THE EFFECTS OF DIETARY INCLUSION OF DIFFERENT LEVELS OF FLAXSEED ON THE DIGESTIBILITY, GROWTH PERFORMANCE, BLOOD PARAMETERS AND FATTY ACID PROFILE IN GROWING NEW-ZEALAND WHITE (NZW) RABBITS

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SUMMARY

A total number of 60 male New-Zealand White (NZW) rabbits post-weaning was used to study the effect of the inclusion of three levels (4, 6 and 8%) of flaxseed (FS) in the rabbit diet on nutrients digestibility, growth performance, blood parameters and fatty acid profile. Rabbits were distributed among 4 equal groups (3 replicates, 5 rabbits each). The1st group received the basal diet without FS. The other three groups (2nd, 3rd and 4th) received the basal diet with FS at levels 4, 6 and 8%, respectively. Rabbits were fed experimental diets for 8 weeks. Feeding diet contains FS at 6% level significantly (P<0.05) decreased the digestion coefficients as DM and OM compared to the control group while, feeding FS at the 8% level significantly decreased the digestion coefficients of DM, OM, CF and NFE compared to the control group. Feeding FS at the 6 or 8% level in rabbits significantly decreased the daily feed intake compared to the control group. Feeding flaxseed at the three levels 4, 6 and 8% in rabbits significantly (P<0.05) decreased the long dorsal fat and pre-renal fat weight compared to the control group. Feeding the experimental diets contain flaxseed at different levels (4, 6 and 8 %) significantly (P<0.05) decreased triglycerides, total cholesterol and total alkaline phosphatase compared to those of the control group. Feeding diets contain flaxseed at the level 6 and 8% in rabbit rations significantly (P<0.05) increased the α-linolenic acid, eicosapentaenoic acid and palmitic acid levels as well as reduced the arachidonic acid. Comparing these results to the literature, it was found that inclusion of dietary flaxseed at 6 and 8% of total ration considered high levels which significantly improved the blood parameters and profile fatty acids meanwhile a slightly decreased the growth performances and digestibility. Our suggestion under these circumstances is to use the lower level of 4% in rabbit feeding, flaxseeds are used to increase the diet content in omega-3 fatty acids, mostly alpha-linolenic acid.

Keywords: Flaxseeds, rabbits, growth performance, digestibility, carcass characteristics and blood parameters.

INTRODUCTION

Flaxseed Linumusita tissimum L. (Linaceae) is one of the most important field crops for industrial food and feed which relatively rich in protein about 25%, oil about 37% and crude fibre about 10% of DM(Singh et al., 2011). Flaxseed (FS) contains about 10% saturated fatty acids (palmitic and stearic), about 20% monounsaturated fatty acids (mainly oleic acid), more than 55% is α-linolenic acid (ω-3 fatty acid) and about 18% linoleic acid (Prasad et al.,1999) which effectively increase the concentration of polyunsaturated fatty acids and reduce the concentration of saturated fatty acids (Benatman et al.,2011). Flaxseed is one of the best sources of n-3 fatty acids (El-Beltagi et al., 2007) and therefore used as a source of protein and energy in livestock diets as well as a good source of sulphur amino acids (methionine and cysteine) and a branched chain of amino acids (isoleucine, leucine and valine) (Oomah et al., 2007) as well as more lysine (Beaulieu et al., 2010). Flaxseed lignins are transformed into bioactive endogenous lignin’ senterodiol and enterolactone as the health-promoting properties due to the impact on the hormonal activity of the organism and the antioxidative potential and cell protection against oxidative...
stress (Mitchell et al., 1998). The strong effects of antioxidative properties of lignin’s, flavonoids and phenolic acids prevent the degradation of many lipids, DNA, proteins molecules being significant to the metabolism (Prasad et al., 2000) considered as a curative agent (Akhtar et al., 2013) and characterized functional properties (Martinchik et al., 2012). Several studies have demonstrated that the use of flaxseeds up to 20% in feedlot diets does not affect performance and may reduce the incidence of disease (Newkirk, 2008).

Our hypotheses to examine the pros and cons of a direct effect of feeding flaxseeds on digestibility coefficient, growth performance, meat quality, blood parameters and some fatty acids. Therefore, the present study was carried out by using growing New-Zealand White (NZW) rabbits.

**MATERIALS AND METHODS**

**Experimental design and dietary treatment:**
This work was carried out at Research and Production Station, National Research Centre (NRC) located in El-Emam Malik Village, El-Bostan, west of Nubaria and at laboratories of Animal Production Department, NRC. Sixty male NZW rabbits post-weaning with an average body weight of 698 ± 67 g were used. The basal experimental diet was formulated and pelleted to cover the nutrient requirements of rabbits according to NRC (1977) as shown in Table (1). The experimental groups were classified as follows: the 1st group fed on only basal diet (0.0% FS), the 2nd group fed the basal diet with inclusion 4% FS, the 3rd group fed the basal diet with inclusion 6% FS and the 4th group fed basal diet with inclusion 8% FS.

| Item                      | Diets inclusion FS at the levels of |
|---------------------------|-----------------------------------|
| Ingredients               | 0%   | 4%   | 6%   | 8%   |
| Clover hay                | 24   | 25   | 26   | 26.4 |
| Yellow corn               | 20   | 19.4 | 17   | 16   |
| Barley grain              | 15.9 | 12   | 10   | 9    |
| Wheat bran                | 22.5 | 23   | 25.4 | 26   |
| Soybean meal (44% CP)     | 14.5 | 13.5 | 12.5 | 11.5 |
| Flaxseeds (FS)            | -    | 4    | 6    | 8    |
| Limestone                 | 1.7  | 1.7  | 1.7  | 1.7  |
| Di-Ca-phosphate           | 0.7  | 0.7  | 0.7  | 0.7  |
| DL-methionine             | 0.1  | 0.1  | 0.1  | 0.1  |
| Vit. & min. mixture*      | 0.2  | 0.2  | 0.2  | 0.2  |
| Sodium chloride           | 0.3  | 0.3  | 0.3  | 0.3  |
| Anti-fungal agent         | 0.1  | 0.1  | 0.1  | 0.1  |
| Total                     | 100  | 100  | 100  | 100  |

* Vit. & Min. mixture: Each kilogram of Vit. & Min. mixture contains: 2000,000 IU Vit. A, 150,000 IU Vit.D, 8.33 g Vit.E, 0.33 g Vit.K, 0.33 g Vit.B1, 1.0 g Vit.B2, 0.33 g Vit.B6, 8.33 g Vit.B5, 1.7 mg Vit. B12, 3.33 g pantothenic acid, 33 mg biotin, 0.83 g 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.

Rabbits were housed in individual wire cages (30 x 35 x 40 cm) and divided into 4 equal groups divided into 3 replicates, 5 rabbits each. Stainless steel nipples for drinking and feeders allowing for each cage and feed intake was determined for each replicate.

Feed and water were offered ad libitum. Rabbits of all groups were kept under the same administrative conditions as well as average body weight and feed consumption was recorded biweekly during the experimental period.

All rabbits were used in digestibility trials over 7 days to determine the nutrient digestibility coefficients and nutritive values of the tested diets. Feed intake of experimental rations and weight of
feces were recorded daily. Representative samples of feces were dried at 60°C for 48 hrs, grinded and stored for chemical analysis later.

Chemical analysis of experimental rations and feces were analysed according to AOAC (2000) methods. To determine the carcass measurements, three representative rabbits from each treatment were at a similar average weight and fasted for 12 hours before slaughtering according to Blasco et al. (1993). These were removed and individually weighed.

Full and empty weights of the digestive tract were recorded and digestive tract contents were calculated by differences between full and empty digestive tract. Weights of edible and external offal’s were calculated as percentage of slaughter weight (SW). The hot carcass was weighed and divided after head separation into the front and hind parts. The 9th, 10th and 11th ribs were frozen in polyethylene bags for later chemical analysis.

Blood samples were collected at the end of the experiment in heparinized tubes at slaughtering time (3 rabbits/group), and centrifuged at 3000 rpm for 15 minutes to separate clear serum which stored at -20°C for determination of some blood constituents as total lipids (TL), total cholesterol (TC), triglyceride (TG), total protein (TP), alkaline phosphatase, aspartate amino transferase (AST) and alanine aminotransferase (ALT) by spectrophotometer using available commercial kits. Globulin was calculated by subtracting the albumin from the total protein value (Doumas et al., 1971). The serum fatty acids were measured using gas chromatography according to the method described by Frakas et al. (1980).

Statistical analysis:

Collected data were subjected to statistical analysis as a one-way classification analysis of variance using the general linear model procedure of SPSS (1998). Duncan’s Multiple Range Test (Duncan, 1955) was used to separate means when the dietary treatment effect was significant.

RESULTS AND DISCUSSION

Chemical analysis of flaxseed and the experimental rations:

Chemical analysis of the experimental rations is presented in Table (2). The results showed that flaxseed has high contents of CP and EE while low content of NFE. Variation in these results may show that the structure of flaxseed species can vary based on planting process, analysis, environmental factors and diversity (Daun et al., 2003; Morris, 2008 and Maddock et al., 2005). All flaxseed treatments at the different levels used 4, 6 and 8 % in rabbit rations are almost in iso-caloric and iso-nitrogenous, but the EE and NFE percentage increased as the proportion of flaxseed in the diets increases (Table 2). These

| Item | flaxseed whole | Diets inclusion FS at the levels of (%)  |
|------|----------------|----------------------------------------|
|      |                | 0% | 4% | 6% | 8% |
| DM   | 90.50          | 91.55 | 91.00 | 92.06 | 91.54 |
| OM   | 93.60          | 91.20 | 91.33 | 91.11 | 91.01 |
| CP   | 23.50          | 16.33 | 16.58 | 16.66 | 16.63 |
| CF   | 11.60          | 12.17 | 12.70 | 13.21 | 13.48 |
| EE   | 31.00          | 3.50 | 4.14 | 4.68 | 5.21 |
| NFE  | 27.50          | 59.20 | 57.91 | 56.56 | 55.69 |
| Ash  | 6.40           | 8.80 | 8.67 | 8.89 | 8.99 |
| GE** (Kcal/KgDM) | 5864 | 4214 | 4256 | 4277 | 4299 |
| DE*** (Kcal/KgDM) | 2950 | 2586 | 2587 | 2539 | 2515 |

** Gross energy (GE) was 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) was calculated according to Fekete and Gippert (1986) using the following equation: DE (kcal/kg DM) = 4253 – 32.6 (CF %) – 144.4 (total ash %).
results showed that as the level of flaxseed in ration increased, the proportion of EE and CF tend to increase while its content of nitrogen-free extract decreased.

**Effect of FS levels on rabbit’s digestibility:**

Feeding FS at the 8% level significantly decreased the digestion coefficients as DM, OM and CF while significantly increased the digestion coefficients as EE and NFE compared to the control group (Table 3). These results may be due to the high levels of mucilage that modifies the enteric microflora activity (Martinchik et al., 2012). The significant decrease of dry matter, organic matter and crude fibre digestibility may be due to the effect of FS mucilage on the proliferation of epithelial cells which have a direct impact on the digestive and absorptive function of the small intestine (Wang et al., 2019). Decreasing the digestion coefficients at the 8% level of FS probably due to the viscous nature of the linseed and its interference with the digestion and absorption of fat (Kristensen et al., 2013).

The significant (P<0.05) increase of EE and NFE digestibility at the 8% level may be due to the polyphenols in FS (Singh et al., 2011) which can induce the alteration in the microbial composition of the intestine as a contributing this effect (Fiesel et al., 2014). In other words, the flavonoids in FS (Zuk et al., 2011) may be affecting to increase the EE digestibility in ruminants (Hassan et al., 2020). The significant (P<0.05) increase of EE and NFE digestibility at the 8% level may be due to the formula that as the fat intake in FS increased the excretion of internal fats in the stool decreased in less effect on the calculated apparent digestibility (Van Manen et al., 1989). With increasing the dietary linseed percentage the digestibility of EE increased (Peiretti et al., 2007). This discrepancy between different studies may be not only due to the utilized lipid sources and the level of rabbit’s digestibility, but could also be attributed to animal species (Huo et al., 2019). In other words, increased EE and NFE digestibility with higher supplemented fat diets 8% FS in this study may be a result of the reduced DM intake observed with the added more FS diets as showed in ruminant by Haddad and Yonis (2003). A similar result is consistent with El Hag et al. (1985), who observed an increase in EE digestion when 10% tallow was added to sheep diets.

| Item                        | Dry matter intake, g/h/d | Nutrients digestibility,%: | Diets inclusion FS at the levels of | ±SE | Sig |
|-----------------------------|--------------------------|----------------------------|-----------------------------------|-----|-----|
|                             |                          |                            | 0%                                |     |     |
|                             |                          |                            | 4%                                |     |     |
|                             |                          |                            | 6%                                |     |     |
|                             |                          |                            | 8%                                |     |     |
|                             |                          |                            | ±SE                               |     |     |
| Dry matter intake, g/h/d    | 95.97                    | 91.61                      | 82.76                             | 61.39 | 1.86 |
| Nutrients digestibility,%:  |                          |                            | 3.07                              |     |     |
| DM                          | 78.38                    | 73.18                      | 61.72                             | 61.39 | 3.27 |
| OM                          | 80.27                    | 74.75                      | 64.35                             | 63.81 | 3.27 |
| CP                          | 78.89                    | 78.84                      | 69.24                             | 66.21 | 3.66 |
| CF                          | 49.30                    | 41.04                      | 40.45                             | 32.12 | 2.72 |
| EE                          | 72.43                    | 75.00                      | 82.51                             | 85.95 | 2.74 |
| NFE                         | 69.56                    | 79.70                      | 81.06                             | 83.89 | 2.09 |
| Feeding value,%:            |                          |                            |                                   |     |     |
| TDN                         | 74.41                    | 72.72                      | 67.98                             | 63.96 | 2.00 |
| DCP                         | 13.00                    | 12.94                      | 11.44                             | 11.10 | 0.64 |

*a and b* means in the same row within each treatment having different superscripts differ significantly at P<0.05. SE: standard error of the mean. NS: non-significant. *: P<0.05.

**Effect of FS levels on the rabbit’s growth performance:**

Feeding FS at the 6 or 8% level in rabbit rations significantly (P<0.05) decreased the daily feed intake compared to the control group (Table 4). This result may be due to the FS gel may be slowing down the emptying of the stomach and slightly effect on appetite (Kristensen et al., 2011). The gradual decrease of the daily feed intake at the three levels used of FS probably due to the secoisolariciresinol diglucoside (SDG) which enhances the production of leptin enzyme that reduces the feed intake (Orzechowski et al., 2002). As well as the protease inhibitors (e.g., trypsin inhibitors) as anti-nutritional compounds in FS may decrease the protein absorption and consequently diminish the growth performance (Cardoso et al., 2012). A similar result showed that supplementation of different types of fats did not influence animal performance in Dorper sheep (Behan et al., 2019).
Feeding FS at the 6 or 8% level in rabbit rations decreased the daily weight gain compared to the control group (Table 4). The reduction in growth performance may be due to the phytic acid effect in FS that binds proteins and minerals decreasing the bioavailability (Robert et al., 2017). On the other hand, the flaxseed lignin may have a direct relation to health improvement via both pangs of hunger suppressed (Martinchik et al., 2012). Also, probably due to the FS mucilage that absorbs water that increases the intestinal viscosity causing a laxative effect result in reduced performance (Alzueta et al., 2003). Some authors have linked the presence of toxins in whole flaxseeds with reduced energy use and thus poor growth rates (Bianchi et al., 2006). Similar studies showed that rabbits fed diets containing whole flaxseed and fully extruded flaxseed had a low growth rate (Colin et al., 2005 and Bianchi et al., 2006).

The reduction in growth performance probably due to the mucilage percentage that modifies the enteric microflora activity producing several unfavourable changes in the gastrointestinal tract which slows down the emptying of the stomach, slightly affected appetite, palatability and feed intake (Martinchik et al., 2012). In other words, these results may be due to the flaxseed characterize within fibre crops by a genotype for heavy metal tolerance or accumulation (Lawrence et al., 2004). The reduction in growth performance may be due to the FS constipation effect as shown in sows (Whetsell et al., 2008). Some authors have linked the presence of toxins in whole flaxseeds with reduced energy use and thus poor growth rates (Bianchi et al., 2006). Similar studies showed that rabbits fed diets containing whole flaxseed and fully extruded flaxseed had a low growth rate (Colin et al., 2005 and Bianchi et al., 2006).

Table (4): Growth performance as affected by different levels of FS in ration of rabbits.

| Item                   | Diets inclusion FS at the levels of |
|------------------------|-------------------------------------|
|                        | 0% | 4% | 6% | 8% | ±SE | Sig |
| Initial weight (kg)    | 0.696 | 0.699 | 0.688 | 0.706 | 0.18 | NS |
| Final weight (kg)      | 2.140 | 2.110 | 1.998 | 1.866 | 0.81 | NS |
| Final gain weight (kg) | 1.444 | 1.411 | 1.310 | 1.160 | 0.73 | NS |
| Daily weight gain (g)  | 25.8 | 25.2 | 23.4 | 20.7 | 3.05 | NS |
| Feed intake (kg)       | 4.66a | 4.55a | 4.24b | 4.02b | 0.89 | *  |
| Daily feed intake (g)  | 83.2a | 81.3a | 75.7b | 75.0b | 5.82 | *  |
| Feed conversion ratio g DMI/g gain | 3.23 | 3.23 | 3.24 | 3.62 | 2.66 | NS |

**Means in the same row within each treatment having different superscripts differ significantly at P<0.05. SE: standard error of the mean. NS: non-significant. *: P<0.05.**

**Effect of FS levels on the rabbit’s carcass characteristics:**

Feeding flaxseed at the three levels (4, 6 and 8 %) in rabbit rations significantly (P<0.05) decreased the long dorsal fat and pre-renal fat weight compared to the control group (Table 5). These results may be due to the high proportion of lignin fibres “secoisolariciresinol diglycoside” which are responsible for the reduction of visceral fat mass (Fukumitsu et al., 2008 and Park and Velasquez, 2012). On the contrary, some results showed that the fat thickness of the FS group was greater (P>0.05) than the other groups.

Table (5): Carcass characteristics as affected by different levels of FS in ration of rabbits.

| Item                   | Diets inclusion FS at the levels of |
|------------------------|-------------------------------------|
|                        | 0% | 4% | 6% | 8% | ±SE | Sig |
| Live body weight (g)   | 2032 | 2031 | 2034 | 2036 | 19.5 | NS |
| Slaughter wt (g)       | 1228 | 1256 | 1261 | 1290 | 70.50 | NS |
| Digestive tract wt (g) | 234 | 227 | 225 | 222 | 5.70 | NS |
| Long dorsal fat wt (g) | 55.3a | 50.3b | 49.3b | 45.3c | 3.85 | *  |
| Prerenal fat wt (g)    | 21.7a | 19.0b | 16.0c | 13.7d | 2.85 | *  |
| Head (g)               | 165.0 | 165.7 | 165.7 | 164.3 | 2.01 | NS |
| Heart (g)              | 7.3a | 8.4b | 8.9b | 9.8a | 0.70 | *  |
| Liver (g)              | 74.7b | 76.7b | 79.0ab | 82.3a | 3.92 | *  |

**Effect of FS levels on the rabbit’s carcass characteristics:**

Feeding flaxseed at the three levels used (4, 6 and 8 %) in rabbit rations significantly (P<0.05) increased the heart weight (Table 5). This result probably due to the biologically...
active substances in FS, such as lignin, fibres and linoleic acid which provide the cardioprotective effects (Prim et al., 2012). Feeding FS at the three levels used in rabbit rations slightly increases the liver weight (Table 5). This result probably due to that the oil in FS which can increase the concentrations of the n-3 fatty acid ALA in liver tissue (Barceló and Murphy, 2009). In other words, the essential amino acids in FS are of great importance in the synthesis of protein which contributes to the repair and maintenance of cells, tissues and organs (Omoni and Aluko, 2006).

Chemical analysis of the 9th, 10th and 11th ribs fed the experimental ration:

Feeding FS at 6 or 8% level significantly (P<0.05) increased the chemical analysis on DM basis of CP while significantly (P<0.05) decreased the EE in the meat ribs compared to the control group (Table 6). These results probably due to the changes in the lipid composition of the diet being able to alter the protein content of meat (Bourre, 2004). We can conclude that FS in rabbit diets improved the nutrition value of rabbit meat. On the contrary, flaxseed at 5% or 7.5%, did not affect the total lipid content in thigh tissues (Roth-Maier et al., 1998). In general, feeding flaxseed tends to increase meat quality parameters such as the marbling score (Maddock et al., 2005 and 2006).

Table (6): Chemical analysis of 9th, 10th and 11th ribs as affected by different levels of FS in ration of rabbits.

| Item                      | Diets inclusion FS at the levels of | 0%  | 4%  | 6%  | 8%  | ±SE  | Sig |
|---------------------------|------------------------------------|-----|-----|-----|-----|------|-----|
| Chemical analysis on DM basis: |                                    |     |     |     |     |      |     |
| CP                        |                                    | 57.17<sup>b</sup> | 60.07<sup>b</sup> | 64.60<sup>a</sup> | 64.97<sup>a</sup> | 2.05 | *   |
| EE                        |                                    | 35.37<sup>a</sup> | 32.46<sup>a</sup> | 25.27<sup>b</sup> | 25.06<sup>b</sup> | 1.93 | *   |
| Ash                       |                                    | 7.46<sup>b</sup>  | 7.47<sup>b</sup>  | 10.13<sup>a</sup> | 9.97<sup>a</sup>  | 0.28 | *   |

<sup>a</sup><sup>and</sup><sup>b</sup>: means in the same row within each treatment having different superscripts differ significantly at P<0.05. SE: standard error of the mean. NS: non-significant. *: P<0.05.

Effect of FS levels on the rabbit’s blood parameters:

Feeding flaxseed at different levels (4, 6 and 8 %) in rabbits significantly (P<0.05) decreased triglycerides, total cholesterol and total alkaline phosphatase compared to the control group (Table7). The decreased value of triglycerides probably due to the high soluble mucilage fibre lignin content of FS (about 28% by weight) may have yielded the reduction attenuated cholesterol values (Pan et al., 2009).

Table (7): Blood serum constituents as affected by different levels of FS in ration of rabbits.

| Item                      | Diets inclusion FS at the levels of | 0%  | 4%  | 6%  | 8%  | ±SE  | Sig |
|---------------------------|------------------------------------|-----|-----|-----|-----|------|-----|
| Albumin (g/dl)            |                                    | 3.37 | 3.22 | 3.01 | 3.48 | 0.42 | NS  |
| Globulin (g/dl)           |                                    | 2.26 | 2.10 | 2.79 | 2.62 | 0.43 | NS  |
| Total protein (g/dl)      |                                    | 5.63 | 5.32 | 5.80 | 6.10 | 0.35 | NS  |
| Triglycerides (mmol/l)    |                                    | 2.36<sup>a</sup> | 1.47<sup>b</sup> | 1.39<sup>b</sup> | 1.35<sup>b</sup> | 0.56 | *   |
| Total cholesterol (mmol/l)|                                    | 16.8<sup>a</sup> | 14.5<sup>a</sup> | 12.6<sup>b</sup> | 11.4<sup>b</sup> | 1.87 | *   |
| Alkaline phosphatase (U/l)|                                    | 66.6<sup>a</sup> | 52.7<sup>b</sup> | 53.8<sup>b</sup> | 55.4<sup>b</sup> | 2.33 | *   |
| AST (U/l)                 |                                    | 94.7<sup>a</sup> | 86.4<sup>a</sup> | 69.6<sup>b</sup> | 65.2<sup>b</sup> | 3.51 | *   |
| ALT (U/l)                 |                                    | 33.7 | 33.6 | 32.9 | 32.7 | 1.35 | NS  |

<sup>a</sup> and <sup>b</sup>: means in the same row within each treatment having different superscripts differ significantly at P<0.05. SE: standard error of the mean. NS: non-significant. *: P<0.05.

While, the reduction of cholesterol concentrations may be attributed to the essential omega-3 fatty acid (Dupasquier et al., 2007). Similar results showed a significant reduction in triglycerides, total cholesterol
Feeding flaxseed at the 6 and 8 % levels in rabbit rations significantly (P<0.05) increased the α-linolenic acid (ALA), eicosapentaenoic acid and palmitic acid levels (Table 8). These results showed that FS enriched diets with free fatty acids expression in the rabbit serum blood. This result probably due to the long period (56 days) of an experiment is more efficient at increasing ALA content in rabbit meat. A similar result showed that feeding higher levels of flaxseeds for shorter periods versus lower levels for longer periods is more efficient at increasing ALA content in pig meat (Juarez et al., 2010). Feeding ground flaxseeds slightly modifies the long-chain fatty acid profile in the rib eye, by increasing both linoleic (C18:2) and alpha-linolenic (C18:3) acids (LaBrune et al., 2008), as well as the unsaturated fatty acids in the muscle (Maddock et al., 2005). A similar result showed that both raw and processed flaxseed increased fatty acids (saturated or unsaturated) content but decreased or had no effect on short to medium-chain fatty acids and on longer chain fatty acids in milk (Glasser et al., 2008). Feeding on flaxseed at the 6 and 8 % levels in rabbit rations significantly (P<0.05) reduced the arachidonic acid (Table 8). Similar results in blood and tissues are reported by Gotoh et al. (2007). Our results showed that feeding FS in rabbit ration improved the nutritional value of rabbit meat as showed by Kouba et al. (2008). This study confirmed that dietary FS could be considered as a way of enriching the n-3 PUFA in a rabbit. Similar results showed that most of the saturated fatty acids decreased with increasing flaxseed levels except C18:0 while unsaturated fatty acids increased (Hurtad et al., 2010).

Effect of FS levels on the rabbit’s serum fatty acid:

Feeding flaxseed at the 6 and 8 % levels in rabbit rations significantly (P<0.05) increased the α-linolenic acid (ALA), eicosapentaenoic acid and palmitic acid levels (Table 8). These results showed that FS enriched diets with free fatty acids expression in the rabbit serum blood. This result probably due to the long period (56 days) of an experiment is more efficient at increasing ALA content in rabbit meat. A similar result showed that feeding higher levels of flaxseeds for shorter periods versus lower levels for longer periods is more efficient at increasing ALA content in pig meat (Juarez et al., 2010). Feeding ground flaxseeds slightly modifies the long-chain fatty acid profile in the rib eye, by increasing both linoleic (C18:2) and alpha-linolenic (C18:3) acids (LaBrune et al., 2008), as well as the unsaturated fatty acids in the muscle (Maddock et al., 2005). A similar result showed that both raw and processed flaxseed increased fatty acids (saturated or unsaturated) content but decreased or had no effect on short to medium-chain fatty acids and on longer chain fatty acids in milk (Glasser et al., 2008). Feeding on flaxseed at the 6 and 8 % levels in rabbit rations significantly (P<0.05) reduced the arachidonic acid (Table 8). These results may be due to the ability of flaxseed oil to attenuate liver injury by reducing ALT and AST levels (Chen et al., 2015) as well as altered gut microbiota and the decrease of liver inflammation (Zhang et al., 2017) as well as may due to the lack of inflammation (Chen et al., 2015).

Table (8): Serum fatty acids profiles as affected by different levels of FS in ration of rabbits.

| Item                  | Lipid numbers | Diets inclusion FS at the levels of | ±SE | Sig |
|-----------------------|---------------|------------------------------------|-----|-----|
| Arachidonic acid      | C20:4n-6      | 3.14 ± 0.92                         | 0.15* |     |
| Eicosapentaenoic acid | C20:5n-3      | 0.18 ± 0.10                         | 0.10* |     |
| Palmitic acid         | C16:1n-7      | 0.44 ± 0.13                         | 0.13* |     |
| Stearic acid          | C18:1n-9      | 42.51 ± 0.78                        | 4.50 NS |   |
| Linoleic acid         | C18:2n-6      | 9.99 ± 0.15                         | 0.64 NS |   |
| Alpha-linolenic acid  | C18:3n-3      | 0.92 ± 0.15                         | 0.15* |     |

*: means in the same row within each treatment having different superscripts differ significantly at P<0.05.
SE: standard error of the mean. NS: non-significant. *: P<0.05.

CONCLUSION

Feeding flaxseeds at 6 and 8% of the total rabbit ration was considered to be of high levels, leading to a decrease in growth performance and digestion coefficient, while slightly improving the fatty acid profile. Our suggestion under these circumstances is to use the lower level of 4% in rabbit feeding, flaxseeds are used to increase the diet content in omega-3 fatty acids, mostly alpha-linolenic acid.

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تأثير إدخال مستويات مختلفة من بذور الكتان في العقاقير على قابلية الهضم وآداء النمو ومقياس الدم وخصائص الأسماك

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يهدف هذا البحث إلى دراسة تأثير إدخال مستويات مختلفة من بذور الكتان في عقاقير الأرانب النامية وتأثير إدراج هذه المستويات على مظاهاة النمو والأداء الفيزيولوجي، ومقياس الدم وخصائص الدم الناجمة.

- المجموعة الأولى: غذت على العقليه الأساسية.
- المجموعة الثانية: غذت على العقليه الأساسية مع إدراج بنور الكتان في العقليه بنسبه 4%.
- المجموعة الثالثة: غذت على العقليه الأساسية مع إدراج بنور الكتان في العقليه بنسبة 6%.
- المجموعة الرابعة: غذت على العقليه الأساسية مع إدراج بنور الكتان في العقليه بنسبة 8%.

وكانت النتائج كما يلي:

ادي إدخال بنور الكتان في العقليه بنسبه 6% إلى انخفاض في معملات هضم المادة الفضية والمواد يمكنية مقاورة بالمجموعة الأولى على النسبة الأساسية.

ادي إدخال بنور الكتان في العقليه بنسبه 8% إلى انخفاض في معملات هضم الألياف والمستخلصات الخالية من الأزوت مقاورة بالمجموعة الأولى على النسبة الأساسية.

أدت تغذية بذور الكتان بنسبة 6% و8% إلى انخفاض كبير في كمية المكلوك اليومي ومستوى النمو اليومي مقاورة بالمجموع.

ساهمت المداريات الثلاثة المحمولة على بذور الكتان نسبة 4,6,8% من العقليه لانخفاض معنوي في محتواها من الدهون في العقليه المحمولة بالبحوث المحصول والدهون الثلاثية والكولسترول الكلي مقاورة بالمجموع.

أدت التغذية بإدخال بنور الكتان في عقاقير الأرانب بنسبة 6 و7% إلى زيادة معنوية في مستويات حمض الديونيل (أوميغا 6) والفاينوليك (أوميغا 3) وحمض البلانتيك وكذلك حمض الأشادونيك.

أدت تغذية بنور الكتان بنسبة 6% من عقليه الأرانب زيادة معنوية في العقليه الإجمالية المحمولة.

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