Utilization of Flaxseeds *(Linum usitatissimum L.)* in Rabbit Rations. 2. Influence of Flaxseeds Levels Supplementations on Blood Constituents, Carcass Characteristics and Fatty Acids Profile.

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Abstract: The aim of this study was to investigate the effect of inclusion different levels of flaxseeds in rabbit rations on blood constituents, carcass characteristics and fatty acids profile. Flaxseed was used in feeding period for 70 days using 45 male New Zealand White rabbits that divided into 5 equal groups, each 9 rabbits. Tested rations contained flaxseed at levels (0, 2.50, 5.00, 7.50 and 10.00%) for groups 1 to 5, respectively. The tested rations were iso-caloric and iso-nitrogenous. At the end of feeding period, six representative rabbits from each treatment were randomly chosen to determine, some of blood constituents, carcass parameters and fatty acids profile. The results showed that dietary treatments had no significant effect (P>0.05) on blood plasma of cholesterol, triglycerides, alkaline phosphatase and GPT. Generally inclusion flaxseed at different levels 2.5, 5.0, 7.5 and 10% in rabbit rations decreased blood plasma albumin, albumin: globulin ratio (except 5%), cholesterol, triglycerides, alkaline phosphatase, GOT and GPT. However, 2.5% and 5.0% flaxseed containing rations decreased blood plasma of total protein, but, 7.5 and 10% containing rations increased blood plasma of total protein compared to control ration. Rabbits received 7.5 and 10% flaxseeds containing ration significantly increased (P<0.05) total protein and globulin, while it significantly (P<0.05) decreased albumin: globulin ratio and GOT compared to the other tested rations. Dietary treatment had no significant effect (P>0.05) on external offal's, digestive tract, empty body weight (EBW) and edible offal's included (heart, kidneys, lungs, spleen and testes). However, it had significant effect (P<0.05) on carcass weight, carcass weight plus edible offal's and dressing percentages. Inclusion flaxseed at (5.0, 7.5 and 10%) was not affected (P>0.05) carcass weight, carcass weight plus edible offal's and dressing percentages compared to control, while 2.5% flaxseed containing diet significantly (P<0.05) decreased the same carcass parameters mentioned above in comparison with the control ration. Also, dietary treatment had no significant effect (P>0.05) physical and chemical compositions (except for ash % content) of the 9^{th}, 10^{th} and 11^{th} ribs and digestive tract (length and weight), while, carcass cuts (except for hind leg) was significantly (P<0.05) affected by inclusion flaxseed in rabbit rations. Inclusion flaxseeds in rabbit rations insignificantly (P>0.05) decreased saturated fatty acids (SFA), while it insignificantly (P>0.05) increased unsaturated fatty acids (USFA) especially C18:1 (Oleic); C18:2 (Linoleic); C18:3 (Linolenic) and C20:1 (Eicosenoic). Rabbit received 2.5% flaxseeds containing ration recorded the highest value of C16:1 (Palmitoleic); C18:3 (Linolenic) and C20:1 (Eicosenoic), while, 10% flaxseeds ration showed the highest value of C18:1 (Oleic). On the other hand 5.0% flaxseeds containing ration recorded the highest value of C18:2 (Linoleic). But 7.5% flaxseeds containing ration recorded the highest value of total unsaturated fatty acids (total USFA). Results obtained mentioned that flaxseed can be used in rabbit rations without any adverse effect on blood parameters with decreasing in blood plasma of cholesterol, triglycerides, alkaline phosphatase, GOT and GPT). So, it can be using flaxseed until the level of 10% in rabbit rations without any adverse effect on their blood constituents and carcass parameters. Also, exploiting flaxseeds that rich in both polyunsaturated fatty acids and antioxidant substances, it is possible to produce meat with an improved fatty acids composition without increase oxidation in animals and in meat devoted human nutrition.

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1. Introduction:

Historically, flaxseed has been used for food and feed for animals for several thousand years in Europe, Asia and Africa, and more recently in Canada and United States. Oil pressed from flaxseed also has been basic cooking oil in China and other countries for centuries **(Steven's farm, 2013).**

Flaxseed (*Linum usitatissimum* L.) is an excellent source of n-3 polyunsaturated fatty acids (PUFA) and recently there has been increasing interest in enhancing n-3 PUFA in the human diet for heart health and potential chemo-protective purposes (**Huang and Milles**, **1996**; **Huang and Ziboh**, **2001**). Health-conscious consumers have raised the demand for PUFA-enriched meats and numerous studies have been undertaken to increase the PUFA level in meat through dietary supplementation.

Whole ground flaxseed or the derivatized components of flaxseed have exhibited cardio protective and antiatherogenic properties both clinically (**Bloedon and Szapary 2004** and **Dupasquier *et al.*, 2006**) and in several animal models (**Prasad 2005** and **Yang *et al.*, 2005**).

The dietary use of flaxseed has been proposed by many authors to obtain meat with raised n-3 PUFA in beef cattle (**Scollan *et al.*, 2001**; **Raes *et al.*, 2004**), in pigs (**Enser *et al.*, 2000**; **Riley *et al.*, 2000**; **Matthews *et al.*, 2000**) and in chickens (**Rymer and Givens**, **2005**; **Shen *et al.*, 2005**).

The possibility of improving the n-3 PUFA proportion and decreasing the n-6/n-3 ratio of rabbit meat by dietary supplementation has important implications and the inclusion of flaxseed in diets has successfully been attempted in rabbits (**Bernardini *et al.*, 1999**; **Cavani *et al.*, 2003**; **Dal Bosco *et al.*, 2004; Colin *et al.*, 2005; Bianchi *et al.*, 2006, 2009; Kouba *et al.*, 2008).** The utilization of flaxseeds was limited due to the presence of certain antinutritional components such as antivitamin B_6 and cyanogenic glycoside **(Oomah *et al.*, 1992).**

Prasad (2000) noted that flaxseed contains 32-45% of its mass as oil, of which 51-55% is alpha linolenic acid (n-3 fatty acids, omega 3 fatty acids). Flaxseed lignan (secoisolariciresinol diglucoside; SDG) is isolated from defatted flaxseed.

For human health the target for meat production towards leaner meat with lower saturated fat and higher monounsaturated (MUFA) and polyunsaturated fatty acid (PUFA) contents, because of the effects of fatty acids (FA) on numerous cancers, atherosclerosis and coronary heart disease **(Scollan *et al.*, 2006; Simopoulos, 2004).** For human health meat production studies are now focused on increasing the n-3 PUFA content, decreasing then n-6 PUFA: n-3 PUFA ratio and increasing the content of conjugated linoleic fatty acids (CLA). CLA contents in meat are increased when the animals are fed concentrates supplemented with unsaturated fat, rich in linoleic acid **(Bauman *et al.*, 2000)** or rich in n-3 PUFA and with pasture based diets **(Dannenberger *et al.*, 2005).**

So this work was made to investigate the effects of inclusion flaxseeds at different levels in rabbit rations on blood constituents, carcass characteristics and fatty acids profile.

2. Materials and Methods

Flaxseed was used in feeding period that lasted for 70 days using 45 male New Zealand White rabbits that divided into 5 equal groups, each 9 rabbits. Tested rations contained flaxseed at (0, 2.50, 5.00, 7.50 and 10.00%) for groups 1 to 5, respectively. Rations were offered pelleted and 4 mm diameter. The experimental rations were formulated to cover the nutrient requirements of rabbits according to (**NRC, 1977**). Composition of the experimental rations (kg/ton) is illustrated in Table (1).

Table 1. Composition of the experimental rations (kg/ton)

Item	Experimental rations				
	0% Flaxseed	2.5% Flaxseed	5% Flaxseed	7.5% Flaxseed	10% Flaxseed
Yellow corn	230.0	205.0	130.0	90.0	70.0
Barley grain	50.0	50.0	70.0	75.0	50.0
Wheat bran	270.0	270.0	300.0	320.0	300.0
Soybean meal	150.0	140.0	120.0	110.0	100.0
Flaxseed	---	25.0	50.0	75.0	100.0
Alfalfa hay	270.0	280.0	300.0	300.0	350.0
Di-Ca-Phosphate	10.0	10.0	10.0	10.0	10.0
Limestone	10.0	10.0	10.0	10.0	10.0
Sodium chloride	5.0	5.0	5.0	5.0	5.0
Vit. & Min. mixture*	3.0	3.0	3.0	3.0	3.0
DL-Methionine	1.0	1.0	1.0	1.0	1.0
Anti fungal agent	1.0	1.0	1.0	1.0	1.0
Price, L.E/Ton	1986	2066	2152	2236	2293

*Vit. & Min. mixture: Each kilogram of Vit. & Min. mixture contains: 2000.000 IU Vit. A, 150.000 IU Vita. D, 8.33 g Vit. E, 0.33 g Vit. K, 0.33 g Vit. B_1, 1.0 g Vit. B_2, 0.33g Vit. B_6, 8.33 g Vit.B_5, 1.7 mg Vit. B_{12}, 3.33 g Pantothenic acid, 33 mg Biotin, 0.83g Folic acid, 200 g Choline chloride, 11.7 g Zn, 12.5 g Fe, 16.6 mg Se, 16.6 mg Co, 66.7 g Mg and 5 g Mn.

At the end of feeding period, six representative rabbits from each treatment were randomly chosen to determine the carcass parameters according to (**Blasco *et al.*, 1993**). Rabbits were fasted for 12 hours before slaughter, which was performed according to the Islamic rules. Animals were weighed just before slaughter, slaughter weight (SW) was recorded and as well as after complete bleeding.

Edible offal's (Giblets) included heart, liver, kidneys, lungs, spleen and testes were removed and individually weighed.

Full and empty weights of small and large intestines were recorded and contents of small and large intestines were calculated by differences between full and empty small and large intestines.

Hot carcass was weighed and divided into fore, middle and hind parts. The 9^{th}, 10^{th} and 11^{th} ribs were frozen in polyethylene bags for later chemical analysis. The best ribs of samples were lyophilized applying the lyophilizer apparatus (Snijders, Holand). Samples were analyzed for DM, EE and ash according to the **A.O.A.C. (2000)** methods, while CP percentage was determined by difference as recommended by **O'Mary *et al.* (1979)**. Physical composition of the 9^{th}, 10^{th} and 11^{th} ribs was divided into lean, bone and fat weight, g. Weight and length of digestive tract of the experimental groups were recorded. Fatty acids profiles of the extracted fat for best 9^{th}, 10^{th} and 11^{th} ribs of different experimental groups were also estimated.

Weights of external offal's, digestive tract and edible offal's were calculated as percentages of body weight at slaughtering (SW). While, physical composition (lean, bone and fat) were calculated as percentages of best ribs weight (RW). On the other hand, carcass cuts were calculated as percentages of carcass weight (CW).

Blood samples were taken from six rabbits in each treatment during slaughtering process in heparinized test tubes and centrifuged at 3000 rpm for 15 minutes, the plasma were collected and preserved in a deep freezer at -18°C until the time of analysis. Various blood plasma chemical parameters were calorimetrically determined using commercial kits, following the same steps as described by manufactures. Plasma total protein was determined according to **Armstrong and Carr (1964)**; albumin according to **Doumas *et al.* (1971).** Globulin was calculated by subtracting the albumin value from total protein value. Plasma Glutamic Oxaloacetic Transaminase (GOT) and Glutamic Pyruvic Transaminase (GPT) activities were determined as described by **Reitman and Frankel (1957).** Alkaline phosphatase colorimetric method measured according to **Belfield and Goldberg (1971).** Triglycerides (**Fossati and Principe, 1982**) and total cholesterol (**Pisani *et al.*, 1995).** Albumin: globulin ratio (A: G ratio) were also, calculated.

Chemical analysis of flaxseeds and experimental rations were analyzed according to **A.O.A.C (2000)** methods.

Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL)} determined according to **Goering and Van Soest (1970)** and **Van Soest *et al.* (1991).**

Fatty acid profile was determined by extracted best (9^{th}, 10^{th} and 11^{th} ribs) fat with diethyl ether and evaporated from the extract and fat was kept under refrigeration for determination of fatty acid using gas liquid chromatography (GLC) technique according to **Mason and Waller (1964)**.

Gross energy (Kcal/ Kg DM) calculated according to **Blaxter (1968)**. Each g CP= 5.65 Kcal, g EE= 9.40 Kcal and g (CF & NFE) = 4.15 Kcal.

Digestible energy (DE) calculated according to **Fekete and Gippert (1986)** by applying the following equation:

DE (kcal/ kg DM) = 4253 – 32.6 (CF %) – 144.4 (total ash %).

Collected data of blood constituents, carcass parameters and fatty acid profiles were subjected to statistical analysis as one way analysis of variance using the general linear model procedure of **SPSS (2008). Duncan's Multiple Range Test (1955)** was used to separate means when the dietary treatment effect was significant.

3. Results and Discussion

Chemical analysis of flaxseeds and the experimental rations

Data of Table (2) showed that flaxseed considered a good source of CP, CF and EE, While, it lower in their content of NFE.

The composition of flax can vary based on variety, environmental factors and method of analysis (**Daun *et al.*, 2003; Maddock *et al.*, 2005 and Morris, 2008**). Values of most commonly flax used are 41% oil, 20% protein and 28% dietary fiber (**Canadian Grain Commission, 2001**; DM basis). On the other hand, **Daun and Pryzbylski (2000**) noted that protein value of flaxseed ranged from 18.8% to 24.4%.

Peiretti and Meineri (2007) noted that flaxseed contained 93.20% DM; 24.5% CP; 30.2% EE; 41.0% NDF; 29.4% ADF; and 4.2% Lignin.

Chemical composition of the experimental rations (Table 2) formulated to have iso-caloric and iso-nitrogenous. CP ranged from 15.55 to 15.76% and digestible energy that ranged from 2517 to 2561 kcal/ kg DM for the rations contained flaxseeds at levels (0, 2.5, 5, 7.5 and 10%).

Incorporation flaxseeds in rabbit diets lead to increase the ether extract and acid detergent fiber (ADF) contents, while, it decreased the hemicellulose content. These results in agreement with those obtained by **Peiretti *et al.* (2007a)** who used false flax (*Camelina sativa L.*) seeds (FFS) at different levees 0, 10 or 15% in crossbred rabbit diets.

Table 2. Chemical analysis (%) of flaxseeds and the experimental rations

Item	Flax seed	Experimental rations				
		0% Flax seed	2.5% Flax seed	5% Flax seed	7.5% Flax seed	10% Flax seed
Dry matter (DM)	92.46	89.57	90.38	90.24	90.30	90.83
Chemical analysis on dry matter basis						
Organic matter (OM)	78.24	90.64	90.57	90.70	90.62	90.75
Crude protein (CP)	20.93	15.71	15.76	15.56	15.75	15.55
Crude fiber (CF)	12.23	10.45	10.56	11.72	11.56	11.64
Ether extract (EE)	29.14	3.45	4.08	4.91	5.85	5.52
Nitrogen–free extract (NFE)	15.94	61.03	60.17	58.51	57.46	58.04
Ash	21.76	9.36	9.43	9.30	9.38	9.25
Growth energy (Kcal/kg DM)[1]	5091	4178	4209	4255	4304	4289
Digestible energy (kcal/kg DM)[2]	1107	2561	2547	2528	2517	2538
Cell wall constituents						
Neutral detergent fiber (NDF)	36.96	35.79	35.86	36.62	36.52	36.57
Acid detergent fiber (ADF)	25.36	17.43	18.46	18.88	19.82	20.74
Acid detergent lignin (ADL)	4.00	4.20	4.07	5.49	4.40	4.21
Hemicellulose[3]	11.60	18.36	17.40	17.74	16.70	1.83
Cellulose[4]	21.36	13.23	14.39	13.39	15.42	16.53

[1]Gross energy (kcal/kg DM) was calculated according to **Blaxter (1968).** Each g CP = 5.65 kcal, g EE = 9.40 kcal and g (CF & NFE) = 4.15 kcal.
[2] Digestible energy (DE) was calculated using the following equation
DE (kcal/ kg DM) = 4253 – 32.6 (CF %) – 144.4 (total ash %)
[3]Hemicellulose = NDF – ADF.
[4]Cellulose = ADF – ADL.

Data of Table (3) cleared that flaxseed rich in unsaturated fatty acids (USFA) 88.82% in comparison with their contents of saturated fatty acids (SFA) 11.18%. Linoleic acid shows the highest value 54.59% followed by oleic acid 32.10%. These results in agreement with those obtained by (**Maddock *et al.*, 2005).**

Table 3. Fatty acid profiles of flaxseeds

Item	Saturated fatty acids (SFA)				Unsaturated fatty acids (USFA)				
	C16:0	C18:0	C20:0	Total	C18:1	C18:2	C18:3	C20:1	Total
	6.30	4.39	0.49	11.18	32.10	54.59	1.57	0.56	88.82

Blood plasma constituents of the experimental groups

Data of Table (4) showed that dietary treatments had no significant effect (P>0.05) on blood parameters of cholesterol, triglycerides, alkaline phosphatase and GPT.

Generally inclusion flaxseed at different levels 2.5, 5.0, 7.5 and 10% in rabbit rations decreased blood plasma albumin, albumin: globulin ratio (except 5%), cholesterol, triglycerides, alkaline phosphatase, GOT and GPT. However, 2.5% and 5.0% flaxseed containing rations decreased blood plasma of total protein, but, 7.5 and 10% containing rations increased blood plasma of total protein in comparison with control ration.

Rabbits received 7.5 and 10% flaxseeds containing ration significantly increased (P<0.05) total protein and globulin, while it significantly (P<0.05) decreased albumin: globulin ratio and GOT compared to the other tested rations.

These results were in agreement with those obtained by **Lee and Prasad (2003)** who studied the effects of flaxseed oil on serum lipids and atherosclerosis in hypercholesterolemic rabbits. They reported that serum total cholesterol, triglycerides, and low density and high density lipoprotein cholesterol, and risk ratio of total cholesterol to high density lipoprotein cholesterol, were elevated to a similar extent. They also, suggested that flaxseed oil does not produce an alteration in serum lipids or in the extent of hypercholesterolemic atherosclerosis; however, it decreases white blood cell chemiluminescence. The ineffectiveness of flaxseed oil was associated with its ineffectiveness in altering the levels of oxidative stress.

Also, **Dupasquier *et al.* (2006)** evaluated the effects of flaxseed supplementation on atherosclerosis and vascular function under prolonged hypercholesterolemic conditions in New Zealand White rabbits for 6, 8, or 16 wk of feeding**.** They noticed that cholesterol feeding resulted in elevated plasma cholesterol levels and the development of atherosclerosis. They concluded that dietary flaxseed is a valuable strategy to limit cholesterol induced atherogenesis as well as abnormalities in endothelial-dependent vasorelaxation. However, these beneficial effects were attenuated during prolonged hypercholesterolemic conditions.

On the other hand**, Ander *et al.* (2004)** determined whether a flaxseed-rich diet is antiarrhythmic in normal and hypercholesterolemic rabbits. Male New Zealand White (NZW) rabbits were fed as follows: regular diet (REG group); diet containing 10% flaxseed (FLX group); 0.5% cholesterol (CHL group); or 0.5% cholesterol + 10% flaxseed (CHL/FLX group) for up to 16 wk. They found that plasma cholesterol was significantly elevated in the CHL and CHL/FLX groups. Plasma triglycerides were unchanged. ALA levels increased significantly in plasma and hearts of the FLX and CHL/FLX groups. Also, they demonstrated that dietary flaxseed exerts antiarrhythmic effects during ischemia reperfusion in rabbit hearts, possibly through shortening of the action potential.

While, **Ray (2011**) noted that flaxseed helps to lower overall cholesterol levels, especially low density lipoprotein (LDL), or bad cholesterol levels. The tiny nutty flavored seeds also are instrumental in lowering triglyceride levels and reducing high blood pressure. Flaxseed use leads to overall cardiovascular improvements because it lowers cholesterol levels, although Mayo Clinic doctors report that the seeds may do little to prevent coronary artery disease. As a healthy fiber, flaxseed can keep platelets from sticking to the arteries to reduce the risk of heart attack.

In contrast, **Bruso (2011)** noted that total cholesterol was not reduced with flax supplementation; however, rabbits fed flaxseeds had much lower levels of atherosclerosis, or plaque buildup in the arteries, than rabbits that weren't given flaxseed.

Table 4. Blood plasma constituents of the experimental groups

Item	Experimental rations					SEM
	0% Flaxseed	2.5% Flaxseed	5% Flaxseed	7.5% Flaxseed	10% Flaxseed	
Total protein (g/dl)	4.54^{c}	4.25^{c}	4.30^{c}	6.33^{b}	6.97^{a}	0.31
Albumin (g/dl)	3.05^{a}	2.71^{b}	2.99^{ab}	2.92^{ab}	2.85^{ab}	0.05
Globulin (g/dl)	1.49^{c}	1.54^{c}	1.31^{c}	3.41^{b}	4.12^{a}	0.32
Albumin: Globulin ratio	2.05^{a}	1.76^{a}	2.28^{a}	0.86^{b}	0.69^{b}	0.18
Cholesterol (mg/dl)	187.7	182.8	180.4	179.3	175.8	2.34
Triglycerides (mg/ dl)	187.0	184.0	179.5	177.6	175.8	7.99
Alkaline phosphatase (IU/L)	74.71	73.69	73.33	72.50	71.73	0.53
GOT (U/ml)	54.83^{a}	41.69^{b}	36.45^{c}	35.25^{c}	33.95^{c}	2.10
GPT (U /ml)	31.20	28.73	27.90	27.57	26.88	0.66

a, b and c: Means in the same row having different superscripts differ significantly (P<0.05).
SEM: Standard error means

Carcass traits of the experimental groups

External and edible offal's, carcass weight and dressing percentages of the experimental groups

Data illustrated in Table (5) cleared that dietary treatment had no significant effect (P>0.05) on external offal's, digestive tract, empty body weight (EBW) and edible offal's included (heart, kidneys, lungs, spleen and testes). However, it had significant effect (P<0.05) on carcass weight, carcass weight plus edible offal's and dressing percentages. Inclusion flaxseed at (5.0, 7.5 and 10%) was not affected (P>0.05) carcass weight, carcass weight plus edible offal's and dressing percentages compared to control, while 2.5% flaxseed containing diet significantly (P<0.05) decreased the same carcass parameters mentioned above in comparison with the control ration. The results were similar with that obtained by **Peiretti *et al.* (2007b)** how used three levels of false flaxseed (*Camelina sativa L.*) (FFS) 0%, 10% or 15 in rabbit diets to study its effects on some carcass characteristics. They noticed that there were no significant differences among the groups in carcass yield and the percentages of edible organs. The percentage values of head, skin and limbs, fore legs, hind legs, breast and ribs, loin and abdominal wall were not affected by the inclusion level of FFS.

Romans *et al.* (1995) found no differences in carcass traits of growing gilts that received diet contained 15% ground flax.

Table 5. External and edible offal's, carcass weight and dressing percentages of the experimental groups

Item		Experimental rations					
		0% Flaxseed	2.5% Flaxseed	5% Flaxseed	7.5% Flaxseed	10% Flaxseed	SEM
Slaughter weight (SW), g		2739	2215	2203	2472	2325	94.84
External offal's							
Head	weight, g	147	124	127	139	133	3.94
	% of SW	5.38	5.60	5.76	5.62	5.72	0.09
Fur + legs + ears	weight, g	579	481	464	567	511	25.72
	% of SW	21.13	21.71	21.07	22.94	21.98	0.38
Total	weight, g	726	605	591	706	644	29.33
	% of SW	26.51	27.31	26.83	28.56	27.70	0.39
Digestive tract, g							
Full	weight, g	385	377	329	306	290	15.99
	% of SW	14.06[ab]	17.02[a]	14.93[ab]	12.38[b]	12.47[b]	0.62
Empty	weight, g	170	168	150	158	146	5.50
	% of SW	6.21[b]	7.58[a]	6.81[ab]	6.39[b]	6.28[b]	0.18
Content	weight, g	215	209	179	148	144	12.70
	% of SW	7.85[ab]	9.44[a]	8.12[ab]	5.99[b]	6.19[b]	0.51
Empty body weight (EBW), g							
	weight, g	2524	2006	2024	2324	2181	91.93
	% of SW	92.15[ab]	90.56[b]	91.87[ab]	94.01[a]	93.81[a]	0.51
Edible offal's, g							
Liver	weight, g	94[a]	64[b]	64[b]	75[ab]	67[ab]	4.73
	% of SW	3.43	2.89	2.91	3.03	2.88	0.12
Heart	weight, g	9	8	7	8	8	0.51
	% of SW	0.33	0.36	0.32	0.32	0.34	0.02
Kidneys	weight, g	18	15	16	17	16	0.71
	% of SW	0.66	0.68	0.73	0.69	0.69	0.02
Lungs	weight, g	17	13	14	16	15	0.72
	% of SW	0.62	0.59	0.64	0.65	0.65	0.02
Spleen	weight, g	1	1	1	1	1	0.00
	% of SW	0.04	0.05	0.05	0.04	0.04	0.003
Testes	weight, g	9	8	9	8	9	0.35
	% of SW	0.33[b]	0.36[ab]	0.41[a]	0.32[b]	0.39[ab]	0.01
Total	weight, g	148[a]	109[b]	111[ab]	125[ab]	116[ab]	6.01
	% of SW	5.40	4.92	5.04	5.06	4.99	0.11
Carcass weight		1468[a]	1111[b]	1147[ab]	1279[ab]	1238[ab]	53.92
Carcass weight + edible offal's		1616[a]	1220[b]	1258[ab]	1404[ab]	1354[ab]	59.11
Dressing percentages (DP)%:							
DP [1]		53.60[a]	50.16[b]	52.11[ab]	51.74[ab]	53.25[a]	0.47
DP [2]		58.16[a]	55.38[b]	56.72[ab]	55.03[b]	56.76[ab]	0.44
DP [3]		64.03[a]	60.82[b]	62.20[ab]	60.41[b]	62.08[a]	0.44

a and b: Means in the same row having different superscripts differ significantly (P<0.05).
SEM: Standard error means. DP [1]: Dressing percentages calculated as (carcass weight / slaughter weight).
DP [2]: Dressing percentages calculated as (carcass weight / empty body weight).
DP [3]: Dressing percentages calculated as (carcass weight + edible offal's / empty body weight).

Physical composition, chemical analysis of the 9*th*, 10*th* and 11*th* ribs and carcass cuts of the experimental groups

Data of Table (6) showed that dietary treatment had no significant effect (P>0.05) on physical (except bone weight) and chemical compositions (except ash % content) of the 9*th*, 10*th* and 11*th* ribs, while carcass cuts (except for hind part weight) was significantly (P<0.05) affected by inclusion flaxseed in rabbit rations. Our results were agreement with that obtained by **Kouba *et al.* (2008)** who reported that n-3 poly unsaturated fatty acids rich diet with 3% extruded flaxseed did not have any effect on the dry matter, protein or lipids of the rabbit muscles. Similarly, the chemical composition of the *longissimus dorsi* muscle was unaffected when rabbits were fed 8% flaxseed diet **(Dal Bosco *et al.*, 2004)**.

Also, **Peiretti and Meineri (2010)** studied the effects of three levels (0, 8, or 16%) of the golden variety of flaxseed (GFS; *Linum usitatissimum* L.) on carcass characteristics of rabbit meat and perirenal fat. They noticed that there were no significant differences between the groups in the carcass yield or the proportions of various carcass parts and edible organs. They also, noted that decreasing the n-6/n-3 ratio and reducing the saturation, atherogenic and thrombogenic indexes of the meat, with consequent benefits on the nutritional quality of rabbit meat for consumers. No differences were noted for carcass characteristics, including 12*th* rib fat thickness, rib eye area or and quality grades when feedlot steers fed diets contained 3 or 6 % ground flax **(Maddock *et al.*, 2004)** included in finishing diets for.

Table 6. Physical composition, chemical analysis of the 9*th*, 10th and 11*th* ribs and carcass cuts of the experimental groups

Item	Experimental rations					SEM
	0% Flaxseed	2.5% Flaxseed	5% Flaxseed	7.5% Flaxseed	10% Flaxseed	
Physical composition of the 9, 10 and 11th ribs						
Ribs weight (RW), g	116	103	103	109	114	2.38
Lean						
Weight, g	91	81	82	90	87	2.03
% of RW	78.45	78.64	79.61	82.57	76.31	1.20
Bone						
Weight, g	13^{b}	14^{ab}	13^{b}	16^{a}	12^{b}	0.44
% of RW	11.21^{c}	13.59^{ab}	12.62^{b}	14.68^{a}	10.53^{c}	0.44
Fat						
Weight, g	12	8	8	3	15	1.84
% of RW	10.34^{ab}	7.77^{ab}	7.77^{ab}	2.75^{b}	13.16^{a}	1.51
Chemical analysis of the 9th, 10th and 11th ribs						
DM	41.54	38.13	37.61	37.45	42.79	1.23
Chemical composition on DM basis						
CP	46.79	52.36	53.40	56.53	44.88	2.41
EE	47.60	39.93	38.21	35.09	48.09	2.72
Ash	5.61^{b}	7.71^{ab}	8.39^{a}	8.38^{a}	7.03^{ab}	0.41
Carcass cuts						
Carcass weight (CW), g	1468^{a}	1111^{b}	1148^{ab}	1279^{ab}	1238^{ab}	53.92
1- Fore part						
Weight, g	449^{a}	323^{b}	341^{ab}	376^{ab}	372^{a}	18.89
% of CW	30.59	29.07	29.73	29.40	30.05	0.44
2- Middle part						
Weight, g	477^{a}	349^{b}	357^{b}	406^{ab}	388^{a}	18.33
% of CW	32.49	31.41	31.12	31.74	31.34	0.35
3- Hind part						
Weight, g	542	439	449	497	478	18.20
% of CW	36.92^{b}	39.52^{a}	39.15^{ab}	38.86^{ab}	38.61^{ab}	0.38

a, b and c: Means in the same row having different superscripts differ significantly (P<0.05).
SEM: Standard error means.

Weight and length of digestive tract of the experimental groups

Data of Table (7) showed that dietary treatments had no significant effect (P>0.05) on digestive tract (stomach, small and large intestine) length and digestive tract weight (full, empty and content)

Fatty acids profiles of the best 9*th*, 10*th* and 11*th* ribs for the experimental groups

Data of Table (8) and Fig. (1, 2, 3, 4 and 5) cleared that inclusion flaxseeds in rabbit ration insignificantly (P>0.05) decreased saturated fatty acids (SFA), while insignificantly (P>0.05) increased unsaturated fatty acids (USFA) especially C18:1 (Oleic); C18:2 (Linoleic); C18:3 (Linolenic) and C20:1 (Eicosenoic).

Table 7. Weight and length of digestive tract of the experimental groups

Item		Experimental rations					SEM
		0% Flaxseed	2.5% Flaxseed	5% Flaxseed	7.5% Flaxseed	10% Flaxseed	
Slaughter weight (SW), g		2739	2215	2203	2472	2325	
1- Stomach:							
Full	weight, g	125^{a}	87^{b}	89^{b}	72^{b}	70^{b}	6.31
	% of SW	4.56^{a}	3.93^{ab}	4.04^{a}	2.91^{c}	3.01^{bc}	0.20
Empty	weight, g	34^{a}	31^{ab}	28^{ab}	25^{ab}	25^{b}	1.53
	% of SW	1.24^{a}	1.40^{a}	1.27^{a}	1.01^{b}	0.99^{b}	0.05
Content	weight, g	91^{a}	56^{b}	61^{b}	47^{b}	47^{b}	5.23
	% of SW	3.32^{a}	2.53^{ab}	2.77^{ab}	1.90^{b}	2.02^{b}	0.17
2- Small intestine:							
Full	weight, g	75^{ab}	62^{ab}	65^{ab}	78^{a}	53^{b}	3.84
	% of SW	2.74^{ab}	2.80^{ab}	2.95^{a}	3.16^{a}	2.28^{b}	0.10
Empty	weight, g	65	55	54	65	48	3.06
	% of SW	2.37^{ab}	2.48^{ab}	2.45^{ab}	2.63^{a}	2.06^{b}	0.08
Content	weight, g	10	7	11	13	5	1.60
	% of SW	0.37	0.32	0.50	0.53	0.22	0.06
3- Large intestine:							
Full	weight, g	185	228	175	156	167	11.02
	% of SW	6.74^{b}	10.29^{a}	7.94ab	6.31^{b}	7.18^{b}	0.51
Empty	weight, g	71	81	68	69	75	2.42
	% of SW	2.59^{c}	3.66^{a}	3.09^{abc}	2.79^{bc}	3.23^{ab}	0.12
Content	weight, g	114	147	107	87	92	9.89
	% of SW	4.15^{ab}	6.63^{a}	4.85ab	3.52^{b}	3.95^{ab}	0.44
4- Digestive tract:							
Full	weight, g	385	377	329	306	290	15.99
	% of SW	14.06^{ab}	17.02^{a}	14.93^{ab}	12.38^{b}	12.47^{b}	0.62
Empty	weight, g	170	168	150	158	146	5.50
	% of SW	6.21^{b}	7.58^{a}	6.81^{ab}	6.39^{b}	6.28^{b}	0.18
Content	weight, g	215	209	179	148	144	12.70
	% of SW	7.85^{ab}	9.44^{a}	8.12^{ab}	5.99^{b}	6.19^{b}	0.51
Digestive tract length, cm		447	465	464	454	418	15.66
Stomach, cm		23	25	25	21	22	0.69
Small intestine length, cm		272	283	277	300	273	12.21
Large intestine length, cm		152	157	162	133	123	7.55

a, b and c: Means in the same row having different superscripts differ significantly (P<0.05).
SEM: Standard error means.

Rabbit received 2.5% flaxseeds containing ration recorded the highest value of C16:1 (Palmitoleic); C18:3 (Linolenic) and C20:1 (Eicosenoic), while, 10% flaxseeds ration showed the highest value of C18:1 (Oleic). On the other hand 5.0% flaxseeds containing ration recorded the highest value of C18:2 (Linoleic). But 7.5% flaxseeds containing ration recorded the highest value of total unsaturated fatty acids (total USFA).

Several studies have highlighted that flaxseed enriched diets generally increase the unsaturation of depot lipids (**Bianchi *et al.*, 2006, 2009**) and reduce their n-6/n-3 ratio **(Dal Bosco *et al.*, 2004; Colin *et al.*, 2005; Maertens *et al.*, 2008).**

Ander *et al.* (2010) fed rabbits diet containing 10% ground flaxseed that is highly enriched with the omega-3 polyunsaturated fatty acid alpha-linolenic acid (ALA).

The high-flaxseed diet resulted in an incorporation of ALA in all tissues, but mostly in the heart and liver with little in the brain. Docosahexaenoic and eicosapentaenoic acid levels were also selectively increased in some tissues, and the effects were not as large as ALA. Arachidonic acid and the ratio of omega-6/omega-3 fatty acids were decreased in all tissues obtained from the flax supplemented group. Consumption of dietary flaxseed appears to be an effective means to increase ALA content in body tissues, but the degree will depend upon the tissues examined.

Table 8. Fatty acids profiles of the best 9th, 10th and 11th ribs of the experimental groups

Item	Experimental rations					SEM
	0%Flaxseed	2.5%Flaxseed	5%Flaxseed	7.5%Flaxseed	10%Flaxseed	
Saturated fatty acids (SFA)						
C6:0 Caproic	1.34	1.22	1.30	1.27	1.28	0.17
C8:0 Caprylic	1.18	1.15	1.21	1.15	1.13	0.10
C14:0 Myristic	6.27	6.26	4.91	3.58	2.16	0.64
C16:0 Palmitic	35.95	33.54	35.47	32.51	35.92	1.62
C18:0 Stearic	6.45	6.00	5.61	6.22	5.65	0.48
Total SFA	51.19	48.17	48.50	44.73	46.14	2.15
Unsaturated fatty acids (USFA)						
C16:1 Palmitoleic	1.61	2.06	1.77	1.74	0.98	0.18
C18:1 Oleic	31.15	34.06	34.22	37.47	39.05	1.39
C18:2 Linoleic	7.06	5.69	7.65	7.31	5.80	0.66
C18:3 Linolenic	8.05	8.96	6.85	7.78	7.00	1.14
C20:1 Eicosenoic	0.94	1.06	1.01	0.97	1.03	0.09
Total USFA	48.81	51.83	51.50	55.27	53.86	2.15

SEM: Standard error means.

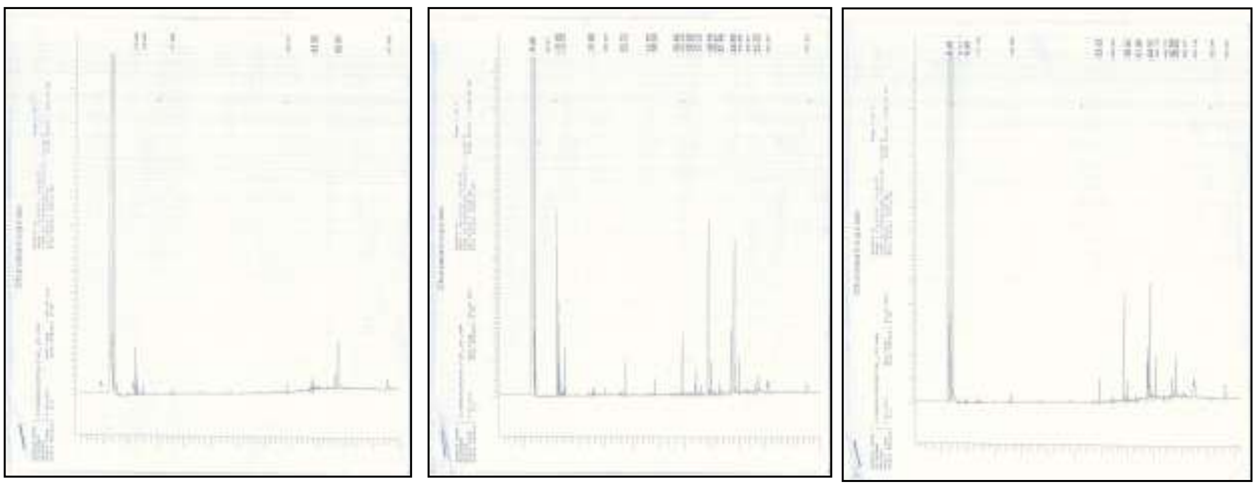

Fig. 1. Fatty acids profile of rabbit's meat fed control diet.

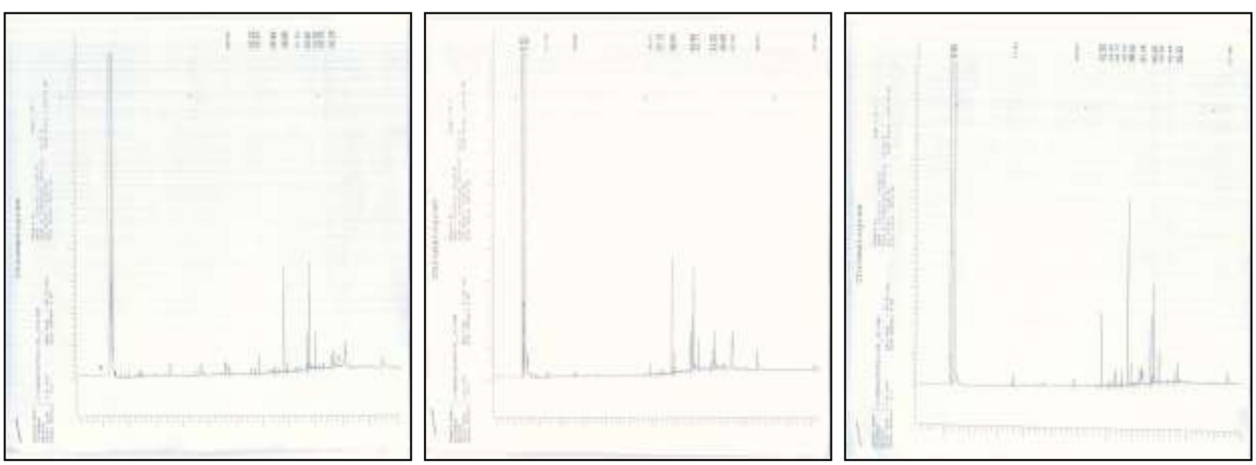

Fig. 2. Fatty acids profile of rabbit's meat fed 2.5% flaxseeds containing diets.

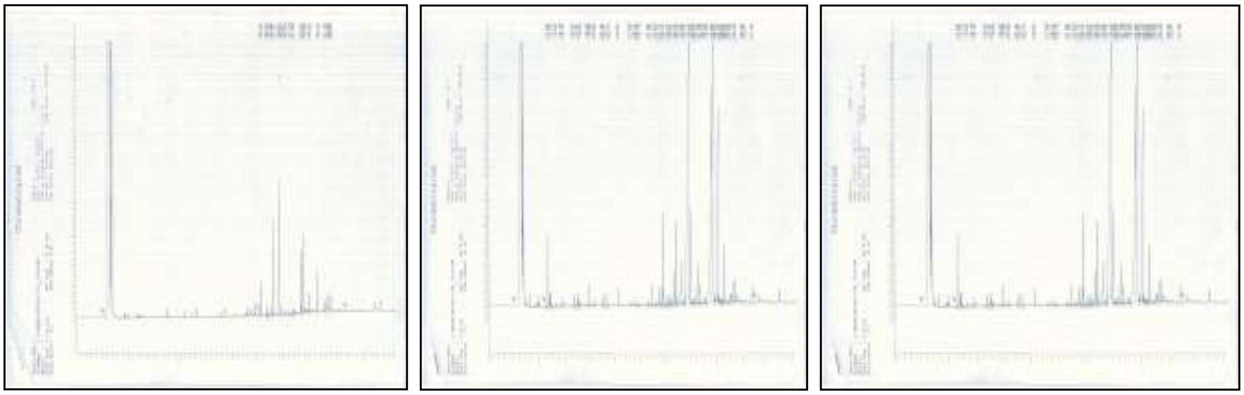

Fig. 3. Fatty acids profile of rabbit's meat fed 5% flaxseeds containing diets.

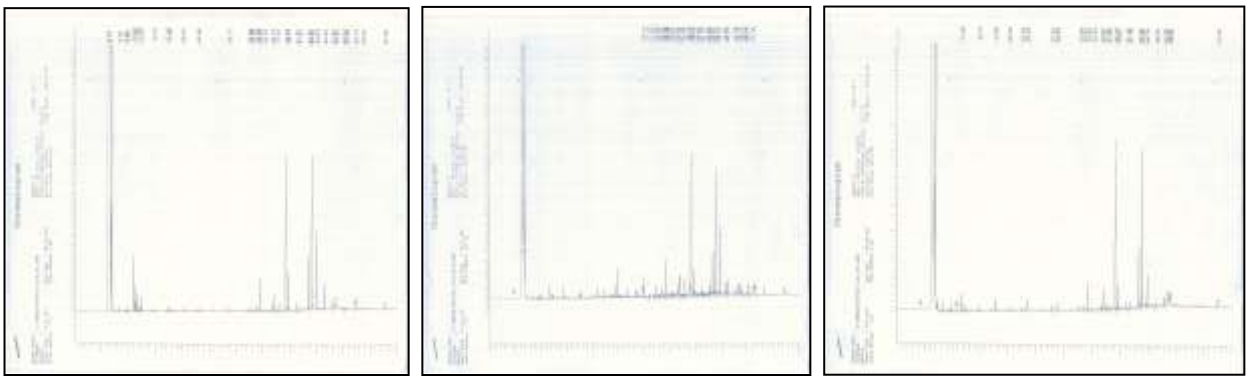

Fig.4. Fatty acids profile of rabbit's meat fed 7.5% flaxseeds containing diets.

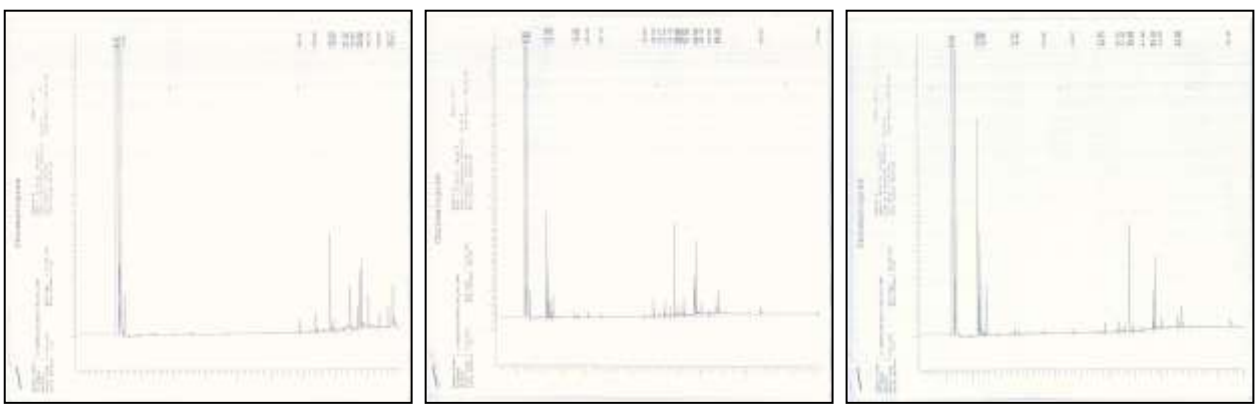

Fig.5. Fatty acids profile of rabbit's meat fed 10% flaxseeds containing diets.

Also, they noted that diets rich in omega-3 polyunsaturated fatty acids are associated with decreased incidences of cardiovascular disease. The extent of incorporation and distribution of these beneficial fats into body tissues is uncertain. Also, **Peiretti and Meineri (2010)** showed that although the chemical composition of the meat was not significantly affected by the dietary treatment, the saturated fatty acid and monounsaturated fatty acid proportion in the *longissimus dorsi* muscle (22% and 24%, respectively) and perirenal fat (34% and 29%, respectively) decreased and the polyunsaturated fatty acid (PUFA) increased (+36% in the muscle and 43% in the fat, respectively) with increased GFS inclusion. While, **Peiretti and Meineri (2010)** recorded decreasing in n-6/n-3 ratio and reducing the saturation, atherogenic and thrombogenic indexes of the meat, with consequent benefits on the nutritional quality of rabbit meat for consumers. They were also noticed a decrease for C14:0, C14:1, C15:0, C16:0, C16:1 and C18:1 n-9 with an increasing GFS inclusion level in both tissues, while a decreasing trend was also found in the perirenal fat for C18:0 and C20:1 n-9. As far the main fatty acids, the increased percentages of α-linolenic acid (ALA, C18:3 n-3) in the *longissimus dorsi* muscle and perirenal fat of the rabbits fed diets with increasing levels of GFS is the results of a progressively higher proportion of this fatty acids in the 8 and 16% GFS diets than the control diet.

Bianchi *et al.* (2009) found a close relationship (R^2=0.99) between the α-linolenic acid (LNA, C18:3 n-3) content in rabbit meat and the whole flaxseed content in the diet, but the LNA proportion that found in experiment that made by **Peiretti and Meineri (2010)** in the *longissimus dorsi* muscle of rabbit fed GFS supplemented diet was lower than that found in the work at the same flaxseed inclusion level. Another close relationship (R^2=0.94) between the n-3 PUFA feed level and the rabbit meat composition was found by **Colin *et al.* (2005).**

On the other hand, **Kouba *et al.* (2008)** found that when flaxseed fed to rabbits, significantly increased the polyunsaturated fatty acids (PUFA) content and lowered the n-6/n-3 ratios, saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) contents of the *longissimus dorsi* muscle and perirenal fat compared to the control diet.

Some of the discrepancies could be due to effects of metabolizable energy intake, losses in energy with experimental conditions and age at weaning and slaughter. Under similar environmental conditions and at the same age, increases in lipid content of the diet did not affect muscle lipid content (**Bolte, *et al.*, 2002** and **Solomon *et al.*, 1991**).

Prola *et al.* (2011) found that incorporation false flaxseeds (*comelina sataiva*) in rabbit diets at 10 and 15% improved fatty acid composition of rabbit meat and at these levels does not increase oxidation neither in meat nor in animals. Also, they noted that exploiting seeds rich both in polyunsaturated fatty acids and in antioxidant substances, it is possible to produce meat with an improved fatty acids composition without increase oxidation in animals and in meat devoted human nutrition. While, **Bernardini *et al.* (1999)** showed the possibility of improving the n−3 PUFA content of rabbit meat by manipulating dietary lipids because a rabbit effectively synthesizes endogenousn−3 fatty acids from their precursor in the liver and the amount produced depends on the dietary n−6/ n−3 PUFA ratio. Recommendations for human diets (**British Nutrition Foundation, 1993**) suggested that increasing the n−3 PUFA consumption and decreasing the n−6/n−3 ratio to 6/1. Therefore, the possibility of improving the n−3 PUFA content and decreasing the n−6/n−3 ratio of meat by dietary supplementation has important implications.

Peiretti *et al.* (2007b) conducted an experiment to study the effects of various levels of false flax (*Camelina sativa L.*) seed (FFS) in the rabbit diets on fatty acid profile of rabbit's meat and fat. Three levels (0%, 10% or 15%) of FFS were used in their experiment. They recorded that although the chemical composition of the meat was not significantly affected by the dietary treatment, the polyunsaturated fatty acid (PUFA) concentration in the *longissimus dorsi* muscle and perirenal fat was significantly increased with the increasing of FFS inclusion, while saturated fatty acid (SFA) decreased. Then−6/n−3 PUFA ratio of the meat decreased from 3.86 in the control group, to 1.19 in the 15% of FFS group. They also, noted that use of a diet supplemented with FFS was effective in reducing the saturation, atherogenic and thrombogenic indexes, with consequent benefits on the nutritional quality of rabbit meat for consumers. While, **Maertens *et al.* (2008)** noticed that the dietary inclusion of extruded linseed during the whole fattening period had a very strong impact on the overall fatty acid composition reflected in both the saturated fatty acids SFA (30.65 vs.27.92% for control and linseed rabbits, respectively) and poly unsaturated fatty acids PUSFA (44.67 vs. 49.80% for control and linseed diet rabbits, respectively). Rabbits fed continuously the omega 3 diet had a 330% higher α-linolenic acid content compared with the rabbits fed the control diet while their linoleic content was 26.5% lower. This corresponds with the change of both fatty acids in control and linseed diet (29.7 and 27.6%, respectively).

Also, **Bielanski and Kowalska (2008)** concluded that the addition of linseed oil to rabbit diets had a favorable effect on the composition of the lipid fraction of rabbit meat, causing a significant decrease in total saturated fatty acids (SFA) and an increase in polyunsaturated fatty acids (n-3 PUFA).

4. Conclusion

Under the conditions of this study, results obtained mentioned to incorporate flaxseed in rabbit rations give the best results in terms of blood parameter such as (cholesterol, triglycerides, alkaline phosphatase, GOT and GPT) of rabbits. So, it could be used flaxseed until the level of 10% in rabbit rations without any adverse effect on their blood constituents and carcass parameters. Also, exploiting flaxseeds that rich in both polyunsaturated fatty acids and antioxidant substances, it is possible to produce meat with an improved fatty acids composition without increase oxidation in animals and in meat devoted human nutrition.

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