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EFFECT OF FLAXSEED ENRICHMENT ON QUALITY ATTRIBUTES OF RABBIT MEAT AND MEAT PRODUCT

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ABSTRACT

Rabbit is reared in rural areas of Pakistan under backyard farming system for local consumption to get meat and fur. Quality characteristics of rabbit meat make it more nutritious with game animal taste, light flavor and also with firmer meat texture. For improvement of nutritional profile, fatty acid composition, the current study was carried out to investigate the dietary responses of flaxseed from 3.5 – 7 %. The treatment plan was as (T0 = control feed, T1 = 7 % flaxseed/kg feed, T2 = 3.5 % flaxseed/kg feed). Growth parameters like weight gain and feed intake were significantly increased by dietary supplementation of flaxseed. The rabbits fed on 7 % level of linseed gained maximum weight while the lowest body weight gain was found in rabbits fed on control (T0). The FCR was found significantly higher in rabbits fed on control (T0) and lowest FCR was found in broilers fed on 7 % linseed (T3). Poly unsaturated fatty acid ratio was higher over saturated fatty acid in T1 as compared to other supplemented group. The poly unsaturated fatty acids were observed significantly higher in loin and hind leg meat of rabbits fed on 7 % linseed (T1). The nuggets made from meat of group fed on highest level of linseed 7 % (T3) showed higher pH with storage intervals, higher water activity, higher color values and texture. Sensory evaluation was carried out by applying nine point hedonic scales by trained panelist who preferred loin rabbit nuggets of T1 which showed highest acceptance to consumer having light flavor and nice appearance

Key words: Rabbit; rabbit meat; flaxseed enrichment; n-3 PUFA; rabbit meat nuggets.

INTRODUCTION

A functional food can be a natural food, a food to which an element has already been added, or perhaps a food in which a constituent can be excluded through technological or even biotechnological indicates. It can also be a food, in which the nature of a number of constituent can be modified, or the food where the bioavailability of a number of constituent may be modified, or any mixture of these options (Hernández, 2008). Functional foods are categorized in to two primary classes based on the anticipated effects: those planning to enhance physical roles, and aiming of people to slow up the danger of particular pathologies. Within both instances, it should stay meals, and this must show its results in quantities in general likely to be frenzied within the food (Diplock *et al.,* 1999). The nutritional worth of meat comes with a rising significance one of the factors identifying customer acceptability and meat high quality. Certainly, meat is really a major supply of proteins as well as essential amino acids. It is a source associated with mineral deposits, group B vitamins, and additional biologically active substances. Though, meat can be a chief supply of cholesterol and saturated essential fatty acids and its consumption might be associated with CVDs illnesses, diabetes, hypertension and overweight (Valsta *et al.,* 2005).

There are numerous techniques with regard to introducing quantitative and qualitative adjustments in meat as well as derivatives of meat to attain a much more purposeful meat and meat products. The enhancement of meat and meat products practical worth is possible in the following ways: 1. With the addition of functional compounds, for example CLA (Conjugated Linoleic Acid), vitamin, ω-3 essential fatty acids, as well as Se into animal diet programs; 2. Through the addition of practical ingredients, for example vegetable proteins, herbal treatments, fibers, herbs, spices and lactic acid germs as well as probiotics into meat items throughout handing out; 3. Through favoring actual manufacturing associated with functional elements (particularly biologically active peptides) throughout dispensation as well as enzyme hydrolysis (Zhang *et al.,* 2010).Within last 50 years, world rabbit meat manufacturing have elevated by three fold as much as 2.6 million tons last year. China happens to be the planet's leading maker (seven hundred, thousands tones/year) as well as France 51,400 tones/year would be the chief rabbit meat suppliers in European countries (FAOSTAT, 2010). Even though rabbit meat provides outstanding dietary and dietetic attributes, it may be supplementary prepared with biologically active constituents to acquire meat regarded as functional: rabbits feeding along with diets that are supplemented with high polyunsaturated fatty acids or even elongated chains of ω-3 fatty acid material (linseed-

entire or even oil, Oat as well as barley and fish essential oil) enrich actual meat along with essential fatty acids, bioactive type of ω-3 fatty acids. Since fatty acid profile of the muscle linearly react to that from the actual feed. Optimum four percent linseed in rabbit diet may be viewed as sufficient in order to both accomplish the enrichment associated with ω-3 fatty acid and gaze after good item quality (DalleZotte and ZsoltSzendrő, 2011). The diets based on grass play a key role in changing rabbit meat fatty acidity composition. Forrester-Anderson *et al.,* (2006) advised that the diets based on grass fed in order to reared rabbits outside on meadow altered the actual fatty acidity profile, improving ω3 fatty acid contents. Vannini *et al.,* (2003) showed that the dietary supplements of entire linseeds restricted the development rate associated with several microbial organizations (other than psychrotrophic germs) having a consequent improves in meat shelf existence. In addition, dehydrated alfalfa dinner at higher percentages within the diet appears to also come with an inhibiting impact on microbial development in rabbit meat items (Vannini *et al.,* 2002). The objective of this study was to explore the effect of dietary use of whole linseed (upto 7%) on growing rabbitsand quality of meat and meat product (nuggets).

MATERIALS AND METHODS

Rabbits, diet and management: Research was carried out in order to explore the influence of various inclusion levels of whole linseed (up to 7%) in diets for growing rabbits on composition offatty acids, susceptibility to lipid oxidation, and sensory quality of the meat product. A total of four hundred and fifty rabbits of New Zealand White strains (30±5 days) were purchased from National Institute of Health Islamabad, Pakistan and divided into three groups. The rabbits were housed in separate cages of the animal room and the cages were disinfected by using fumigation method. The room temperature was maintained at 25 ºC. The experimental diets were formulated to meet the nutritional requirements of growing rabbits and whole linseed was given in two proportions 7 % and 3.5 % as indicated in Table of feed composition of the diet. Diet was only differed in the amount of whole linseed. Rabbits were fed ad libitum until 8 weeks.

Slaughtering and sample collection: At the end of the 8 weeks, the rabbits were slaughtered following the national regulations applied to commercial slaughtering and sampling of loin and hind leg meat was done. Rabbits were slaughtered at the farm by cervical dislocation and then the meat was stored at −4 °C in a refrigerator (Sanyo, Japan) for further analysis. The blood samples were also collected from the jugular vein and stored in the heparinzed blood sample tubes at -18 ºC.

Measurements: Individual feed consumption (FC) was measured on week basis for all rabbits from 30 days of age until 12 weeks of age. This was obtained by the difference between food distributed at the beginning of the week and refused food removed at the end of the week. Animals were individually weighed on weekly basis. The feed conversion ratio (FCR) was estimated between 30 days of age and 12 weeks.

Physico-Chemical Analysis of meat: The pH of the meat was measured by using pH meter following the method as described by Sallama *et al.,* (2004). Ten gram of sample was homogenized with 50 mL distilled water and pH value was measured by a digital pH-meter. The water activity of meat was determined by using an electronic Hygropalm water activity meter (Model Aw-Win, Rotronic, equipped with a Karl-Fast probe) by following the method as described by Cosenza *et al.,* (2003). The protein and fat analysis was determined by kjeldhal method as described in AOAC (2000). The textural characteristics of meat was analyzed using a Texture Analyzer (model TA_XT Plus, Stable Microsystems, Surrey, UK) by adopting the method as described by Carlos *et al.,* (2009).

Fatty acids Profile: The fatty acids content of each sample was determined by running samples through GC (Agilent Technologies 6890 N) using Flame Ionization Detector. Nitrogen gas was used as a carrier with flow rate of 1.3 ml/ min. The fatty acid profile was estimated according to the method described by AOCS (1998).

Table 1. Formulation of rabbit feed.

Ingredients (%)	T0	T1	T2
Alfalfa Fresh	65.00	62.00	64.00
Flaxseed	0.00	7.00	3.50
Soyabean meal (44 %)	30.00	26.00	27.50
Calcium-phosphate	1.35	1.35	1.35
Vitamin mineral premixa	1.20	1.20	1.20
Molasses	1.00	1.00	1.00
Salt	0.70	0.70	0.70
Calcium-carbonate	0.70	0.70	0.70
DL-methionine	0.05	0.05	0.05
Total	100	100	100
CP	15.87	15.59	15.53
GE MJ/Kg DM	15.20	15.83	15.90

Product development: Rabbit meat was utilized in the preparation of nuggets as method described by Perlo *et al*. (2006). The basic recipe of the nuggets is as (rabbit boneless 500 g, oil as required for frying, Egg 1, Black pepper 12 g, Plain flour 120 g, Onion 100 g, Garlic paste 10 g, salt 20 g, Bread crumbs 70 g). Nuggets were vacuum sealed in plastic bags and then stored at −18 °C in a freezer and analyses were done after every 15 days interval.

Physico-Chemical Analysis of Nuggets: The pH of the nuggets was measured by using pH meter following the method as described by Sallama *et al.,* (2004). Ten gram of sample was homogenized with 50 mL distilled water and pH value was measured by a digital pH-meter. The water activity of Nuggets was determined by using an electronic Hygropalm water activity meter (Model Aw-Win, Rotronic, equipped with a Karl-Fast probe) by following the method as described by Cosenza *et al.*, (2003). The protein and fat analysis was determined by kjeldhal method as described in AOAC (2000). The textural characteristics of nuggets was analyzed using a Texture Analyzer (model TA_XT Plus, Stable Microsystems, Surrey, UK) by adopting the method as described by Carlos *et al.,* (2009).

Measurement of TBA andPeroxide value: The TBA assay of nuggets was carried out after 15 days interval to determine the malonaldehyde produce during storage of the nuggets by following the method as described by Schmedes and Holmer, (1989). The Peroxide values (POV) of rabbit nuggets were determined peroxide milli equivalent/kg sample according to the method as described in AOAC International (2000).

Sensory evaluation: The sensory evaluation of fried nuggets was carried out for the different attributes like color, appearance, taste and texture by using nine point hedonic scale after 0, 15, 30 and 45 days of storage at -20 ^{o}C by trained panelists as the method described by Meilgaard *et al.,* (2007).

Statistical analysis: The data was statistically analyzed by Over the Year Design using two factors analysis of variance (ANOVA) for the growth parameters and three factors for the storage study of the rabbit meat, using software (Statistic 8.1). The comparison of means was done by the Duncan Multiple Range test (Steel *et al.*, 1997).

RESULTS AND DISCUSSION

Rabbit growth performance: Results presented in Table 2 showed that enrichment of 7 % flaxseed exerted highly significant effect on weight gain of rabbits. T2 that contains 3.5 % flaxseed also showed significant effect. Rabbits that fed on control diet gained minimum weight i.e 2143 gm at the end of 8 weeks trial. T1 fed on 7 % flaxseed showed maximum weight gain i.e 2334 gm at the end of trial. The feed conversion ratio (FCR) of the treatment T1 was 2.94 and the treatment T0 was 3.16. It means that the group containing flaxseed enrichment increased the performance of rabbit's growth as compared to control diet. The results of this study are against the findings of (Ajuyah *et al.,* 1993) who stated that chickens fed on a diet containing 15% whole linseed when compared with a control diet showed slightly lower live weight and poorer weight gain in broiler. Theyconcomitant the lesser growth rate to the existence of toxic compounds in raw whole flaxseed that depressed utilization of energy.

Table 2. Rabbits weight gain on weekly basis in (g/week).

Weeks	w1	w2	w3	w4	w5	w6	w7	w8
T0	593±4.35	803±5.71	1048±6.91	1303±7.11	1538±8.24	1748±9.34	1948±10.01	2143±11.52
T1	609±3.68	844±4.83	1114±5.04	1394±6.21	1654±7.41	1889±8.57	2114±9.73	2334±10.95
T2	604±4.76	826±5.97	1083±6.23	1350±7.39	1597±8.63	1819±9.71	2031±10.81	2238±11.95
Means	602.0^{H}	824.3^{G}	1081.7^{F}	1349.0^{E}	1596.3^{D}	1818.7^{C}	2031.0^{B}	2238.3^{A}

Different superscripts in a row indicate significant difference between the means ($p \leq 0.05$)

More recently (Colin *et al.,* 2005) who used diets supplemented with extruded flaxseed, stated a reduced growth and lower live weight at slaughter in rabbits fed flaxseed. Theconfirmation was also stated by (Verdelhan *et al.,* 2005) who detected a reduced (-70g) live weight of rabbits at slaughter by using linseed oil in the diet. However, (Bernardini *et al.,* 1999) and (Dal Bosco *et al.,* 2004) did not detect any harmful effect of flaxseed on productive recitals of rabbits. But in our case we used on fresh alfalfa meal as a control diet hence these findings are in correlation with the findings of (Dal Bosco *et al.,* 2014) where rabbits fed on alfalfa gained minimum weight as compared to control.

Table 3. Feed Conversion Ratio (FCR) of the experimental rabbits

Weeks	w1	w2	w3	w4	w5	w6	w7	w8	Means
T0	1.71±0.08	2.13±0.01	2.47±0.06	2.98±0.05	3.44±0.03	4.01±0.07	4.17±0.08	4.37±0.08	3.16^{A}
T1	1.62±0.03	2.01±0.03	2.34±0.05	2.80±0.06	3.20±0.05	3.68±0.04	3.82±0.04	3.98±0.09	2.94^{C}
T2	1.67±0.05	2.06±0.04	2.40±0.02	2.88±0.05	3.33±0.02	3.83±0.06	3.99±0.06	4.18±0.05	3.05^{B}
Means	1.67^{H}	2.07^{G}	2.41^{F}	2.89^{E}	3.33^{D}	3.84^{C}	4.00^{B}	4.18^{A}	

Different superscripts in a row indicate significant difference between the means ($p \leq 0.05$)

Effects on physico-chemical analysis of loin and hind leg of rabbit meat: The results of physic-chemical analysis are depicted in table 4. Linseed enrichment has highly significant effect on pH values of both loin and hind leg meat. T2 showed maximum value i.e 5.98 and T0 showed minimum i.e 5.63 in case of loin meat while in case of hind leg values were 5.95 and 5.57 respectively. The results of this study are in correlation with the findings of (Benatmane *et al.,* 2011) that used linseed in the diet of rabbits. Water activities has non-significant effect in both loin and leg meats. Flaxseed exerted significant effect on protein percentage of both meats. T2 showed maximum protein percentage i.e 24.10 and control rabbits (T0) showed minimum values i.e 21.11 in case of hind leg meat the values were 23.76 and 20.86 respectively. T2 showed maximum values for fat percentage i.e 2.32 while T0 showed minimum21.11 in case of loin meat while the values are 4.55 and 3.41 respectively in the hind leg meat. The results of protein and fat are similar with the findings of (Pla *et al.,* 2004) that loin meat showed high percentage of protein and fat with respect to loin meat of rabbits. Flaxseed enrichment also showed significant effect on textural properties of both meats. T0 showed minimum value i.e 2.16 and T1 showed maximum i.e 2.84 in case of loin meat while the values are 1.79 and 2.64 in case of hind leg meat respectively.

Fatty acid composition: The fatty acid composition was melodramatically prejudiced by inclusion of dietary flaxseed in the diet. With respect to the main classes of fatty acids, the flaxseed resolute a higher content of polyunsaturated fatty acids of Loin and leg meat and lesser content of total saturated fatty acids as depicted in Table 5 (Bianchi *et al.,* 2006). Table 5 showed that enrichment of flaxseed raised the concentration of monounsaturated fatty acids (MUFA). T2 showed higher percentage i.e 29.42 in loin and 30.85 in case of hind leg. We also observed increasing levels of n-3 PUFA ($P < 0.001$) from control group (2.98 % in Loin and 5.10 % in leg meat) towards groups fed 7% flaxseed (T1) (5.38% in Loin and 8.13% in leg meat), 3.5 % flaxseed (T2) (3.55% in loin and 5.57% in leg meat). The enhanced contents of n-3 PUFA was ultimately because of the higher concentration of α-linolenic acid that epitomizes the key fatty acid of flaxseed (Bianchi *et al.,* 2009). Due to large concentration of n-3 PUFA, it was in a position to retard the n-6/n-3 PUFA ratio as evidenced in table 5. Though EPA and DHA concentration presented in both the loin and leg meat was not too much (About 0.1%) and it was not enhancing from control to T2 group showing the inadequate competence of α-linolenic acid renovation to the long chain n-3 PUFA in rabbits. As stated (Stanley *et al.,* 2007), n-6/n-3 PUFA ratio should not practice single-handedly as assessment index of the wholesome worth of rabbit meat. The efficiency of whole flaxseed to enhance the PUFA and α-linolenic acid concentrations of the meat has formerly been recounted by numerous studies on both rabbit (Bernardini *et al.,* 1999) and other species (Maertens *et al.,* 2008). Considering that 3.5% dietary flaxseed determined n-3 PUFA content of 8.13% of the total fatty acids in hind leg. It can be estimated a content of 396 mg n-3 PUFA/100g meat which represents about 19% of recommended daily allowance (RDA) for n-3 PUFA (EFSA *et al.,* 2009).

Physico-chemical analysis of nuggets: The pH results depicted in Table 6 showed that the treatments have highly significant effect on pH of the nuggets. At 0 day maximum value was observed in T3 i.e. 6.13 and minimum value was observed in T0 that is 5.70 in case of rabbit loin nuggets and in leg meat nuggets it was 6.03 and 5.65 in the same treatments. Table also showed that pH increased with the passage of time and at 45 days of storage the same trend was observed in the range of pH as it was at 0 day. Our findings are in agreement with the work of (Yadav and Sanyal, 1996; Devendra and Tanwar, 2011) who also observed increase in pH with the storage of nuggets. As storage period extends protein breakdown increase so pH increases in the nuggets.

In case of colour values treatments showed highly significant effect as lightness (L*), redness (a*) and yellowness (b*) values. Minimum value of L* was observed in T0 i.e 48.52 at 0 day in loin meat nuggets and 48.5 in hind leg meat nuggets while maximum value was seen in T1 (69.37) at 45 day storage and that was 69.36 in case of hind leg nuggets. It showed non-significant effect between both nuggets (loin, hind leg). Redness increased with passage of time. At 0 day minimum value was observed T1 (10.95) in loin and 10.92 in leg meat nuggets while maximum value was seen in T0 (15.13) and 15.11 in case of loin and hind leg nuggets respectively. Yellowness also increased with passage of time in all treatment it ranged from 7.31-14.39 in loin nuggets while in case of hind leg nuggets it was 7.29-14.63. Changes in colour values might be due to oxidation of fat content that decreased the shining of nuggets. Our results are in agreement with (Naveena *et al.,* 2008) who observed the color value of the chicken patties that declined with storage days and the patties color changed from red to brown that might be due to the development of metmyoglobin in the treatments.

Texture analyses as showed in Table 6 revealed that treatments have significant effect and interactive effect between treatment and storage was highly significant. As storage days increased textural values increased because of breakdown of protein linkage. These results are in correlation with the findings of (Ruiz *et al.,* 1999**)** who observed significant effect of storage on patties.

Table 4. Physico-Chemical Analysis of loin and hind leg of rabbit meat

	Loin					Hind leg				
Treatment	**pH**	**Aw**	**Protein**	**Fat**	**Texture**	**pH**	**Aw**	**Protein**	**Fat**	**Texture**
T0	5.63±0.02^{B}	0.85±0.01^{A}	21.11±0.07^{C}	1.61±0.05^{C}	2.16±0.04^{C}	5.57±0.02^{B}	0.87±0.02^{A}	20.86±0.01^{C}	3.41±0.05^{C}	1.79±0.02^{C}
T1	5.91±0.01^{A}	0.85±0.01^{A}	23.27±0.03^{B}	2.14±0.02^{B}	2.84±0.03^{A}	5.87±0.03^{A}	0.87±0.02^{A}	22.95±0.01^{B}	4.30±0.04^{B}	2.64±0.03^{A}
T2	5.98±0.02^{A}	0.84±0.01^{A}	24.10±0.05^{A}	2.32±0.05^{A}	2.64±0.03^{B}	5.95±0.02^{A}	0.87±0.02^{A}	23.76±0.01^{A}	4.55±0.02^{A}	2.41±0.02^{B}
Means	5.84	0.85	22.83	2.02	2.55	5.79	0.87	22.52	4.09	2.28

Different superscripts in a row indicate significant difference between the means ($p \leq 0.05$)

Table 5. Fatty acid profile (% of total fatty acid) and fatty acid ratio of selected fatty acid-related indexes

	Fatty acid profile of loin			fatty acid profile of leg		
Fatty acid composition (%)	T0	T1	T2	T0	T1	T2
C14,0	1.22	1.84	1.96	1.80	2.34	2.25
C16,0	27.93	26.99	26.87	25.74	24.21	23.91
C18,0	6.12	7.47	7.24	5.08	6.38	6.28
SFA	39.26	35.63	36.07	36.61	32.93	32.44
C14,1	0.07	0.03	0.20	0.13	0.08	0.06
C16,1	0.61	2.86	3.73	1.77	4.18	3.52
C18,1	23.03	24.73	25.48	24.57	26.09	27.27
MUFA	23.71	27.62	29.42	26.47	30.35	30.85
C18,2	22.82	23.06	24.13	24.02	24.47	26.95
C18,3	2.98	5.38	3.55	5.10	8.13	5.57
C20,3	0.44	0.26	0.30	0.33	0.16	0.12
C22,5	1.18	0.62	0.40	0.74	0.11	0.09
C22,6	0.23	0.15	0.19	0.25	0.17	0.11
PUFA	27.65	29.46	28.57	30.44	33.04	32.84
UFA	51.36	57.08	57.99	57.91	63.40	63.69
SFA/UFA	0.764	0.624	0.622	0.632	0.519	0.509
PUFA/SFA	0.704	0.827	0.792	0.831	1.003	1.012

Table 6. pH, Colour (L, a, b), Texture, Aw, TBA and POV of loin nuggets and leg nuggets stored at −18 °C

	Storage days										
	Rabbit Loin meat nuggets					Rabbit Leg meat nuggets					
Tr pH	**0 day**	**15 day**	**30 day**	**45 day**	**Means**	**Tr**	**0 day**	**15 day**	**30 day**	**45 day**	**Means**
T0	5.70±0.02	5.82±0.03	5.98±0.02	6.07±0.03	5.89^{C}	T0	5.65±0.03	5.77±0.03	5.93±0.01	6.02±0.03	5.84^{C}
T1	5.92±0.02	6.03±0.06	6.18±0.02	6.23±0.02	6.09^{B}	T1	5.95±0.04	6.06±0.02	6.16±0.04	6.18±0.05	6.09^{B}
T2	6.13±0.02	6.24±0.05	6.34±0.01	6.37±0.04	6.27^{A}	T2	6.03±0.03	6.14±0.03	6.29±0.04	6.34±0.04	6.20^{A}

Means	5.92^{D}	6.03^{C}	6.17^{B}	6.22^{A}		Means	5.87^{D}	5.99^{C}	6.13^{B}	6.18^{A}	
Colour											
Lightness (L*)											
T0	48.52±0.26	49.72±0.27	54.15±0.04	61.06±0.05	53.36^{B}	T0	48.5±0.26	49.7±0.27	54.12±0.04	61.05±0.05	53.34^{B}
T1	63.08±0.03	66.18±0.05	66.95±0.03	69.37±0.04	66.40^{A}	T1	63.06±0.03	66.16±0.05	66.92±0.03	69.36±0.04	66.34^{A}
T2	62.75±0.18	65.8±0.17	66.06±0.03	68.89±0.04	65.88^{A}	T2	62.73±0.18	65.78±0.17	66.03±0.03	68.88±0.04	65.86^{A}
Means	58.11^{D}	60.57^{C}	62.39^{B}	66.44^{A}		Means	58.09^{D}	60.55^{C}	62.36^{B}	66.43^{A}	
Redness (a*)											
T0	11.71±0.04	14.78±0.04	9.66±0.03	15.13±0.02	12.82^{A}	T0	11.68±0.04	14.75±0.04	9.63±0.03	15.11±0.02	12.79^{A}
T1	10.95±0.02	13.87±0.02	8.95±0.04	14.26±0.03	12.01^{C}	T1	10.92±0.02	13.84±0.02	8.92±0.04	14.24±0.03	11.98^{C}
T2	11.06±0.03	13.97±0.03	9.34±0.56	14.39±0.02	12.19^{B}	T2	11.04±0.03	13.94±0.03	9.31±0.56	14.37±0.02	12.17^{B}
Means	11.24^{C}	14.21^{B}	9.32^{D}	14.59^{A}		Means	11.21^{C}	14.18^{B}	9.29^{D}	14.57^{A}	
Yellowness (b*)											
T0	9.33±0.02	11.25±0.04	8.15±0.04	7.31±0.02	9.01^{C}	T0	9.3±0.02	11.22±0.04	8.13±0.04	7.29±0.02	8.98^{C}
T1	9.55±0.02	11.45±0.03	13.05±0.02	14.65±0.02	12.18^{A}	T1	9.52±0.02	11.41±0.03	13.03±0.02	14.63±0.02	12.14^{A}
T2	9.29±0.02	11.18±0.03	12.82±0.01	14.46±0.02	11.94^{B}	T2	9.26±0.02	11.15±0.03	12.8±0.01	14.43±0.04	11.91^{B}
Means	9.39^{D}	11.29^{C}	11.34^{B}	12.14^{A}		Means	9.36^{D}	11.26^{C}	11.32^{B}	12.12^{A}	
Texture											
T0	4.36±0.04	4.19±0.02	4.23±0.02	4.16±0.01	4.23^{C}	T0	4.96±0.03	4.78±0.03	4.79±0.05	4.72±0.05	4.81^{C}
T1	5.04±0.03	5.17±0.02	5.31±0.02	5.54±0.03	5.27^{A}	T1	4.84±0.04	4.97±0.03	5.11±0.07	5.35±0.03	5.07^{A}
T2	4.84±0.03	5.62±0.59	5.07±0.02	5.23±0.03	5.19^{B}	T2	4.61±0.02	5.38±0.58	4.83±0.01	5±0.04	4.96^{B}
Means	4.75^{C}	4.99^{A}	4.87^{B}	4.98^{A}		Means	4.80^{C}	5.05^{A}	4.91^{B}	5.02^{A}	
Aw											
T0	0.82±0.01	0.80±0.02	0.77±0.02	0.71±0.01	0.77^{B}	T0	0.84±0.01	0.82±0.01	0.79±0.01	0.74±0.01	0.80^{B}
T1	0.88±0.02	0.86±0.02	0.83±0.01	0.7o±0.01	0.84^{A}	T1	0.9±0.01	0.88±0.01	0.85±0.01	0.81±0.01	0.86^{A}
T2	0.86±0.02	0.84±0.02	0.81±0.02	0.78±0.02	0.82^{A}	T2	0.88±0.01	0.86±0.01	0.83±0.01	0.8±0.01	0.84^{A}
Means	0.85^{A}	0.83^{A}	0.80^{B}	0.76^{C}		Means	0.87^{A}	0.85^{A}	0.82^{B}	0.78^{C}	
TBA											
mgMD/kg											
T0	0.55±0.02	0.60±0.02	0.65±0.01	0.72±0.01	0.63^{B}	T0	0.59±0.02	0.64±0.02	0.69±0.03	0.76±0.01	0.67^{B}
T1	0.61±0.02	0.66±0.01	0.72±0.02	0.83±0.02	0.71^{A}	T1	0.65±0.02	0.7±0.05	0.76±0.01	0.87±0.02	0.75^{A}
T2	0.58±0.02	0.6±0.01	0.65±0.01	0.73±0.02	0.64^{B}	T2	0.62±0.02	0.64±0.01	0.69±0.01	0.77±0.05	0.68^{B}
Means	0.58^{D}	0.62^{C}	0.68^{B}	0.76^{A}		Means	0.62^{D}	0.66^{C}	0.72^{B}	0.80^{A}	
POV mEq/kg											
T0	6.77±0.02	7.77±0.02	8.24±0.03	9.62±0.05	8.10^{C}	T0	6.81±0.01	7.80±0.02	8.28±0.03	9.66±0.05	8.14^{C}
T1	6.93±0.03	8.06±0.03	9.58±0.04	11.76±0.03	9.08^{A}	T1	6.97±0.03	8.1±0.05	9.62±0.04	11.80±0.03	9.12^{A}
T2	6.84±0.03	7.79±0.03	8.29±0.03	9.73±0.03	8.16^{B}	T2	6.88±0.03	7.83±0.03	8.33±0.03	9.77±0.02	8.20^{B}
Means	6.85^{D}	7.87^{C}	8.70^{B}	10.37^{A}		Means	6.89^{C}	7.91^{C}	8.74^{B}	10.41^{A}	

Different superscripts in a row indicate significant difference between the means ($p \leq 0.05$)

The data regarding the water activities as depicted in Table 6 showed highly significant effect on treatments. With storage periods the Aw values decreased and the product hardened with the passage of time. At 0 day analyses Aw values ranged between 0.82-0.90 in both type of nuggets and these values were ranged between 0.74-0.84 at 30 days. These findings are in agreement with (Ruiz *et al.,* 1999) who stated that water activity decreased with the passage of time.

Oxidative stability of nuggets: Peroxidation of lipids is main process involved in quality deterioration of meat and meat products. Hence to ensure quality attributes like colour, falvour, texture and appearance and nutritive value, it should be examined on time to check the stability of meat and meat products.

The data regarding the TBA values as depicted in Table 6 showed highly significant effect on treatments and storage. At 0 Day minimum value was seen in T0 (0.55) and 0.59 of loin and hind leg nuggets respectively while at 30 days it was 0.72 and 0.76. The data presented in Table 6 regarding peroxide value showed that POV has highly significant effect on treatment and storage. With the passage of time POV value increased. Minimum increase was observed in T0 at 30 days storage interval because rabbit fed on fresh alfalfa so contained less PUFA. More TBA and POV values were observed in hind leg nuggets due to PUFA accumulation in it. These values are in control limit and product is saved till 30 days storage with natural diet supplementation of flaxseed. The flaxseed was supplemented with fresh alfalfa that contained high retinol content so it might possible that it reduced lipid oxidation in the nuggets. The results of our study are in agreement with the work of (Dal Basco, 2014) who found similar results from meat of rabbits fed on fresh alfalfa.

Effect on sensory parameters of nuggets: Quality is the ultimate criterion of the desirability of any food product to the consumer. Overall quality depends upon quantity, nutritional and other hidden attributes and sensory quality. Sensory quality is of much concern to consumer and processor. It is the combination of various senses of perception coming into play in selection and eating food. Sensory attributes like color, smell, aroma, appearance, taste etc. can be judged by the natural human senses like sight, smell, taste and touch. The results regarding the sensory score are presented in Table 7 showed highly significant effects on all treatments regarding colour, appearance, taste, texture and overall acceptability. Sensory score varied with passage of time in all treatments. T1 showed the best sensory score in all parameters than the other parameters and nuggets prepared from loin meat showed high acceptability from judges. Data regarding the colour values is shown in table. Minimum value was observed in T0 at 45 day i.e. 5.6 and 6.0 in loin and hind leg nuggets respectively. Maximum score was seen in T1 at 45 day of storage. Colour score decreased due to oxidation of the lipids that retarded the shining of nuggets (Sohaib *et al*., 2012).

Appearance score was also decreased with passage of time in both loin and leg meat nuggets. Minimum score was seen in T2 (5.9) hind leg nuggets. The score regarding the taste of loin and leg meat nuggets decreased with storage period due to rancidity produced by lipids. Minimum score was seen in T0 at 45 days of storage i.e. 4.8 in case of hind legs. Maximum score was obtained by T1 (6.8) loin nuggets at 0 day. The decreasing trend in taste of nuggets may be associated with the peroxidation of PUFA. Our finding are in agreement with the results of (Devendra and Tanwar, 2011; Biswas *et al*., 2006) who observed highly significant effect of taste in nuggets with storage periods. The results of the mean Tables of the nuggets showed that T1 was highly satisfactory by the judges as it received maximum score for overall acceptability while T0 received minimum score for the overall acceptability but in acceptable limit. My results are in correlation with (Sohaib *et al*., 2012) who stated that the sensory quality score decreased considerably with the passage of storage period.

Table 7. Colour, Appearance, Taste, Texture and overall acceptability of rabbit loin and leg meat nuggets stored at −18 °C

	Storage days										
Rabbit Loin meat nuggets						**Rabbit Leg meat nuggets**					
Tr	**0 day**	**15 day**	**30 day**	**45 day**	**Means**	**Tr**	**0 day**	**15 day**	**30 day**	**45 day**	**Means**
Colour											
T0	6.2±0.27	6.0±0.14	5.8±0.31	5.6±0.19	5.9^{C}	T0	6.6±0.15	6.4±0.32	6.2±0.15	6.0±0.26	6.3^{C}
T1	7.1±0.31	7.2±0.28	7.3±0.11	7.5±0.16	7.3^{A}	T1	7.5±0.14	7.6±0.25	7.7±0.19	7.9±0.12	7.7^{A}
T2	6.5±0.22	6.4±0.29	6.3±0.26	6.2±0.25	6.4^{B}	T2	6.9±0.33	6.8±0.26	6.7±0.11	6.6±0.26	6.8^{B}
Means	6.6^{A}	6.5^{A}	6.5^{A}	6.4^{B}		Means	7.0^{A}	6.9^{A}	6.9^{A}	6.8^{B}	
Appearance											
T0	7.6±0.51	7.3±0.21	6.9±0.16	6.5±0.19	7.1^{A}	T0	7.15±0.15	6.9±0.29	6.5±0.15	6.1±0.21	6.7^{A}
T1	7.6±0.33	7.3±0.13	6.9±0.19	6.5±0.21	7.1^{A}	T1	7.2±0.16	6.9±0.33	6.5±0.19	6.1±0.28	6.7^{A}
T2	7.3±0.31	6.9±0.23	6.8±0.14	6.3±0.27	6.8^{B}	T2	6.9±0.25	6.5±0.17	6.4±0.13	5.9±0.15	6.4^{B}
Means	7.5^{A}	7.2^{B}	6.8^{C}	6.4^{D}		Means	7.1^{A}	6.8^{B}	6.4^{C}	6.0^{D}	

Taste											
T0	5.7±0.23	5.3±0.16	5.3±0.15	5.1±0.31	5.3 ^{C}	T0	5.5±0.36	5.0±0.19	5.0±0.17	4.8±0.43	5.1 ^{C}
T1	6.8±0.26	6.4±0.24	6.1±0.11	5.6±0.29	6.2 ^{A}	T1	6.5±0.23	6.1±0.26	5.9±0.12	5.4±0.35	6.0 ^{A}
T2	6.5±0.32	6.0±0.12	5.7±0.17	5.4±0.25	5.9 ^{B}	T2	6.3±0.37	5.8±0.25	5.5±0.32	5.1±0.29	5.7 ^{B}
Means	6.3 ^{A}	5.9 ^{B}	5.7 ^{C}	5.4 ^{D}		Means	6.1 ^{A}	5.6 ^{B}	5.5 ^{B}	5.1 ^{C}	
Texture											
T0	6.3±0.25	6.1±0.11	5.9±0.18	5.8±0.13	6.0 ^{B}	T0	6.1±0.43	6.0±0.17	5.8±0.19	5.7±0.12	5.9 ^{B}
T1	6.8±0.23	6.7±0.16	6.4±0.23	6.1±0.17	6.5 ^{A}	T1	6.6±0.48	6.5±0.25	6.2±0.23	5.9±0.38	6.3 ^{A}
T2	6.5±0.23	6.2±0.09	6.1±0.31	5.7±0.11	6.1 ^{B}	T2	6.4±0.13	6.1±0.23	6.0±0.14	5.6±0.17	6.0 ^{B}
Means	6.5 ^{A}	6.3 ^{B}	6.1 ^{C}	5.9 ^{D}		Means	6.4 ^{A}	6.2 ^{B}	6.0 ^{C}	5.7 ^{D}	
Overall Acceptability											
T0	6.6±0.15	6.4±0.32	6.2±0.18	5.9±0.15	6.2 ^{C}	T0	6.6±	6.2±0.32	5.8±0.17	5.5±0.11	6.0 ^{C}
T1	7.3±0.21	7.1±0.16	7.0±0.29	6.9±0.14	7.1 ^{A}	T1	7.2±	7.0±0.21	6.6±0.11	6.5±0.21	6.8 ^{A}
T2	7.0±0.15	6.8±0.42	6.5±0.27	6.3±0.19	6.6 ^{B}	T2	6.9±	6.6±0.35	6.1±0.24	5.9±0.18	6.4 ^{B}
Means	7.0 ^{A}	6.8 ^{B}	6.6 ^{C}	6.4 ^{D}		Means	6.9 ^{A}	6.6 ^{B}	6.2 ^{C}	6.0 ^{D}	

Data are means of three replicates ± Standard Deviation. Means in the same row have the same letter are not significantly different at 0.05.

Conclusions: Linseed is a good source of dietary feed ingredient in feed of rabbits in order to enhance the quality of healthier meat production. Its supplementation enhances the immunity response of rabbits in order to disease attack by decreasing the mortality of rabbits that is economical factor for all the farm holders. Growth parameters like weight gain and FCR were significantly increased by dietary supplementation. Results presented in this study concluded that flaxseed supplementation enhanced n-3 PUFA in meat of rabbits. Nuggets made from supplemented feed showed stability due to inclusion of fresh alfalfa in the feed while nuggets prepared from loin meat showed high acceptability. Nuggets can be stored more than 2 months at -18 ºC. A clinical trial should be carried out in future to check the efficacy of rabbit meat nuggets in lowering cholesterol level due to presence of PUFA.

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