 long chain polyunsaturated fatty acids	3.42	1.49	0.17	0.21	1.92	1.79	0.17	0.12

In trial II the data of Table 3.3 characterize the growth, carcass mass and dressing percentage of young rabbits. As regards all three aforegiven figures regarding the rabbits of the trial groups and the control group, no statistically significant differences were found ($P>0.05$), although, like in trial I, the dressing percentages of rabbits who had been fed linseed oil were slightly higher.

Table 3.3. The growth, carcass mass and dressing % of young rabbits in the 2nd trial

Trial group	Body mass at the beginning kg	Body mass at the end kg	Carcass mass kg	Dressing %
I	3.30	3.45	1.81	52.4
	3.25	3.36	1.72	51.2
	3.50	3.54	1.88	53.0
	3.61	3.78	1.91	50.4
	3.42	3.41	1.76	51.6
Average	3.42	3.51	1.82	51.7
II	3.66	3.85	2.06	53.4
	3.00	3.20	1.68	52.5
	3.41	3.65	1.89	51.9
	3.49	3.71	1.89	51.0
	3.69	3.93	2.09	53.1
Average	3.45	3.67	1.92	52.5
III control	3.30	3.54	1.80	50.8
	3.20	3.29	1.70	51.7
	3.59	3.72	1.94	52.1
	3.37	3.45	1.76	50.9
	3.50	3.70	1.97	52.0
Average	3.39	3.54	1.82	51.5

The fatty acids content in the meat lipids of young rabbits is presented in Tables 3.4 and 3.5. The above tables indicate the following.

1. The amount of unsaturated fatty acids in the lipids of rabbit meat decreased both in the event of longer (II group) and shorter (I group) feeding duration. Of meat lipids the percentage of unsaturated fatty acids made up 41.39% and 46.99%, respectively. The corresponding figure in the meat lipids of the control group rabbits was 47.03%. The fatty acid analysis of internal fat showed a similar tendency.

2. In case of monounsaturated fatty acids the above regularity could not be found.

3. There were fewer ω-6 fatty acids in the meat lipids of the rabbits: 15.32 in group I, 16.2 in group II and 17.97% in the control group, respectively. On the analysis of internal fat the linear dependence among trial groups and control group given above could not be found.

4. The content of the most essential fatty acids, ω-3 fatty acids, in the meat lipids of rabbits was 11.5% as a result of feeding them with linseed oil for a longer period (II group); as a result of feeding them for a shorter period (I group), the percentage was 8.4. In the control group the figure was 4.81%. Due to feeding linseed oil, the ω-3 fatty acids content in the lipids of rabbit meat increased in the I group by 1.75 times and in the II group by 2.4 times. The amounts of ω-3 fatty acids in internal fat of rabbits of the I group were 10.65%, 16.40% of the II group and 4.85% of the control group. Thus, ω-3 fatty acids content had increased in comparisom with the control group by 2.2 and 3.4 times or significantly more than in the meat lipids.

5. The ratio of ω-6-fatty acids and ω-3 fatty acids in the meat lipids of the control group rabbits was at a very good level, ω-6:ω-3 = 3.75. The ratio was even better in the trial groups: 1.89 in group I and 1.44 in group II. In internal fat the figure was 3.09 in the control group, 1.50 in group I and 0.94 in trial group II.

6. There were fewer long-chained polyunsaturated ω-6 fatty acids (20:2n6, 20:4n6; 22:5n6) in the meat lipids of the trial group rabbits, 2.20% in group I, 2.71% in group II than in the meat lipids of the control group rabbits – 3.70%.

On the analysis of internal fat the given figures were very small and did not differ significantly group wise.

Table 3.4. The fatty acid composition of meat lipids of young rabbits (%)

Fatty acid	I trial goup		II trial group		III control group	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
10:0	0.02	0.02	0.04	0.04	0.12	0.03
12:0	0.06	0.02	0.06	0.01	0.10	0.02
14:0	3.68	0.50	2.98	0.24	3.48	0.24
15:0	0.65	0.06	0.47	0.04	0.79	0.07
16:0	34.23	1.48	30.10	2.15	34.62	1.10
16:1	4.53	0.85	4.87	0.97	4.65	1.20
17:0	0.72	0.06	0.55	0.09	0.87	0.08
17:1	0.51	0.08	0.37	0.04	0.70	0.28
18:0	7.51	0.74	7.11	1.13	6.95	0.53
18:1	23.90	1.69	25.37	1.67	24.35	1.08
18:2n6	13.11	1.23	13.31	1.02	14.26	0.90
18:3n3	7.32	2.27	10.05	2.77	3.19	0.41
20:0	0.11	0.01	0.08	0.02	0.10	0.03
20:1	0.21	0.02	0.23	0.04	0.22	0.04
20:2n6	0.08	0.02	0.11	0.02	0.10	0.02
20:4n6	1.86	0.68	2.25	0.94	3.11	0.56
20:5n3	0.16	0.06	0.18	0.07	0.19	0.04
22:1	0.13	0.03	0.18	0.05	0.21	0.06
22:4n6	0.15	0.04	0.19	0.08	0.33	0.07
22:5n6	0.11	0.04	0.17	0.05	0.17	0.05
22:5n3	0.79	0.30	1.08	0.49	1.21	0.25
22:6n3	0.15	0.06	0.25	0.12	0.21	0.06
Saturated fatty acids	46.99	2.38	41.39	2.99	47.03	1.31
Monounsaturated fatty acids	29.28	2.38	31.03	2.53	30.13	1.89
n6 polyunsaturated fatty acids	15.32	1.61	16.02	1.28	17.97	1.10
n3 polyunsaturated fatty acids	8.42	2.25	11.55	2.41	4.81	0.28
n6/n3	1.89	0.34	1.44	0.31	3.75	0.42
n6 long chain polyunsaturated fatty acids	2.20	0.76	2.71	1.06	3.70	0.67
n3 long chain polyunsaturated fatty acids	1.10	0.39	1.50	0.67	1.61	0.29

7. There were fewer long-chained polyunsaturated ω-3 fatty acids (20:5n3; 22:5n3; 22:6n3) in the meat lipids of the trial group rabbits, 1.10% in group I and 1.50% in group II than in the meat lipids of the control group rabbits – 1.61%.

The same tendency could be observed in the analysis of internal fat with figures 0.17%, 0.14% and 0.22%, respectively.

8. Feeding linseed oil diminished the content of linoleic acid (18:2n6), arachidonic acid (20:4n6) and docosatetraenoic acid, containing ω-6 fatty acids, in the meat lipids. On the analysis of internal fat such a tendency could not be observed, in case of linoleic acid the analysis gave opposite results.

9. Feeding the same amount of linseed oil during 30 days turned out to be considerably more effective than during 14 days.

10. Based on the data of Tables 3.4 and 3.5, 100 g doe meat which has been fed with linseed oil for 30 days (fat content 5.1%) and 100 g internal fat contains ω-3 fatty acids as follows: 0.6 g in 100 g meat and 16.4 g in 100 g fat. Thus, based on the trial data, a human's daily need for ω-3 fatty acids will be covered by 150 g rabbit meat or 20 g internal fat enriched with ω-3 fatty acids.

Table 3.5. The fatty acid composition of inner fat of young rabbits (%)

Rasvhape	I trial group		II trial group		Control group	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
10:0	0.01	0.01	0.04	0.01	0.03	0.03
12:0	0.08	0.02	0.08	0.01	0.11	0.03
14:0	4.13	0.44	3.50	0.25	4.41	0.37
15:0	0.76	0.08	0.58	0.04	0.93	0.06
16:0	34.14	2.82	30.58	2.35	36.71	2.15
16:1	3.68	0.68	3.63	0.43	3.90	0.30
17:0	0.77	0.06	0.61	0.02	0.95	0.04
17:1	0.39	0.06	0.34	0.08	0.50	0.04
18:0	6.52	0.66	5.35	0.56	6.20	1.08
18:1	23.53	1.81	23.09	1.57	25.94	1.77
18:2n6	14.59	0.97	15.04	1.03	14.65	1.22
18:3n3	10.48	3.71	16.27	2.73	4.63	0.27
20:0	0.12	0.01	0.08	0.01	0.13	0.02
20:1	0.26	0.03	0.26	0.03	0.29	0.08
20:2n6	0.09	0.01	0.12	0.02	0.09	0.02
20:4n6	0.10	0.02	0.09	0.03	0.10	0.03
20:5n3	0.03	0.01	0.05	0.03	0.04	0.00
22:1	0.12	0.02	0.22	0.05	0.13	0.01
22:4n6	0.05	0.02	0.00	0.00	0.06	0.01
22:5n6	0.03	0.04	0.00	0.00	0.02	0.01
22:5n3	0.13	0.01	0.09	0.05	0.17	0.01
22:6n3	0.01	0.01	0.00	0.00	0.01	0.01
Saturated fatty acids	46.53	3.58	40.81	2.98	49.47	2.67
Monounsaturated fatty acids	27.98	2.43	27.53	2.05	30.76	1.70
n6 polyunsaturated fatty acids	14.86	0.96	15.25	1.03	14.91	1.23
n3 polyunsaturated fatty acids	10.65	3.71	16.40	2.74	4.85	0.27
n6/n3	1.50	0.39	0.94	0.11	3.09	0.43
n6 long chain polyunsaturated fatty acids	0.26	0.07	0.21	0.04	0.26	0.03
n3 long chain polyunsaturated fatty acids	0.17	0.01	0.14	0.07	0.22	0.01

3.3. Trial conclusions

From linseed oil fed to young rabbits in order to enrich their meat and internal fat with ω-3 fatty acids in two trials, the trial animals assimilated ω-3 fatty acids very successfully, by 70%. Young bucks and does converted ω-3 fatty acids from linseed oil to almost the same degree.

As far as saturated fatty acids are concerned, feeding linseed oil decreased their content in meat lipids and internal fat proportionally with the duration of feeding linseed oil.

In enriching rabbit meat and internal fat, better results were obtained by feeding 2 g linseed oil per day to young rabbits in the course of one month. 100 g of the meat of a rabbit who had been fed in this manner contained 0.4 g and 100 g of internal fat contained 16.4 g ω-3 fatty acids which make up 0.5% and 20.5%, respectively of the daily need of a grown-up human for ω-3 fatty acids.

References

Arnouts, S. 2005. How can poultry products enrich our diet with DHA, a "semi-essential" fatty acid? Book of Abstracts. – XVIIth European Symposium on the Quality of Poultry Meat. XIth European Symposium on the Quality of Eggs and Egg Products. Doorwerth, The Netherlands, 285 pp.

Bernardini, M., Dal Bosco, A., Castellini, C. 1999. Effect of dietary n-3/n-6 ratio on fatty acid composition of liver, meat and perirenal fat in rabbit. – Anim. Sci. 68, p. 647–654.

British Nutrition Foundation. 1993. Unsaturated fatty acids: nutritional and physiological significance. – Report of the British Nutrition Foundation's Task Force.

Burr, M. L., Fehily, A. M., Gilbert, J. F. 1989. Effects of changes in fat, fish and fibre intakes on death and myocardial reinfarction: diet and reinfarction trial (DART). – Lancet, 2, p. 757–761.

Castellini, C., Dal Bosco, A., Cardinali, R., Mugnai, C., Sciascia, E. 2003. Effect of dietary n-3 fatty acids on the composition of doe's milk and tissues of suckling rabbits. – Proceedings of the 8th World Rabbit Congress. 4. Feeding and nutrition, p. 771–777.

Cavani, C., Betti, M., Bianchi, M., Petracci, M. 2003. Effects of the dietary inclusion of vegetable fat and dehydrated alfalfa meal on the technological properties of rabbit meat. – Veterinary Research Communications 27, p. 643–646.

Cave, V. T. 1991. Dietary n-3 polyunsaturated fatty acid effects on animal tumorigenesis. – FASEB Journal, 5, p. 2160–2168.

Connor, W. E, Kritchevsky, D., Carroll, K. K. 1994. Nutrition and disease update. – Heart disease, 1, p. 137.

Dal Bosco, A., Castellini, C., Bianchi, L., Mugnai, C. 2004. Effect of dietary α-linolenic acid and vitamin E on the fatty acid composition, storage stability and sensory traits of rabbit meat. – Meat Sci., 66, p. 407–413.

Decker, E. A., Cantor, A. H. 1992. Fatty acids in poultry and egg products. – Fatty Acid in Foods and Their Health Implications. New York: Marcel Dekker, p. 137–167.

Farrell, D. J. 1997. The importance of eggs in a healthy diet. – Poultry International, September, p. 72–78.

Ferretti, A., Juddi, J. T., Ballad-Barbash, R., Nair, P. P., Taylor, P. R., Clevidence, B. A. 1991. Effect of fish oil supplementation on the excretion of the major metabolite of prostaglandin E in healthy male subjects. – Lipids, 26, p. 500–504.

Folch, J., Lees, M., Stanley, G. 1957. A simple method for isolation and purification of total lipids from animal tissues. – Journal of Biochemical Chemistry, 226, p. 497–509.

Gippert, T. 1980. Utilization of different protein sources in rabbit feeding. – 2nd World Rabbit Congress, Barcelona, 2, p. 193–203.

Huang, Z. B., Leibovitz, J., Lee, C. M., Millar, R. 1990. Effect of dietary fish oil on omega-3 fatty acid levels in chicken eggs and thigh flesh. – J. Agric. Food. Chem., 38, p. 743–748.

Hämmal, J. 2004. Võimalusi linnukasvatussaaduste rikastamiseks ω-3-rasvhapetega ning nende mõju inimese tervisele. – Doktoriväitekiri. Tartu, 143 lk.

Хяммал Я., Тикк Х., Тикк В. 1999. Увеличение количества -жирных кислот в яйцах и мясе перепелов. – Тезисы докладов конференции по птицеводству. Зеленоград, с. 84–85.

Hämmal, J., Tikk, V. 1999. ω-3 ja ω-6-rasvhapped, nende sisaldus söötades, linnukasvatussaadustes ja mõju inimese tervisele (kirjanduse ülevaade). – Agraarteadus, 2, lk 89–122.

Hämmal, J., Tikk, V., Tikk, H., Kuusik, S. 2000. On affecting the fatty acid composition of the chicken broiler's fat. – Eight Baltic Poultry Conference in Finland. – Turku, p. 22–24.

Hämmal, J., Tikk, V., Tikk, H., Viigimaa, M., Kuusik, S. 2001. ω-3-rasvhapete sisalduse suurendamisest linnukasvatussaadustes. – Agraarteadus nr 1, lk 14–30.

Johnston, N. P., Berrio, L. F. 1984. Comperative effects of cottonseed, soybeans, sunflower seeds and flax seeds on the performance of rabbits and Guinea pigs. – 3rd World Rabbit Congress, Rome 1, p. 408–414.

Lebas, F. 2003. Reflections on rabbit nutrition with a special emphasis on feed ingredients utilization. – Proceedings of the 8th World Rabbit Congress. 4. Feeding and nutrition, p. 686–736.

Leskanich, C. O., Noble, R. C. 1997. Manipulation of the n-3 polyunsaturated fatty acid composition of avian eggs and meat. – World's Poultry Science Journal, vol. 53, No. 6, p. 155–183.

Ouhayoun, J., Kopp, J., Bonnet, M., Demarne, Y., Delmas, D. 1987. Influence de la composition des graisses alimentaries sur les propiétés des lipides périrénaux et la qualité de la viande de eapin. – Sciences des Aliments, 7, p. 521–534.

Ramirez, J. A., Diaz, I., Pla, M., Gie, M., Blasco, A., Oliver, M. A. (in press). Fatty acid composition of leg meat and perirenal fat of rabbits selected by growth rate. – Food Chemistry.

Salem, N. Jr. 1989. Omega-3 fatty acids: molecular and biochemical aspects. – New Protective Role of Selected Nutrients, 109 pp.

Sardesai, V. M., Detroit, M. I. 1992. Nutritional role of polyunsaturated fatty acids. – Journal of Nutrional Biochemistry, No. 3, p. 154–166.

Siguel, E. A. 1996. New relationship between total/high density lipoprotein cholesterol and polyunsaturated fatty acids. – Lipids, 31, Suppl. S, p. 51–56.

Simopoulos, A. P. 1991. Omega-3 fatty acids in health and disease and in growth and development. – American Journal of Clinical Nutrition, 54, p. 438–463.

Simopoulos, A. P., Salem N. 1992. Egg yolk as a source of long-chain polyunsaturated fatty acids in infant feeding. – Animal Journal of Clinical Nutrition, 55, p. 411–414.

Singh, B., Negi, S. S. 1987. Evaluation of peanut, mustard, linseed and cottonseed meals for wool production in Angora rabbits. – Journal of Applied Rabbit Research 10, p. 30–34.

Tassinari, M., Mordenti, A., Testi, S., Zotti, A. 2001. Esperienze sulla possibilitā di arricchire con la dieta la carne coniglio di LCPUFA n-3. – Progress in Nutrition, 2, p. 71.

The importance of omega-3 fatty acids for adults and children. – Internet, 1998, http://www.flaxcouncil.ca/flaxnut11.html.

Tikk H., Hämmal, J., Kuusik, S., Mõttus, E. 1999. Polyunsaturated fatty acids content of quail eggs and meat by feeding of the linseed oil. – Proceedings of the International Conference and Exhibition on Veterinary Poultry, July 28–30, 1999. Beijing, China, p. 307–308.

Tikk, H., Hämmal, J., Tikk, V., Kuusik, S. 2002. On increasing ω-3 fatty acid content in quail meat and fat. – Proceedings of the 10th Baltic Poultry Conference. Vilnius, p. 68–72.

Tikk, H., Lember, A. 2004. ω-rasvhapete sisalduse suurendamine kanabroilerilihas. – Agraarteadus nr 4, lk 250–257.

Тикк Х. Лембер А. 2003. Увеличение количества n-3 ненасыщенных жирных кислот в мясе курийных бройлеров. IV Украинская конференция по птицеводству с международым участием. Алушта, с. 329–332.

Tikk, V., Tikk, H., Kuusik, S., Hämmal, J. 2000. Broileriliha rasvhappelisest koostisest. – Akadeemilise Põllumajanduse Seltsi toimetised nr 12. Tartu, lk 89–90.