EXPLORING THE POTENTIAL OF RABBIT MEAT AS A FUNCTIONAL FOOD

By

Muhammad Rizwan Tariq

M.Sc. (Hons.) Food Technology

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

FOOD TECHNOLOGY

NATIONAL INSTITUTE OF FOOD SCIENCE & TECHNOLOGY

UNIVERSITY OF AGRICULTURE

FAISALABAD (PAKISTAN)

2015

To

The Controller of Examinations,

University of Agriculture,

Faisalabad-Pakistan

"We, the Supervisory Committee, certify that the contents and form of thesis submitted by **Muhammad Rizwan Tariq**, Reg. No. **2004-ag-1263**, have been found satisfactory and recommend that it be processed for evaluation, by the External Examiner(s) for the award of degree".

Supervisory Committee

1. Chairman ____________________________

Dr. Muhammad Issa Khan

2. Member ____________________________

Dr. Aysha Sameen

3. Member ____________________________

Dr. Mahr-un-Nisa

DEDICATED

TO

My Respected Supervisor

Dr. Muhammad Issa Khan

And

My Beloved Father

Hafiz Ghulam Mustafa

ACKNOWLEDGMENTS

I offer my humblest sense of gratitude to ***"ALMIGHTY ALLAH"*** the most beneficent, the merciful and the gracious, whose blessings and love enabled me to stand on my feet and yield higher ideas in life and blessed me an opportunity to stay on the way of knowledge to seek my recognition in universe. He helped me to complete this research work and great blessing to his ***Prophet Muhammad (PBUH)*** possessing not only such an immaculate personality who builds the height and standard of character for all over the world but guided his "Ummah" to seek knowledge from cradle to grave.

First of all I would like to thank ***Prof. Dr. Masood Sadiq Butt***, Director General of National Institute of Food Science and Technology, University of Agriculture for his sincere guidance and moral support during my whole study period. My special thanks are to ***Dr. Muhammad Issa Khan,*** Assistant Professor, National Institute of Food Science and Technology, University of Agriculture, Faisalabad, for boosting me to work on such a dynamic project. He helped me in developing my way of thinking, allowed me to make decisions independently.

I would like to thank ***Dr. Ayesha Sameen,*** Assistant Professor, National Institute of Food Science and Technology, University of Agriculture, Faisalabad. She modeled me how to balance both career and personal life and for always being available to answer questions and to ask the challenging ones. Thanks to ***Dr. Mahr-un-Nisa,*** Assistant professor of Department of Animal Nutrition, University of Agriculture, Faisalabad for her guidance for completing this project.

I forward my deep gratitude for ***Mr. Tahir Waqar*** who always lift me up to complete this projects and help me when I needed. I would like to acknowledge my ***Parents*** for teaching me to take the right paths, even though they are not always the easiest ones. I want to express my everlasting gratitude to my brothers ***Umar, Usman, Ali, Irfan*** and my sisters.

My special thanks are for my friends ***Mr. Wasim Sajid and Mr. Sameem Javed***. I would like to express my gratitude and thanks to ***Sheraz Ahmed, Rai Muhammed Amir, Ammar Ahmad Khan, Shahid Bashir, Adnan Nasir, Zaib-un-Nisa and Zarmina Gillani***

`

Muhammad Rizwan Tariq

Table of Contents

List of Tables

List of Figures

DECLARATION

I hereby declare that the content of the thesis "Exploring the potential of rabbit meat as a functional food" are the product of my own research and no part has been copied from any published source (except the references, equations/formulas/protocols etc.). I further declare that this work has not been submitted for the awards of any other diploma/degree. The university may take action if any information provided is found inaccurate at any stage. (In case of any default the scholar will be proceeded against as per HEC plagiarism policy).

Muhammad Rizwan Tariq
2004-ag-1263

ABSTRACT

Rabbit is reared in rural areas of Pakistan under backyard farming system for meat production. Quality characteristics of rabbit meat make it more nutritious being game animal taste, light flavor and firmer meat texture. For improvement of nutritional profile and fatty acid composition seventy five rabbits were reared for two months on different level of oat and linseed twice during the experimental year 2012 and 2013. The feed treatments resulted significant variation in body weight gain and FCR while no influence was found on the feed intake. The highest body weight gain (248.75 g/week) was observed in rabbits fed on 7% linseed (T3) while lowest (223.75 g/week) body weight gain was noted in rabbits fed on control feed (T0). The highest FCR (3.172/week) was observed in rabbits fed on control feed (T0) while lowest FCR (2.895/week) was observed in rabbits fed on 7% linseed (T3). The raw rabbit meat was subjected to physico-chemical (pH, fat, protein, color and texture) analysis. pH, Aw, protein, fat and textural values differed significantly between loin and leg meat of rabbits fed on feed having different levels of oat and linseed. pH, protein and textural values were found significantly higher in loin as compared to hind leg meat. The composition of saturated fatty acid and unsaturated fatty acid in loin and hind leg meat of rabbits were significantly influenced by different feed treatments. The poly unsaturated fatty acid were observed significantly higher in loin and hind leg meat of rabbits fed on 7% linseed (T3) and lowest poly unsaturated fatty acid were observed in rabbits fed on 4% oat (T1). The serum lipid profile of rabbits was influenced by different feed treatments. The total cholesterol (105.27 mg/dl & 106.05 mg/dl) and triglycerides (66.67 mg/dl & 65.79 mg/dl) were found the lowest in rabbits fed on 4% oat in fed (T1). Nuggets were prepared from experimental rabbit meat and evaluated for their stability and acceptability during storage. The physico-chemical analysis of rabbit nuggets indicates that feed treatment exert significant effect on the pH, color, texture and water activity tested after different storage interval. The nuggets made from meat of rabbits fed on 7% linseed (T3) showed higher pH, color, water activity and textural values with storage intervals. The production of MDA in loin and hind leg meat nuggets of rabbits was noted lower in a in a group fed on 4% oat (T1) while the highest MDA were recorded in the loin and hind leg meat of rabbits fed on 7% linseed (T3). The lowest decrease in pH and TBA values indicated that oat is a good source of antioxidant. Sensory evaluation was carried out by trained panelist using nine point hedonic scales. The feed treatments exhibited significant effect on the color, flavor, taste, texture and overall acceptability of the nuggets during storage. The panelist preferred loin rabbit nuggets of T3 (rabbits fed on 7% linseed) that showed highest acceptance having light flavor and nice appearance. In order to assess the impact of rabbit functional meat on human blood lipid profile, a study trial was conducted. Subjects were provided with rabbit meat in comparison with chicken meat by following the study design. The bio-chemical profile of human blood serum showed that feed treatment exerted significant effect on blood chemical profile. The cholesterol, triglycerides and low density lipoprotein were found to be lower in blood serum of human subject group treated with 7% linseed meat (G4) while the higher values were observed in G6 (Group fed on chicken meat). The data obtained for various parameters were subjected to statistical analysis by using over the year design. The enrichment of oat and linseed in the feed is more beneficial in increasing the quality of rabbit meat and also helped in lowering the cholesterol and improves the poly unsaturated fatty acid profile of rabbit meat.

CHAPTER 1

INTRODUCTION

A food to which an element has already been added, or a food from which a constituent has been excluded through technological or biotechnological ways is referred as a functional food (Hernández, 2008). Food products that assure some specific health benefits beyond the traditional nutrients they contained are also known as functional foods (Drozen *et al.,* 1998). The concept of functional foods raised in Japan during 1980's where industry used this term to describe foods fortified with specific ingredients imparting certain health benefits. The Japanese government nurtured the concept because of its concern with ageing population of the country and the resultant cost of health-care (Heasman, 1997). The first functional ingredient was the dietary fiber that obtained commercial success as well as rapid increase in demand for drinks containing high levels of fiber in 1980's. This was the start of market for the functional foods in Japan and rest of the world. A wide variety of nomenclatures for description of functional foods are being used such as designer foods, nutraceutical, nutritional foods, longevity foods, medical foods, hyper super foods, nutritional foods, prescriptive foods, pharma foods, therapeutic foods, phyto-foods, foodiceuticals, fitness foods and various other terms (Hilliam, 1995).

Functional foods are becoming famous due to uncertainty and negative image of drugs and supplements. Everywhere the population require to eat a healthy foods without change in their traditional dietary style (Becker and Kyle, 1998). Consumption of healthy diet has attained more attention in the recent years due to disliking of fat, sugar and salt because people have health concerns (Hilliam, 1995). Healthier diets consisting no fat or low fat and reduced-calories are in higher demand by the customer. The functional foods provide alternative way to the customers to have better food (Ohr, 2005) and should be taken as a part of regular diet. Traditional foods are being tested for their functional ingredients to develop new food products which can produce beneficial health effects. Factors contributing to the development of functional foods to grow well into the 21^{st} century include: increased health care costs, an aging population, autonomy in health care and self-efficacy as well as advancing scientific evidences to show that food can change prevalence and progression of diseases (Hasler *et al.,* 2000).

Functional foods are categorized into two primary classes based on the anticipated effects: (1) those planning to enhance physical roles. (2) 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 feverish within the food (Diplock *et al.,* 1999). Functional foods can be divided into four major groups; basic functional foods, the products which are naturally rich in the biological active compounds such as psyllium and oat bran that are rich in dietary fiber and linked in lowering of coronary heart diseases. Second are those that have been fortified to increase the level of a specific nutrient or food component that aids in the controlling or prevention of a disease or other clinical conditions such as pasta, calcium-fortified orange juice, or rice marketed to lower osteoporosis risk. Third category are whole foods that have been linked with reduced risk of diseases such as fermented dairy products (probiotics), which has shown improvement in gastrointestinal health (Goldin, 1990). The fourth category of functional foods includes the foods, which have substantial scientific support but currently lack approved health claim (Reuter *et al.*, 1996) such as n-3 fatty acids found in linseed and fish aid in lowering serum cholesterol level in clinical trials (Von *et al.,* 1997). There are three basic requirements for a food to be regarded as functional (Goldberg, 1994): (1) it is a food (not powder, capsules or tablets) obtained from naturally occurring ingredients. (2) it should be utilized as a part of the daily food. (3) once ingested, it should regulate specific processes such as preventing and treating specific diseases, enhancing biological defense mechanisms, controlling mental and physical conditions, and delaying the process of ageing..

Meat is the whole or part of carcass of any animal tissues (Williams, 2007). It plays important role in human nutrition because meat and meat products are excellent sources for fats, protein, minerals, vitamins and essential amino acids (Weiss *et al.*, 2010). 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 cardiovascular diseases (CVDs) illnesses, diabetes, hypertension and overweight (Valsta *et al.,* 2005). The meat processing industry is driven by increasing consumer demand for healthier meat products which includes products with reduced level of fat, cholesterol, sodium and nitrite, improved fatty acid composition, including omega-3 fatty acids enriched meat products (Jimenez-Colemenero *et al.,* 2001). Healthier meat development is the most important issues challenging the meat industry. So the production of healthier meat for protective and healthy life is prime need of new era. Healthier meat is rich in protein, low in fat, higher in n-3 fatty acids and lower in n-6 fatty acids. Numerous interrelating factors like genotype, breed, feeding programs, slaughtering and storage conditions affect quality of meat. Amongst them, nutrition of animal plays a significant role due to its regulatory influence on biological processes in muscle that are reflected in the meat quality (Andersen *et al.*, 2005).

There are numerous techniques with regard to introducing quantitative and qualitative adjustments in meat to attain a much more purposeful meat and meat products. Fundamentally, these approaches emphasis on limiting the concentration of compounds with antagonistic physiological effects and increasing the contents of those which are more beneficial (Jiménez-Colmenero *et al.*, 2001; Decker and Park, 2010; Zhang *et al*., 2010). Practical worth in enhancement of meat and meat product is possible by the following approaches: 1. With the addition of functional compounds, for example CLA, vitamin, ω-3 essential fatty acids, as well as Selenium (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 the 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).

Rabbit meat offers excellent nutritive and dietetic properties (Combos, 2004). Within last 50 years, world rabbit meat production have elevated by three fold as much as 2.6 million tons last year. China (700,000 tons/year) and France (51,400 tons/year) are the leading rabbit meat suppliers to European countries (FAOSTAT, 2010). In connection to elevated level of protein contents, rabbit meat also consists of high level of desired amino acids (EAA). Minerals level is steady from 1.2-1.3 g/100 grams meat. The meat leanest cut within the rabbit meat is loin having an average fat level of just 1.8 g/100 gram meat, whereas the actual fatty part is the fore leg by having an average fat content of 8.8 g/100 grams. The majority of quantitatively essential cut is the hind leg and its lipid content is very low (normally 3.4 g/100 grams) when compared to the other meat (Dalle Zotte, 2002).

High level of essential amino acid (EAA) are present in the meat of rabbits compared to other meats, it is actually richer within lysine (2.12 g/100 grams), sulfur-containing proteins (1.10 g/100 grams), threonine (2.01 g/100 grams), valine (1.19 g/100 grams), isoleucine (1.15 g/100 grams), leucine (1.73 g/100 grams) as well as phenylalanine (1.04 g/100 grams) (Hernàndez and Dalle Zotte, 2010). These prominent as well as balanced essential amino acids content provides rabbit meat proteins higher biological worth due to simple digestibility.

In addition, highly obtainable micronutrients, such as minerals and vitamins are also being supplied by the meat. Also, low material content of purines are preset in rabbit meat and doesn't have the crystals (Hernández, 2007). The primary components associated with meat, eliminating water, tend to be proteins as well as fats. Rabbit meat is almost a lean meat that consists of high valuable proteins which is characterized through high amounts of essential proteins. In contrast to red meat rabbit meat is seen as its reducing energy value because of its little body fat content (Dalle Zotte, 2004). Lipid content changes largely according to the carcass part from 1.7-13.5% (intermuscular body fat content as well as intramuscular edible fat) by having 6.8% of an average value (Hernández and Gondret, 2006). High polyunsaturated fatty acids are present in fatty acid composition associated with rabbit meat. The cholesterol concentration of rabbit meat is 59 mg/100 grams of muscle tissues (Combes, 2004) reduce contents than other meats (81 mg within chicken, 67 mg within beef, 59 mg within pork) (Dalle Zotte, 2004). The nutrient composition associated with rabbit meat is observed as its reduced levels of Sodium (49 mg/100 grams for loin and 37 mg/100 grams for hind leg) as well as Iron (1.1 to 1.3 mg/100 g for loin and hind leg respectively) while Phosphorus contents are higher (222 to 230 mg/100 g for loin and hind leg respectively) (Combes, 2004). Rabbit meat contains a reduced Zinc level (0.55 mg/100 g) (Lombardi-Boccia *et al.*, 2005).

The major dietary sources of α-linolenic acid are green leaves and some cooking oils such as linseed, rapeseed and soybean oils, in which it accounts for up to 10% of total fatty acids (Burdge and Calder, 2006). Linseed oil is predominantly rich in α-linolenic acid (50-60% of total fatty acids) (Bean and Leeson, 2002) and is frequently used as a nutritional supplement in humans (Burdge and Calder, 2006).

The use of linseed in animal feeding has been suggested by many authors as an alternative vegetable source to fish meal or fish oil, to enhance the concentration of n-3 polyunsaturated fatty acids and mainly α-linolenic acid (C18:3 n-3) in poultry (Ajuyah *et al.,* 1993; Rymer and Givens, 2005) and rabbit meat (Bernardini *et al.,* 1999; Dal Bosco *et al.,* 2004; Colin *et al.,* 2005; Bianchi *et al.,* 2006; Maertens *et al.,* 2008). Providing the enhanced quantity of n-3 essential fatty acids in human diet through consumption of normal meat can contribute to balance the unbalanced n-6/n-3 polyunsaturated fatty acid (PUFA) ratio of the consumer diet. Thus helps to avoid certain diseases such as hypercholesterolemia-related heart strokes and attacks (Prasad, 1997; Simopoulos, 2000; Wood *et al.,* 2004). The concentration of α-linolenic acid (n-3 PUFA) in flaxseed oil ranges from approximately 40–60 % (Williams *et al*., 2008). Dietary linseed supplementation increases antioxidant defenses through both reduced reactive oxygen species (ROS) generation and increased ROS detoxification (Lee *et al*., 2008). Linseed antioxidant may have potential application in food and health industry as food stabilizer and nutraceutical compound. Scientific evidence supports linseed consumption; many people are still unaware of the benefits of this product and its possible applications in the production of foodstuffs. As an antioxidant it shows hypolipidemic effects (Newairy and Abdou, 2009). Linseed supplementation decreased average fasting serum glucose concentrations by 16% (Rhee and Brunt, 2009). The similar benefits obtained by the consumption of DHA and EPA (Theodoratou *et al*., 2007).

Oat is a significant source for water-soluble fibers such as β-glucan and the beneficial properties of oat and oat products on the lipoprotein profile are attributed to their soluble fiber compound (Kerckhoffs *et al.,* 2003). In addition, oat is a source of various phenolic compounds and antioxidants, such as tocols (Aly, 2012). Antioxidants of oat have been testified to obstruct low-density lipoprotein (LDL) oxidation and encourage reactive oxygen species scavenging (Chen *et al.,* 2006; Stevenson *et al.,* 2008). There are numerous studies demonstrating the ability of oat bran in total cholesterol (TC) and LDL-C concentrations reduction while either enhancing or having no influence on plasma concentrations of HDL-C in humans (Stevenson *et al.*, 2008; Charlton *et al.*, 2011; Othman *et al.*, 2011). Enhancing the dietary fibers that are resistant to digestion by human gastrointestinal enzymes has been used for reducing the concentration of cholesterol (Glore *et al.,* 1994; Truswell, 1995). Due to high antioxidant activity, oats and oat products were among the first antioxidant suggested to use for stabilization of oils, fats and fat-containing food (Peters and Musher, 1937). Several naturally occurring phenolic compounds are possessed by oats that have been revealed to have lipid antioxidant attributes (Collins, 1986; White and Armstrong, 1986). Daniels and Martin (1967, 1968) recognized at least twenty four antioxidant phenolic substances in oats. Some oat sterols have also been revealed to postpone the thermal changes at frying temperature (White and Armstrong, 1986). Esters of ferulic and caffeic acids seemed to be the most significant oats antioxidants (Pokomy, 1991).

Rabbit meat is lower in fat, higher in protein and has fewer calories than other meats. One of the best white meats that are available in the today's market is rabbit meat (Fernandez and Fraga, 1996). Meat of rabbit is exclusively suggested for the elderly whose digestive system has slow down and ingestion is negotiated, for superior diets such as for heart patients, due to life stage or illness. It is also recommended for weight reduction diets and low sodium diets because it is easily digestible. Doctors also suggested rabbit meat for patients who feel trouble in ingestion of other meats. It has splendid taste and there are many ways to cook it. In view of all these apprehensions, present study is conducted for the enrichment of poly unsaturated fatty acids ratio in meat muscles tissues of rabbits by utilizing oat and linseed in feed supplementation in order to enhance the quality and stability of meat and meat product to ensure its worth against life style disorders. Due to the activity in disease controlling, functional foods are becoming famous in all over the world. One of the main features of functional food is the addition of the functional ingredient in the daily diet without influencing the pattern of diet of the subjective population. In this scenario present study was designed to explore the health benefits of rabbit meat as a functional food with following objectives:

- Development of low fat and PUFA enriched rabbit meat for hypercholesterolemic persons.
- Improvement in nutritional properties for the development of healthier rabbit meat and meat product.
- To assess the acceptability and stability of low fat and linseed PUFA enriched rabbit meat.

CHAPTER 2

REVIEW OF LITERATURE

Novel health care strategies of the millennium have illuminated functional and n-3 fatty acids enriched meat and meat products as one of the promising therapeutic tool to combat various lifestyle disorders. Plant derived food ingredients are effective in this context to tailor specific healthy diet for the target population .The escalating consumption of these n-3 meat products provides a viable approach towards nutrient optimization and food synergy. According to the current nutritional guidelines diet and health interplay has encouraged the consumers to choose food with some additional health benefits beyond basic nutrition. Changing life style is also narrowing the gap in food selection due to sedentary and robotic living nevertheless; functional n-3 fatty acids enriched meat moieties are helpful to bridge the trench. Recently there has been a moderate resurgence in the use of flaxseed food. The potential technique to increase the intake of n-3 PUFA is to fortify traditional food items such as meat and meat products with n-3 PUFA. Thus the improvement of n-3 fatty acid is the prerequisite towards the development of healthier meat in order to accomplish the demand of consumer. Therefore now a day's meat is considered as implicated in leading cause of the imbalanced fatty acid intake of today's consumers. It have been verified that diet supplemented with linseed have positive health effects in several pathological diseases (Newairy and Abdou, 2009).

Livestock production is a vital part of Pakistan's agriculture sector and plays a dynamic role in national economy. At present, livestock is contributing about 51.8% to the agricultural sector and 11.3% to the GDP. During preceding 50 years, rabbit meat production at world level has amplified as 2.5 folds until 1.6 million tons in the year of 2009. The country of China is formerly the world's top producer (700,000 tons per year), Spain (74,161 tons per year year), Italy (230,000 tons per year) and at last France (51,400 tons per year) are the chief rabbit meat production countries in the region of Europe (FAOSTAT, 2010). The market in the world for rabbit meat is also growing. Global consumption of rabbit meat in the world is highest in Malta, 7.5 kg per head, followed by Italy, 5.5 kg and France, 3.0 kg (Hernandez *et al.*, 2000). Functional foods happen to be broadly defined because "foods similar to look at to traditional foods which are included in a regular diet and also have demonstrated physical benefits and slow up the risk associated with chronic illness beyond fundamental nutritional properties" (Clydesdale, 1997). It is actually emphasized which functional foods are thought as meals, show their own effects within quantities that may normally be anticipated to end up being consumed within the diet, and tend to be consumed as part of a regular food design. Natural or even traditional foods could be advertised or even sold as functional meals, provided that they are accompanied through any new brand expression of the health advantages (Kwak and Jukes, 2001). Through first indicates, the lipid, fatty acid (FA), and tochopherol contents could be changed, while through the second, lipids could be detached through mechanical procedures. Initiatives are primarily aimed regarding meat products, towards their reformulation through changing the actual fats as well as FA contents with the addition of a number of functional elements (dietary fiber, vegetable fats, monounsaturated or even PUFA, calcium supplement, vitamins and phytochemicals) Jimenez-Colmenero *et al.,* 2001). Meat is consumed as protein supplement by eighty percent of world population. Most of the countries, particularly small Pacific Islands and Middle East, are entirely dependent on meat imports. White meat is considered superior in health point of view as compared to red meat as it has comparatively less fat and cholesterol contents. Consumers also prefer white meat because of less bad cholesterol and soft texture (Jaturasitha, 2004). Meat constitutes a substantial component of the human diet and meat is also a good source of essential minerals, superior class animal proteins, fat and vitamins (Warris, 2000). A comprehensive debate regarding the various aspects of the instant research has been inferred herein.

2.1. Meat quality parameters

2.2. Healthier meat

2.3. Strategies for healthier meat development

2.4. Natural products with antioxidant and functional properties

2.5. Unsaturated fatty acids

2.6. Conjugated linoleic acid

2.7. Cholesterol

2.8. Biological value of proteins

2.9. Rabbit meat quality

2.10. Health benefits of rabbit meat

2.11. Sensory meat quality

2.12. Trends in rabbit meat processing

2.1. Meat quality parameters

Meat quality defines broadly by the processor, the consumer or the distributor but consumer is most probably the final judge about the quality of meat. The changing attitude of consumer in society that is presented by media results in improved quality of meat. Meat quality parameter comprise not only nutritional properties, such as proteins, lipids, proper quantities of bioactive compounds, and their important sub-constituents; sensory appearances such as colour, flavor and tenderness; technological aspects such as capacity to be processed, health aspect regarding saturated and unsaturated fatty acid, but also on the situation of production of animal which is related to animal safety, the environment and of course food safety. Meat quality is influenced by composition, areas of muscle fibre and capillary density of the muscles which is changed due to ante and post mortem biochemical processes (Alasnier *et al.,* 1996; Dalle Zotte and Ouhayoun, 1998; Gondret and Bonneau, 1998). Muscle fibres and their biochemical character are related to tenderness, colour stability, eating quality as well as water-holding capacity (WHC) (Aquaron and Serratrice, 1972; Ouhayoun and Dalle Zotte, 1993) and lipid oxidation (Alasnier *et al.,* 1996). People pay attention to control their fat intake and composition of fatty foods in the developed countries. Therefore, the meat researchers these days are mainly focused to produce a healthy and dietetic food to enhance the unsaturated fatty acid and to decrease saturated fatty acid. Considering the fat content, rabbit meat have low fat content (on average 6.8 g/100 g fresh meat) and calories (on average 618 kJ/100 g fresh meat) as compared of the red meats. By considering the cholesterol levels, rabbit meat among the more popular meats, have the lowest levels (on average 53 mg/100 g fresh meat) (Lukefahr *et al.,* 1989). Rabbit meat having significant amount of polyunsaturated fatty acid and it can be very valuable food in human diet (Romans *et al.,* 1974; Alasnier *et al.*, 1996) and a very low FA-n6/FA-n3 ratio (Castellini *et al.*, 1999). However, meat will be deteriorating due to increase in unsaturation of animal tissues by the manipulation of diet that increase oxidation during processing and storage of meat. The shelf life of raw and cooked rabbit meat is low due to high amount of long chain polyunsaturated fatty acid (Lee and Ahn, 1977; Fernàndez-Esplà and O’Neill, 1993; Lopez-Bote *et al.*, 1997). Lipid oxidation is one of the most important mechanisms capable of producing characteristic flavor but it can also control flavor development and also having effect on the health of human as it produces cholesterol oxides (Gandemer, 1998). So there is close relationship between antioxidants such as vitamin E and changes in dietary fat in feed that affect meat and meat-product shelf life, stability, toxic compound and sensory properties. Researchers are trying to evaluate and developed method for the evaluation of quality of meat such as electronic nose, taste sensing, TOBEC, NIRS, NMR, Reflectance Fat Probe, ultrasound and Video Image Analysis (Cross and Belk, 1992). However, due to high cost and problem in online production the meat industry has applied very little of them. Research should be done to improve the quality of meat in order to meet the requirements of markets. Research on rabbit carcass and on quality of meat was done with the objective of advancement in knowledge and not to meet the demand of consumers.

2.2. Healthier meat

Healthier meat will be low in in fat, high in protein, greater proportion of unsaturated fatty acid over saturated fatty acids, tender and longer storage stability. Dietary recommendations for reduced intake of saturated fat and increased awareness of the beneficial health effects of polyunsaturated fatty acids (PUFA) have led to an amplified demand for omega-3 fatty acid enriched meat and meat products (Valencia *et al.,* 2008).Today consumers are no more satisfied with the concept of nutritional quality of meat even though they demand the type of meat and meat product that provide the health benefits beyond the basic nutritional benefits. In this positive perception to mitigate various physiological disorders during different stages of life from child hood to elderly age, consumption of healthier meat is a core element for optimal health. Conversely, there is lack of evidence on the enrichment of omega-3 fatty acids in rabbit meat products. It is predicted that by 2020, EPA/DHA fortified foods will represent 78% of all the n-3 fatty acids enriched foods in the USA (Heller, 2009). Up till now USA and Europe have launched 1300 n-3 fatty acids enriched products in 2007 (Daniells, 2008). These products ranged from bread to milk, juices, salad dressings, chocolates, yogurt, drinks, spreads, meal bars, margarines, mayonnaise, butter and eggs. These changes have resulted in consumer demand for development of novel functional meat products (Arihara, 2006). Presently, functional foods containing n-3 lipids are one of the fast growing food product categories. As meat is a major source of dietary fat in human diet, hence changing the lipid content and FA profile of meat can be an effective way to improve the consumer's health (Daniells, 2008). The expectation of the consumer for meat is that it should be healthy, rich in protein, low in fat, tender, and have a typical flavor to cover the long-term health objectives (Zuidhof *et al.*, 2009). The impressive growing mandate by consumers for healthier meat products has resulted in strategies to lessen the use of animal fat (Youssef and Barbut, 2009). As it is estimated that up to 30% coronary heart disease (CHD) deaths are due to unhealthy diets (American Heart Association 2006).

2.3. Strategies for healthier meat development

The low intake of omega-3 fatty acids and increasing scientific evidence of the beneficial effects of EPA and DHA has led to introduced n-3 fatty acids enriched foods in the market (Jacobsen, 2010). In 2010, consumption of red meats decreased while there was an increase in the consumption of chicken meat among Canadians with per capita amount of 31.5 kg/person (Canada Poultry Annual, 2010) Consumption of meat and meat products is progressively being viewed as causes for enhanced risks of appealing coronary ailments such as cancer, obesity and stroke. In the United States this is predominantly the case, where occurrences of cardiovascular disease, obesity, cancer and hypertension are growing thus placing an increased load on health caring systems (CDC National Center for Chronic Disease Prevention, 2005). Varying the demands of consumer and increased global production are triggering the meat product manufacturing segment to develop new technologies for processing and new ingredient systems, which is long term and remarkable tactic to product and process development in the meat industry. This is possible since perception of consumer that meat and meat products are good source of vitamins, minerals and comprise “complete” proteins (proteins that in comparison to proteins of plant-based contain all the nine of essential amino acids) is progressively giving approach to a more negative view (Verbeke, 2010). In the meanwhile, meat processing industry is facing competition regarding the use of increasingly lavish raw material (meat) more proficiently and produces lower cost products. In this scenario different strategies are used for the development of healthier meat in order to fulfil the dietary requirement of meat and health benefit beyond the basic nutrition. By using the dietary strategy a healthier meat is developed.

1. Advanced ingredient systems for meat products
2. Changes in fat profiles in meat products

3. Modulations of lipid content and composition in meat products
4. Nitrite reduction or replacement in meat products
5. Reduction of cholesterol level in meat products
6. Salt and sodium reduction in processed meat products
7. Increased shelf life by the use of nitrite substitutes
8. Decreased oxidation by the use of novel antioxidants
9. Sanitizing meat surfaces
10. Enzymes as novel texture modifiers
11. Novel naturally occurring antimicrobials

This can be consummate by replacement of fat with oils rich in n-3 fatty acids which would lead to a healthier fatty acid profile in the final product.

2.4. Natural products with antioxidant and functional properties

In the past, use of synthetic antioxidants in the meat industry was associated with toxicity of meat products. Consumer concerns related to safety of meat diverted the industry towards the use of natural sources (Coronado *et al.,* 2002). Among natural resources, spices and herbs i.e., sage, rosemary, clove, green tea, nutmeg, cinnamon and rose petals were found to be effective ingredients of food in minimizing the susceptibility of meat to oxidative changes. Antioxidant activity of these natural substances is due to the presence of phytochemicals which are prospective natural antioxidants sources, including tannins, flavonoids, phenolic acids, phenolic diterpenes and also endorsing antimicrobial, anticancer and anti-inflammatory activities (Zhang *et al.,* 2010). Some plant based natural antioxidants, for example citrus peel, soybean, olives, sesame seed, grape skin and carob pod could also have equivalent or greater potential against rancidity in meat (Fernández-Ginés *et al.,* 2005). Furthermore, it has been found that the crude canola (*Brassica Napus*) polyphenol extract of diet inhibited oxidation of lipid in ground cooked beef (Brettonnet *et al.,* 2010). Some herbs and spices (rosemary extracts, sage, garlic) are being used to enhance flavor, to retard rancidity, to control microbial growth and for lowering the risk of some cardiovascular diseases. A study revealed that raw and minced beef and pork treated with sage and oregano essential oils exhibited appreciable results during a twelve day storage duration. Better effects were observed in cooked rather than in raw meat (Fasseas*et al.,* 2007). This is the reason that some herbs and spices might be used as functional ingredients to meats and meat products with positive effects on meat's physical and sensory properties (Zhang *et al.,* 2010). Oxidative stability of rabbit meat has also been improved by using different natural antioxidants. In few earlier studies, increased dietary oat levels resulted in reduction in oxidation of rabbit meat (López-Bote *et al.,* 1998). Later on, Paci *et al.* (2001) used polyphenol oleuropeine (200 mg/kg) present in dry extracts of olive oil leaves on rabbit meat but failed to observe any reduction in the lipid oxidation in meat.

Oregano (*Origanum Vulgare* subsp. hirtum) essential oil contains phenolic antioxidants (78–82% carvacrol, thymol) (Vekiari *et al.*, 1993). Dietary supplementation of poultry with oregano essential oils (300 mg/kg) has been widely studied with positive effects on meat lipid oxidation (Botsoglou *et al.*, 2002; Botsoglou *et al.,* 2003). In another study, it has also been confirmed that lower doses (200 mg/kg) of dietary oregano essential oil significantly reduced lipid oxidation in rabbit meat (Botsoglou*et al.*, 2004) and also reduced average microbial activity on muscles during the whole storage period (Soultos *et al.,* 2009). Chia (*Salvia hispanica*) is rich in omega-3 fatty acids, mostly α-linolenic acid (Peiretti and Gai, 2009). Chia seed oil is also a source of strong antioxidants (quercetin, myricetin and kaempferol) (Taga *et al.*, 1984; Reyes-Caudillo *et al.*, 2008). In rabbits, the influence of chia seeds was studied on carcass quality, live performance and the fatty acid profile of the meat (Peiretti and Meineri, 2008). Antioxidant effect on meat has also been studied (Meineri *et al.,* 2010).

Tannins are potential candidates among natural antioxidants. These are diverse group of phenolic polymers and can be classified into hydrolysable and condensed tannins. Tannins are known to have antiphlogistic, antimicrobial and antiparasitic. In a study, it has been demonstrated that condensed tannin extract possess the antioxidant and antiradical activity (Marín-Martinez *et al.,* 2009). In rabbit meat, condensed tannins of red quebracho trees have been exposed to increase the b* value (DalleZotte and Cossu, 2009) whereas inconclusive results were found to be associated with hydrolysable tannins from chestnut tree. Gai *et al.* (2009) observed the reduction in TBARS values at 0.5% supplementation, but only at 30 min of induced oxidation, compared to 60, 120 and 180 min. Pro-oxidant effect of hydrolysable tannins was detected at 1% inclusion level while iron content increased significantly (Liu *et al.,* 2009). Dalle Zotte *et al.,* (2009) detected that 0.6% enrichment expressively enhanced saturated fatty acid and mono saturated fatty acid contents.

A blue-green microalga *(Spirulina platensis)* has attained significant consideration due to its potential health benefits, such as lipid lowering, antiobesity, antioxidant effect and hypocholesterolemic action. Spirulina being a good source of protein (over 60%) contains significant quantities of β-carotene, α-tocopherol, vitamin B12 and essential fatty acids, mainly γ-linolenic acid (Ramadan *et al.,* 2008). Peiretti and Meineri (2009) determined the influence of dietary S. *platensis* supplementation on nutrient digestibility, live performance, hygiene risk in rabbits (Peiretti and Meineri, 2008, 2009), and composition of rabbit meat (Peiretti and Meineri, 2009). They found abridged digestibility of almost all the nutrients excluding the crude protein, which exhibited effect of dose level. These studies did not unfortunately determine antioxidant properties.

2.5. Unsaturated fatty acids

Diet/health relationship is greatly affected by the fatty acid composition because each fatty acid imposes its own effect on plasma lipids. In general, low density lipoprotein cholesterol levels in the plasma increases in the presence of SFA thus increases CVD risk. On the other hand, PUFA help in lowering cholesterol levels of low density lipoprotein (Whitney and Rolfes, 2002). It is the reason why considerations have been diverted to the use of PUFA, especially n-3 in meat and meat products (Harris, 2007). According to World Health Organization, the suggested dose of essential poly unsaturated fatty acids in a daily healthy diet is 5–10/1 (n-6/n-3). High risks of chronic diseases can be reduced by using lower levels of these ratios (Simopoulos, 2002). Entire consumption of long chain n-3 poly unsaturated fatty acids is much more significant than the n-6/n-3 ratio (De Smet *et al.,* 2010), even if one study (Gogus and Smith, 2010) determined that further study was needed to define whether or not n-3 fatty acids are significant functional supplements with no adverse effect. The fatty acid composition of muscle foods from monogastric animals, such as poultry, pigs, fish and rabbit can easily be changed by feed, and thus poly unsaturated fatty acids content could be amplified by enriching feeds with vegetable, such as rapeseed oil, linseed or with fish oils (Decker and Park, 2010; Zhang *et al.,* 2010). Furthermore, enrichment of meat with ingredients such as linseed (source of linolenic acid) acorn (source of oleic acid) (Narvaez-Rivas *et al.,* 2008), or by feeding of grass (source of linolenic acid) could be supportive in enhancing poly unsaturated fatty acid levels. It is a thing of consideration that grass feeding can raise DHA levels (Wood *et al.,* 2008). Increasing levels of PUFA in muscles foods result in oxidation as they contain high percentages of pro oxidative metals, usually low in endogenous antioxidants, and frequently exposed to processing and cooking operations. Dietary fortification with poly unsaturated fatty acids sources must be accompanied with antioxidant fortification. As far as composition is concerned, rabbit meat could be a very valuable food in diets of human. In rabbit meat, unsaturated fatty acids accounts for 60% of the total fatty acid, and the poly unsaturated fatty acids represents 32.5% of the total fatty acids that is much higher than in other meats including poultry (Salma *et al.*, 2007; Wood *et al.*, 2008). Linoleic acid (18:2 n-6) constitutes the major portion of diet for all species. Its absorption in adipose tissues and muscles is greater than that of other FAs (Wood *et al.*, 2008) of total FAs, rabbit meat contains 22±4.7% (Hernàndez and DalleZotte, 2010). Alfalfa grass is an important raw material in rabbit feed. Major proportion of this grass consists of α-linolenic acid (18:3 n-3) FA. Rabbit meat contains high amounts of linoleic acid that accounts for 3.3±1.5% of the total FA (Hernàndez and DalleZotte, 2010) as compared to values reported in other meats (1.37 in lamb, 0.95 in pork and 0.14–2.34% in beef) (Enser*et al.,* 1996; Muchenje *et al.*, 2009). The richness of α-linolenic acid in lean meat of rabbit subsidizes to the maximum percentage of total n-3 fatty acids (5.5% total fatty acid) among the meats. Within long chain poly unsaturated fatty acids, the eicosapentaenoic acid content in loin meat of rabbit is 0.15% and the docosahexaenoic acid is 0.31% of total fatty acid. The n-6/n-3 ratio of lean rabbit meat exhibited that loin rabbit meat possessed a fairly low ratio (7.0±3.6), lower than that of pork loin (21.9), beef (8.9) and chicken breast (15.8), and comparable to that of loin meat of veal (6.6). Eicosapentaenoic acid and Docosahexaenoic are the most bioactive form of n-3 fatty acid, while α- linolenic acid has very little bioactivity due to its conversion to eicosapentaenoic acid is very low in humans (Decker and Park, 2010); these two functional food ingredients can be enhanced in meat of rabbit through feeding of animals. Feeding and housing conditions impose direct effect on the FA profile of meat. Studies have suggested that genetic variation for long- chain PUFA metabolism may help in selecting improved FA profile (Ntawubizi *et al.,* 2010). Ramírez *et al.* (2005) studied that selection for growth rate in rabbits increased the fat content in hind leg meat and improved its FA profile. Studies also revealed that 14 generations of selection increased the percentage of C14:0, C16:0 and C16:1 cis n-7 while decreasing the percentage of C18:2 n-6 and C20:4, n-6. On the other hand, the n-6/n-3 ratio improved slightly. In a recent study, an increase in lean meat and PUFA was observed whereas MUFA decreased by using long-term Computer Tomography (CT)-based selection in rabbit's meat (DalleZotte *et al.* 2009). A lowering trend in n-6/n-3 was observed but ratio of n-6/n-3 changed non-significantly. Taken together, it can be noticed that FA profile in rabbit meat can be modified by good genetic selection. It has also been observed that housing conditions also have a good impact on FA profile modification. A significant increase was observed in SFA, PUFA, n-6, n-3 when rabbits were housed in larger cages (Dal Bosco *et al.*, 2002; DalleZotte *et al.*, 2009; Lazzaroni *et al.*, 2009). Some studies suggested that exercise and regular electrical stimulation infra-vitam affected FA profile in muscles (Szabó *et al.*, 2002; Szabó *et al.*, 2004. Szabó *et al.* (2002) observed that exercise increased the proportion of oleic acid (C18:1 n-9) significantly while decreasing stearic (C18:0) and arachidonic (C20:4 n-6) acids.

Alternative approaches to housing conditions and feeding methods have been studied. Cavani *et al.* (2004) compared indoor i.e., 2 rabbits/cage and outdoor rearing systems that can be classified into movable cages, 6 rabbits/cage. Hind leg meat of those rabbits reared outdoor contained higher amounts of SFA, lower MUFA and higher PUFA (higher content of n-6, n-3, EPA and DHA). These outdoor conditions did not affect PUFA/SFA and n-6/n-3 ratios. Preziuso *et al.* (2008) compared rabbits reared indoor (4 rabbits/cage) or outdoor (8 rabbits/cage, colony cage with straw litter). Pasture availability has been studied by Forrester-Anderson *et al.* (2006), Dal Bosco *et al.* (2007) and Mugnai *et al.* (2008). Organic rabbit production was examined by Dal Bosco *et al.* (2007) and Pla (2008). Taken together, rabbits grown under alternative housing approach had less MUFA, and was richer in PUFA, n-3, and α- tocopherol.

Omega 3 fatty acids and α-tocopherol contents in the meat of rabbits can be enhanced by various alternative methods like pasture grazing and organic production, hence proposing customers a healthier selection of meat. Meat quality is highly affected by feeding. Considerable research has focused on enhancing n-3 poly unsaturated fatty acids content in the meat of rabbits through feed. This enhancement can be achieved in the monogastric animals by improving feeds with vegetable oil and ingredients that are rich in omega 3 poly unsaturated fatty acids. The replacement of fat (animal with vegetable oil sources like soybean, rapeseed, sunflower, coconut, and palm) in rabbit feeds was the first method adopted to in poly unsaturated fatty acids in meats (Dalle Zotte, 2002). Unsaturation index of intramuscular lipids is increase by the dietary improvement with vegetable oils. Lopez-Bote *et al.* (1997) compared the feeds enriched with olive oil or sunflower oil and non-enriched diet and stated that addition of oils reduced n-3 fatty acid concentration in polar lipids of rabbits meat. The utilization of linseed oil as a source of linolenic acid in the feed of rabbits as an effective way to raise the n-3 poly unsaturated fatty acids content and retard the n-6/n-3 PUFA ratio in meats was explored. Linseed oil enrichment deteriorated oxidative stability but was vetoed by dietary enrichment with α-tocopheryl (Tres *et al.*, 2008; Zsédely *et al.*, 2008). The usage of linseed in rabbit feeding as a raw material was also tested. Bianchi *et al.* (2006) determined the outcomes of dietary utilization of whole linseed (8%) on meat quality of rabbits and described a momentous retardation in the n-6/n-3 ratio. Again (Bianchi *et al.*, 2009) enriched the rabbit feed with different levels of whole linseed (3, 6 or 9%). Linseed enrichment expressively reduced the saturated fatty acids and enhanced the poly unsaturated fatty acid contents in the meats of rabbits, but at the same time the increase of C18:3, n-3 was the maximum. As predictable, the n-6/n-3 ratio remarkably reduced in the loin muscle and hind leg meat. A close relation between the content of C18:3 in meat and the content of whole linseed in the feed were also found (Bianchi *et al.*, 2009): The authors suggesting 3% dietary linseed enrichment appropriate for attaining both the enhancement of the meat with α-linolenic acid and preserving better quality product. Ander *et al.* (2010) stated that the use of ground linseed (10%) in the feed consequence in assimilation of α-linolenic acid in all the tissues of rabbit (kidney, plasma, heart, brain, liver, carotid, aorta). EPA and DHA levels were also tremendously enhanced in various tissues, though their properties were not as good as with α-linolenic acid. n-6/n-3 fatty acid ratio and arachidonic acid also reduced in all tissues of rabbits achieved from the linseed enriched group.

In most of the studies, the enrichment of dietary linseed was provided from weaning up to butchery. It has also been an effective approach to provide dietary enrichment for short term duration. Two dissimilar feeds were given to rabbits between the ages of 4 and 12 weeks. One was rich in saturated fatty acids and the other was rich in unsaturated fatty acids. Rabbits were nourished saturated fatty acids or unsaturated fatty acids feed up to eight weeks of age. After that the feeds were overturned (saturated fatty acids-unsaturated fatty acids, unsaturated fatty acids- saturated fatty acids) up to twelve weeks of age. The saturated fatty acids-unsaturated fatty acids treatment presented a momentous enhancement in C18:3, n-3 and a reduction in C20:5 and C18:0, n-3. In the unsaturated fatty acids- saturated fatty acids treatment, C14:0, C16:0, C18-1 n-7, C18:1 n-9 and C18:3 n-3 enhanced meaningfully while C18:2 n-6, C20:4 n-6 and C22:4 n-6 reduced (Szabó *et al.*, 2004a). Later on Gigaud and Combes (2008) reared the rabbits on a commercial feed from thirty five to fifty days of age after that supplemented n-3 fatty acid feed (attained by supplementation of linseed) up to seventy five days of age. In comparison with the control treatment, the n-6/n-3 ratio in the rabbits meat reared on the n-3 supplemented feed was too little. Maertens *et al.* (2008) studied the fatty acid composition of the meat of rabbits reared on an extruded linseed feed for different phases after weaning and determined that when a feed enriched with high extruded linseed concentration (12.8%) is provided for the period of only two weeks before butchery, the contents of omega-3 fatty acids in the meat of rabbits might be double as increase as that of the control treatment. Corresponding to the other ruminants, rabbits comprise branched chain and odd-numbered fatty acids that are of microbial origin in meat because of caecotrophy.

2.6. Conjugated linoleic acid

In the previous two decades awareness in conjugated linoleic acid has amplified because of its impending benefits to human health. In various animal studies, though the trans-11, cis-9 conjugated linoleic acid isomer has been renowned as ought to anti-cancer attributes but still it is not yet recognized either naturally occurring conjugated linoleic acid has noteworthy health influence on the inhibition of cancer or not. Future research is consequently mandatory to authorize the consequences of conjugated linoleic acid on prevention of human cancer (Decker and Park, 2010). Various other favorable biological potentials recognized to conjugated linoleic acid include anti atherosclerotic, antioxidant, anti diabetogenic attributes, bone formation contribution and immune system protection (Zhang *et al.*, 2010). Conjugated linoleic acid has also been linked with anti-obesity: the 10-trans, 12-cis conjugated linoleic acid has been recognized to perform in fat repartitioning. It is not a naturally presenting isomer (Decker and Park, 2010). On the other side, there are also some negative possessions like induction of colon carcinogenesis, fatty spleen and liver and hyperproinsulinaemia have been described for conjugated linoleic acid (Benjamin and Spener, 2009). Sources of food from ruminants (dairy and milk foodstuffs) are recognized ought to remarkably higher conjugated linoleic acid concentrations from monogastric animals. In the ruminants, a substantial quantity of double bonds is of the trans category because of the biohydrogenation in the rumen. The major trans fatty acid, C18:1 trans vaccenic, is converted to C18:2 cis-9, trans-11 conjugated linoleic acid in adipose tissue by the action of stearoyl Co-A desaturase. Conjugated linoleic acid occurs in large magnitudes in neutral than in phospholipid and it is also more in adipose tissue than in muscle. Thus conjugated linoleic acid level rises with fatness of animal. Conjugated linoleic acid is also formed in the animal rumen, but it is synthesized from C18:1 trans vaccenic in tissues (Wood *et al.*, 2008). In spite of this, meat that is obtained from ruminants creates only a little involvement to nutritionally important ranks. The approximate conjugated linoleic acid concentrations in beef range from 6 to 9 mg/g fat, while conjugated linoleic acid dietary consumption from natural sources is assessed to range between 97.5 mg/day but still it is not vibrant if increasing utilization will really produce effects on health (Decker and Park, 2010). According to Zhang *et al.* (2010) 1.5 to 3 g/day/adult is mandatory for healthiness effects. Conjugated linoleic acid concentrations in the meats can be enhanced up to 3 times with the inclusion of dietary oils or oil seeds like linseed or with the straight addition of conjugated linoleic acid into beef diets. Decker and Park (2010) stated that monogastric animals are powerless to produce conjugated linoleic acid; hence the conjugated linoleic acid existing in their meat originates from the feed. Zhang *et al.* (2010) conveyed contradictory possessions of dietary conjugated linoleic acid on growing, body conformation and quality of meat due to animal breed, species, age, period and amounts of conjugated linoleic acid fed the composition of diet and husbandry situations. It is normally acknowledged, however dietetic conjugated linoleic acid can enhance body conformation by retarding fat confession in broilers, rats and pigs. It has inappropriately been exposed that with fat deposition reduction, mono unsaturated fatty acid (palmitoleic acid) and poly unsaturated fatty acid (linoleic, oleic and arachidonic acids) concentrations reduced momentously in pigs and broiler chickens. Commercially accessible conjugated linoleic acid preparations contain 2 key isomers: trans- 10, cis-12 and cis-9, trans-11 almost in 1:1 ratio (Martin and Valeille, 2002). Conjugated linoleic acid contents in monogastrics meats may be enhanced up to thirteen times in breast muscle of chicken (Kawahara *et al.*, 2009) and up to 130 time in pig loin muscle (Joo *et al.*, 2002), by enriching feeds with 2% and 5% synthetic conjugated linoleic acid respectively. Dietary conjugated linoleic acid given to chicken correspondingly enhanced firmness and reduced the juiciness, but meanwhile reduced oxidation of lipids and enhanced stability of colour in cooked meat. In case of pigs, dietary conjugated linoleic acid reduced TBARS value and drip loss but enhanced stability of colour (Zhang *et al.,* 2010). Conjugated linoleic acid has newly established a countless pact of consideration as a feed enrichment in rabbits. Monogastric animals are powerless to produce conjugated linoleic acid¸ unlike other monogastric animals, yet through caecotrophy rabbits are able to hold conjugated linoleic acid in their meat (Gómez-Conde *et al.,* 2006). Determining the impact of feed on the involvement of caecotrophy to tissue fatty acid outlines, Leiber *et al.* (2008) established a normal amount of cis-9, trans-11 conjugated linoleic acid of 0.07 g/100 g. Conjugated linoleic acid contents in the meat of rabbits can be enhanced by dietary inclusion of synthetic conjugated linoleic acid (Lo Fiego *et al.,* 2005).

Supplementation of dietary conjugated linoleic acid (CLA) has been revealed to enhanced body composition of rabbit (Corino *et al.,* 2002; Corino *et al.,* 2003) owing to its capability to retard fat and increase deposition of lean tissues. The highest CLA supplementation level reduced perirenal fat weight, lowered concentrations of serum triglycerides and total cholesterol, decreased meat lipid contents, and improved oxidative stability (Corino *et al.,* 2002, 2003). Marounek *et al.* (2007) considered the conjugated linoleic acid deposition in rabbit tissues with quantity and duration of treatment. Conjugated linoleic acid was provided at 1% during 3 weeks before slaughter and 0.50% during 3 or 6 weeks. Again, in treatments reared with conjugated linoleic acid, the total mono unsaturated fatty acid contents reduced while saturated fatty acid concentration enhanced in both loin and hind leg meat but this time, poly unsaturated fatty acid concentration increased meaningfully. The contents of conjugated linoleic acid in lipids tissue enhanced with enhancing conjugated linoleic acid concentration in the feed. These studies recommended that the consequence of supplementation of dietetic conjugated linoleic acid rely not only on the amount of dietary conjugated linoleic acid but also on the age of animal. Though growth performance of rabbits and carcass characters at marketable slaughter weight were unpretentious by supplementation of dietary conjugated linoleic acid at 0.25 or 0.50%, at heftier slaughter weight (3.1 kg). Period of conjugated linoleic acid serving had non-significant results on conjugated linoleic acid deposition. Hence it is more appropriate to produce conjugated linoleic acid-enriched rabbit meat at lower costs by the inclusion of conjugated linoleic acid at higher concentration in the diet and giving conjugated linoleic acid supplemented feed for a shorter time span.

Supplementation of Dietary conjugated linoleic acid vestiges a sensible choice in production of a valued meat and meat products with valuable healthy possessions for humans.

2.7. Cholesterol

Rabbit meat has low levels of cholesterol (47.0 and 61.2 mg/100 g), for hind and loin legs, respectively of all the common meats (Lukefahr *et al.,* 1989; Dalle Zotte and Paci, 2006; Dalle Zotte *et al.*, 2006). The variation in cholesterol content in different species is due to muscle and fibre type (Chizzolini *et al.,* 1999). The cholesterol content of rabbit meat is influenced by feed intake. As cholesterol have potential implication on the health of human, so feeding strategy must be according to the lower level of cholesterol content. According to Kowalska and Bielanski (2009) a diet supplemented with 3% fish oil lower the cholesterol level significantly in hind leg meat (61.4 mg/100 g) as compared with control group (66.3 mg/kg). Xiccato and Trocino (2003) also indicated that a diet having suitable amount of unsaturated fat lower the cholesterol level in meat.

The impact on levels of cholesterol in plasma of rabbits by conjugated linoleic acid is ambiguous. When a diet supplementing with 1% CLA and 0.1% to 0.2% cholesterol fed to rabbits for 90 days, there was a decrease in 30% of atherosclerosis and increase in the level of serum cholesterol while the total cholesterol content in the liver remained the same (Kritchevsky *et al.*, 2000). Corino *et al.* (2002) found that the serum cholesterol level was significantly higher in 0.5% CLA-fed rabbits and lower in 0.25 or 0.50% CLA-fed rabbits while conducting numerous trials. The content of cholesterol was not measured and there is need of further research to know how conjugated linoleic acid supplemented in diet affects cholesterol contents in rabbit meat. Ubhayasekera *et al.* (2010) tested numerous fat by-products to check influence of oxidized lipids (OXL) and trans fatty acids (TFA) on cholesterol and oxycholesterols in the plasma, liver and meat of rabbits. The authors determined that the levels of cholesterol and oxycholesterol was higher in human which consumed the meat made from rabbits having high levels of trans fatty acid or oxidized lipids

2.8. Biological value of proteins

Rabbit meat comprises great amount of essential amino acid. As compared to other meats, meat of rabbit is richer in lysine (2.12 g/100 g), threonine (2.01 g/100 g), leucine (1.73 g/100 g), valine (1.19 g/100 g), isoleucine (1.15 g/100 g), sulfur-containing amino acids (1.10 g/100 g) and phenylalanine (1.04 g/100 g) (Hernàndez and Dalle Zotte, 2010). This balanced and enhanced essential amino-acid and its easiness in digestibility provides high biological value proteins to rabbit meat. Proteins of connective tissue are considered as lower biological value and its dietetic worth is also less in spite of their enhanced digestibility (Combes and Dalle Zotte, 2005).

2.9. Rabbit meat quality

There is high variability regarding genetics of rabbit among the pure-breed (a large rabbit is five times more heavily than a dwarf at adult weight). For determining the growth rate, the rabbit's body composition and precocity degree, the body weight of adult is most important (Ouhayoun and Rouvier, 1973; Rochambeau, 1997). However, the commercially available hybrid rabbit which is nurtured for meat are selected on the basis of three-way cross in which breeds have adult weights generally ranging from 4 and 5 kg and their ages-weight at commercial slaughter (from 11 to 13 weeks) is not so different for final products. The recent study carried by (Lambertini *et al.*, 1996; Hernàndez *et al.*, 1998) showed that there is great variability to maintain the quality of meat however rabbit meat seems to maintain constancy in quality. In the recent years, growth of rabbit is considerably effected by breeding strategies (Rochambeau, 1997).

Animal body weight depends not only on its age but also both on rabbit weight and its age. Moreover, the research carried on this topic is quite difficult to compare due to use of different strain and also as it considered the influence of age by changing the slaughter weight (Rudolph and Fischer, 1979). The result of the Szendrö *et al.* (1996) study showed better meatiness and dressing percentage from rabbits that weighed in the range of 3.2–3.4 kg when conducted experiment on seven slaughter weights (from 2.2 to 3.5 kg) when ranged into classes in attaining of 200 g. Improved carcass meatiness and decrease in chilling losses are obtained through increase in slaughter age (Bernardini *et al.*, 1995; Xiccato *et al.*, 1999). Delaying the slaughter age improve the growth potential but it effect the economic interest due to decrease in feed conversion ratio and increase in fat content of carcass, however quality of meat improves as rabbit growth increases. Meat smell or flavor is enhanced due to high content of fat but it reduced the water content of meat (Parigi Bini *et al.*, 1994; Jehl and Juin, 1999).

The source and the level of dietary fat play significant role to maintain the meat and carcass quality. However the addition of dietary fat in adequate concentration (3–6%) improve the both the carcass quality and carcass yield (Raimondi *et al.,* 1974; Beynen *et al.,* 1990). However, the effect of dietary fat is mainly concern about the deposition of fat in adipocyte in case of total dissectible or perirenal fat (Lebas *et al.,* 1988). The supplementation of fat in diet increase above these value also enhanced deposition of fat (Lebas *et al.,* 1988; Christ *et al.,* 1996) while it will reduced yield of carcass so causing the enrichment of fat unprofitable (Raimondi *et al.,* 1974). However, during feeding the condition of fat that is added must be restricted to 3% because of problem arises in technological and economic aspect such as decrease in pellets hardness and costs of food production. There are significant consequences of dietary fat that influence composition of meat. There is variability in rabbit meat in concentration of fat by extracting with ether ranging naturally from 1 to 2% in the longissimus dorsi muscle whereas in hind leg it is 3-4% and it is considered as low fat meat (Dalle Zotte *et al.,* 1998). When fat is added at moderate levels there is not significant change in lipid content of longissimus dorsi muscle, on empty body or on whole carcass meat (Raimondi *et al.,* 1974; Fernandez and Fraga, 1996; Cobos *et al.,* 1993). However, increase in dietary fat enhance the fat content (Christ *et al.,* 1996), while reducing protein and water content (Pla and Cervera, 1997). The dietary fat inclusion also affects the sensory properties such as juiciness, colour, flavor, tenderness and overall acceptabilty of cooked rabbit meat which affect the consumer demand (Lebas *et al.,* 1988).

The processing of carcass effect the quality of meat than production feature like feeding system. The quality of meat is highly influenced during storage in refrigeration such as duration of temperature, fluctuation in temperature and also on packaging material etc. (Hulot and Ouhayoun, 1999). pH also play important role during storage as at low pH increase bacteriostatic effect while at pH higher than 6 then it enhance favorable condition for proteolytic microorganisms development.

pH of meat tends to increase during storage at chilling (2–4°C) due to increase in the levels of ammoniacal nitrogen (Sunki *et al.,* 1978). Further, pH continues to decline as temperature decreases and also due to burn up of reserve energy of muscle (Ouhayoun *et al.,* 1989). However, fluctuation in pH that will show increasing trend (5.81–5.91 up to 8 days, 5.88 at the 12th day) in 12 days storage at 2°C that was due to two mechanisms which increase or decrease pH by increase in the level of ammoniacal nitrogen and increase in the formation of free fatty acid (Cabanes *et al.,* 1996).

2.10. Health benefits of rabbit meat

Rabbit meat is lower in fat, higher in protein and has fewer calories than other meats. One of the best white meats that are available in the today's market is rabbit meat (Fernandez and Fraga, 1996). It has a higher percentage of protein that is easily digestible. Our body needs protein in the diet for healthy cellular functions and processes. Protein is needed by the body for tissue repair, development and maintenance. The human body must have protein in the diet for overall fitness and proper body functioning. Meat of rabbit is nearly free cholesteric and lower in sodium contents and consequently precise for heart patients (Pla *et al.*, 2004). The phosphorus and calcium contents of rabbit meat are greater than any other type of meat. Calcium aids in bone wellbeing along with Phosphorus and also supports in fluids regulation. Potassium also provides assistances in the regulation of fluid and aids in removing salts from the body (Stanley *et al.*, 2007).

Rabbit meat contains most of the other minerals and vitamins, which are required by the body in small quantities. Minerals include zinc, copper and iron. Zinc is very significant in calcium absorption and boosting the immune system while iron is imperative in the construction of red blood cells and the absorption and distribution of oxygen throughout the whole body (Weiss *et al.,* 2010). Copper is required for development and cellular growth and is reserved in through food because the human body is unable to yield copper (Decker and Park, 2010). Rabbit also holds selenium that acts as an antioxidant that eliminates those unbounded radicals which can do impairment to the body. Selenium can battle with some types of cancer, as well as the aging consequences. Selenium is also very imperative in supporting a healthy immune system and sustaining better functioning of thyroid glands. Potassium is also present in rabbit meat that benefits with the regulation of body fluids and aids in excluding salts from the human body (Zhang *et al.*, 2010).

Riboflavin or vitamin B2 is an additional nutrient that is present in meat of the rabbit which is vital to retain healthy digestive track. It participates in the process of protein and fats break down. Proper function of the nervous system is maintained by vitamin B12 is also present in the rabbit meat. It is required in the fabrication of red blood cells and protein (Dal Basco *et al.,* 2004). Rabbit meat, that is a low fat high-protein diet, is totally impeccable for loss in weight. It contains anti-aging components and anti-oxidants namely glutathione and selenium. Glutathione is just like protein antioxidant molecule. It should be regularly rehabilitated while the riboflavin in the meat of rabbit facilitates this reaction (Bernardini *et al.,* 1999).

Meat of rabbit is exclusively suggested for the elderly whose digestive system has slow down and ingestion is negotiated, for superior diets such as for heart patients, due to life stage or illness. It is also recommended for weight reduction diets and low sodium diets because it is easily digestible. Doctors also suggested rabbit meat for patients who feel trouble in ingestion of other meats. It has splendid taste and there are many ways to cook it. In view of all these apprehensions, present study is conducted for the enrichment of poly unsaturated fatty acids ratio in meat muscles tissues of rabbits by utilizing oat and linseed in feed supplementation in order to enhance the quality and stability of meat and meat product to ensure its worth against life style disorders.

2.11. Sensory meat quality

Sensory attributes of meat are critical for the customer's choice. The variables that are most important include the texture (juiciness and tenderness) appearance (consistency of the raw meat and colour) and flavor (aroma, smell and taste). Meat of rabbit with the passage of time may change appearance: it may become drier or wet and darker according to systems of packaging, with significances for its suitability to the customer. The customer associates freshness and superiority of lean meat with a decent appearance. In spite of these reasons, conditions of storage and different packaging approaches must be taken into consideration and evaluated. Meat of rabbit is considered to have positive sensory attributes by the modern customer: it is lean, tender and dexterously flavored. However, its characteristic perception of wild game meat is the core reason of refusal occasionally supposed by the customer (De Carlo, 1998). Scientists further examined the different promises to retard rough perception in meat of rabbit having the goal of satisfying this specific customer group.

Gil *et al.* (2006) and Ramı´rez *et al*. (2004) detected an enhancement in the shear firmness in the particular rabbits while comparing different rabbits selected for growth rate with a control group that specifies extra resistance to cutting of the meat. Chewiness gumminess and hardness also improved. Gondret *et al.,* (2002) investigated in a trial relating deviating selection for weight at age of slaughter. They detected larger values of total energy desired and the shear force to cut the meat of the rabbits chosen for enhanced body weight as comparison to those which are chosen for reduced body weight. Larzul *et al.,* (2005) determined a lower value of total energy required and the shear force to cut the meat of the rabbits chosen for enhanced body weight as comparison to those which are chosen for reduced body weight from the same line. Only Herna´ndez *et al.* (2005) investigated the influence of selection for growth rate on rabbit meat's sensory characteristics. There were no differences in juiciness texture and fibrousness of the rabbit meat. Flavor of the liver was appositely greater in selected rabbits. Taylor (1985) recommended while comparing rabbits from various breeds or species at the same maturity stages in order to elude alterations due to the physiological age differences (Pla *et al.,* 1997; Blasco *et al.,* 2003). However, for growth rate selection in rabbits enhances the adult gain in body weight (Blasco *et al.,* 2003). Tenderness of meat is linked to the variations of the myofibrilar proteins on the connective tissues during post-mortem (Møller, 1980). The prime constituent of the connective tissue is collagen. Tenderness of meat depends on the amount of collagen contents and its solubility (Bailey and Light, 1989). Bailey (1985) stated that the age of animal greatly disturbs the collagen structure. The selection effect has not previously been studied for growth rate on the concentration of collagen and its solubility in rabbit meat.

2.12. Trends in rabbit meat processing

The initial stages in current processing of carcasses are slaughtering, evisceration and chilling (Cavani and Petracci, 2004). The majority of processed rabbit meat is sold as fresh cut for direct customer sale for consumption or utilization in institutional markets or restaurants. Both of them needed an extremely unvarying size of rabbit and particular operations for cutting of carcass portion. If cut-up parts are hand deboned, edible tissues may be recovered from bones and skeletal frames by using belt-and-drum deboners and this meat is classified as "mechanically deboned meat" (McNitt *et al.,* 2003; Negatu *et al.,* 2006).

Marination is the liquids addition to meat before cooking the meat. It is an ancient method used in meat preparing either as a preliminary step in preservation or for immediate consumption. Soaking in oils, vinegar or both in combination with condiments enhanced meat flavor and protracted the shelf-life and also masks the off flavor. Recently, marination has been recognized to offer extra benefits including functionality of use of product and enhanced better yield for the producer (Smith and Acton, 2010). Different products formed from the meat of rabbit include meat patties, meat nuggets (such as preformed nuggets and hamburger patties) which are prepared with coarsely ground meat obtained from fore and hind leg. To reduce cost of raw materials, also meat from culled rabbit does are often used to prepare formed products. Until now traditional coarse-ground sausages manufactured by rabbit meat have not gained much interest in marketplace. On the other hand, to produce advanced emulsified products, like bologna and hot dogs, raw meats are finely ground and typical fibrous structure disappears. In pork and poultry since many customers choose the fibrous structure of whole-muscle meat. These products, though very famous, are mostly regarded as having lower esteem than whole-muscle products (Fletcher, 2004).

The lipids oxidation in meat and meat products is a problematic that retards stability of fermented and frozen processed meat, but also of precooked meats. In the latter, lipid oxidation leads to formation of "warmed-over flavors" which refer to the development off-flavor in cooked product when reheated after refrigeration storage (Weiss *et al.,* 2010). Meat of rabbits has a quite higher concentration of polyunsaturated fatty acids (Dalle Zotte and Szendro, 2011) which makes it rather susceptible to lipid oxidation and the subsequent off-flavor (and off-aroma) characteristic of warmed-over flavors (Bianchi *et al.,* 2006). There are several compounds with antioxidant potential which may use as food ingredient (BHA, BHT, sodium nitrate, tocopherols, selenium, ascorbic acid, etc.) (Decker and Park, 2010; Weiss *et al.,* 2010; Zhang *et al.,* 2010) and/or dietary fortification (tocopherols, ascorbic acid, etc.) (Abdel-Khalek, 2010; Dalle Zotte and Szendro, 2011) in order to prevent or at least reduce meat oxidation processes. It is well known that tocopherols are most effective antioxidants also in rabbit meats and their content can be easily increased both by dietary fortification (Lopez-Bote *et al.*, 1997; Castellini *et al.*, 1999) and its use as ingredient with beneficial effects on oxidation of lipid during frozen storage (Castellini *et al.,* 1999; Lo Fiego *et al.*, 2004) cooking (Dal Bosco *et al.,* 2001) colour stability (Dalle Zotte *et al.*, 2000; Corino *et al.,* 1999) as well as some technological properties.

Evolution from whole carcass and cut-up to process products in rabbit sector would imply demand of some degree of extended shelf-life, product diversification and convenience. Convenience is a very important function of modern package together with containment, information and protection. For example, single serving size of sliced meat and microwavable packages allow for cooking/reheating and consumption of the product in a part of the package (Dawson, 2010). In modern retails, rabbit meat products are retailed for display and they are store branded or branded by the supplier. Currently stretchable and clear polyvinylchloride (PVC) film overwraps with product placed on an expanded polystyrene (foam) tray is the common case ready display package for most traditional rabbit products such as whole carcass and cut-up. An absorbent pad can be placed under the meat to adsorb purge (Dawson, 2010).

Rabbit meat offers high nutritional quality meat as it is already lower in fat as compared to other meats. Hence rabbits are monogastric so the addition of oat and linseed in the feed of rabbits will enhance PUFA concentration to a level that is desired to reduce blood cholesterol concentration of hypercholesterolemic subjects.

CHAPTER 3

MATERIALS AND METHODS

This research work "Exploring the potential of rabbit meat as a functional food" was conducted at Meat Science & Technology Laboratory, National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan.

3.1 Procurement of raw material

Twenty five to thirty days old rabbits (New Zealand white breed) were purchased from National Institute of Health Islamabad, Pakistan. All the reagents and chemicals for this research were purchased from Sigma Aldrich (Germany) and Merck (Germany). Oat (*Avena Sativa*) Sargodha 2000 variety and Linseed (*Linum Usitatissimum*) LS Chandni variety were purchased from Ayub Agriculture Research Institute (AARI), Faisalabad, Pakistan. The remaining feed contents were procured form local market of Faisalabad. The rabbits were weighed individually and then randomly divided in to 5 cages of 15 rabbits each.

3.2 Feed composition

The feed of rabbits was supplemented with oat and linseed. The composition of the feed is given below

Table 3.1: Formulation of rabbit feed

Ingredients (%)	**T0**	**T1**	**T2**	**T3**	**T4**
Alfalfa Fresh	95.00	65.00	65.00	65.00	65.00
Oat	0.00	4.00	2.00	0.00	0.00
Linseed	0.00	0.00	0.00	7.00	3.50
Maize	0.00	26.20	28.50	23.00	26.50
Calcium-phosphate	1.35	1.35	1.35	1.35	1.35
Premix	1.20	1.20	1.20	1.20	1.20
Molasses	1.00	1.00	1.00	1.00	1.00
Salt	0.70	0.70	0.70	0.70	0.70
Calcium-carbonate	0.70	0.70	0.70	0.70	0.70
DL-methionine	0.05	0.05	0.05	0.05	0.05
Total	100	100	100	100	100
Dry Matter	89.93	89.96	89.85	89.81	89.87
CP (% DM)	17.58	18.08	17.76	18.47	18.34
GE (Kcal/g)	3.994	3.957	3.982	3.974	3.968

3.3 Experimental plan

Twenty five to Thirty days old rabbits were used for this experiment. The rabbits were divided in to 5 groups with separate cages and 15 replicates in each cage. The detail of the treatments is given below.

Table 3.2: Detail of the treatments

S. No	Treatments/ Groups
T0	Control feed
T1	Feed containing (4%) oat
T2	Feed containing (2%) oat
T3	Feed containing (7%) linseed
T4	Feed containing (3.5%) linseed

3.4 Experimental site management and conditions

The research room and all the pens were thoroughly white washed and disinfected with Bromo-Sept and Formalin aqueous solutions with ratio 1:12 inside and outside the pens prior to the trial conduction. A 2-3 inch thick layer of saw dust was made in each pen as litter to keep the pen bed dry and soft. All the drinkers and feeders were washed thoroughly with water and disinfected with Bromo-Sept aqueous solution in the ratio of 1:3. All the pens were tagged with respective treatments and replication numbers. The rabbits were kept in student reserved research room having 15 pens of 12 sq feet capacity each. A group of 5 rabbits was placed in each pen. The temperature of the experimental room was maintained at 25±5 ºC. Twenty four hour light and proper ventilation was provided in the experimental room throughout the period. Feed along with fresh and clean water was given ad-libitum.

3.5 Feed intake, Weight gain and FCR (Feed Conversion Ratio) Calculation

The rabbits were weighed on first day of trial. Then they were weighed on weekly basis to calculate the weight gain during each week. It is carried out on weekly basis to check significant change in the weight of rabbits. At the start of each week a weighed amount of feed was fixed for feeding the rabbits in each pen. At the end of each week feed intake and weight gain was calculated. Feed conversion efficiency was calculated by dividing the feed consumed in the whole week with weight gain by the rabbits in the respective week.

FCR = Feed consumed by the rabbits in one week / weight gain by the rabbits in one week

3.6 Slaughtering of the experimental rabbits and collection of samples

The experiment was conducted for eight weeks. The weight of the rabbits was recorded on weekly basis for 8 weeks. After slaughtering, loin and hind legs of rabbits were deboned, wrapped with aluminum foil and finally packed in polythene zip lock bags with respective labels and stored in the freezer at -18°C for further analysis. The blood samples were also collected from the jugular vein and stored in the heparinzed blood sample tubes.

Analysis of rabbit meat

3.7 Physico-chemical analysis of meat

The Physico-Chemical Analysis (pH, Water Activity, Crude Protein, Crude Fat and Texture) of loin and hind leg rabbit meat was estimated by their respective analytical methods as discussed below.

3.7.1 pH measurement

The pH of the meat was measured by using digital pH meter (InoLab PH720, WTW 82362, Weiheim, Germany) by following the method as described by Sallama *et al*., (2004). Sample (10 g) was homogenized with 50 ml distilled water and pH value was measured by a digital pH-meter.

3.7.2 Water activity

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, Huntington, NY, USA) as described by Cosenzaa *et al.* (2003). Sample (10 g) was taken in plastic cup and the water activity was measured by water activity meter.

3.7.3 Crude protein analysis

The percentage of nitrogen in each sample was determined by using Kjeldahl's method as given in AOAC (2000). Sample was digested in sulphuric acid H_2SO_4 to convert organic form of 'N' to inorganic form i.e. ammonium sulphate and it was distilled in Kjeldhal's apparatus by using NaOH so that all ammonia liberated and absorbed in boric acid having indicator. Ammonia absorbed by boric acid was noted by titrating against H_2SO_4. The nitrogen content was calculated according to the following formula.

$$N (\%) = \frac{0.0014 \times \text{Vol. of } H_2SO_4 \text{ used} \times \text{Vol. of digested sample} \times 100}{\text{Wt. of sample} \times \text{Vol. of sample taken for distillation}}$$

Crude protein was calculated by multiplying N % with the factor as follows:

Crude protein (%) = N (%) x 6.25

3.7.4 Crude fat content

The crude fat content was determined by using n-hexane solvent in Soxhlet apparatus according to the method described in AOAC (2000). Moisture free samples were packed in thimble and put in the tube of Soxhlet apparatus. The samples were run for 2 hours and the fat extract was collected in the flask of the apparatus. Extra n-hexane was evaporated by putting the fat extract in the drying oven and the crude fat was determined according to the following formula.

$$\text{Crude Fat } (\%) = \frac{\text{Weight of fat in sample}}{\text{Weight of sample}} \times 100$$

3.7.5 Texture analysis

The textural characteristics of samples were analyzed by means of texture analyzer (Mod. TA-XT2, Stable Microsystems, surrey, UK) according to the method as described by Carlos *et al*. (2009).

3.7.6 Fatty acids profile

The total fatty acids were extracted from the rabbit loin and hind leg muscle samples using chloroform: methanol (2:1) (v/v) based on the method of Folch *et al*. (1957) with an antioxidant (alpha lipoic acid) for preventing the oxidation during sample preparation. The experimental rabbit loin and hind leg meat were homogenized in 40 mL chloroform: methanol [2:1 (v/v)] using a homogenizer in a 50 mL stoppered ground-glass extraction tubes. The mixture containing the extracted fatty acids was filtered through a No. 1 Whatman paper (Whatman International Ltd., Maidstone, England) into a 250 mL flask using a laboratory funnel. The paper was washed with 10 mL of chloroform-methanol [2:1 (v/v)]. 12 mL of normal saline solution were added to facilitate phase separation. The mixture was shaken vigorously for one minute and then left to stand for 4 hr. After complete separation at the end of the fourth hour, the upper phase was discarded and lower phase was collected in a round-bottom flask and was evaporated by vacuum rotary evaporation at 70℃. The total lipid extract was then immediately transferred to a capped methylation tube by rediluting it with 5ml fresh chloroform-methanol [2:1 (v/v)]. Transmethylation of the extracted fat to fatty acid methyl esters to their fatty acid methyl esters (FAME) were carried out using KOH in methanol and 14% methanolic boron triflouride (BF3) according to methods of AOCS (1998). The internal standard, heneicosanoic acid (C21:0) was added to each sample prior to transmethylation to determine the individual fatty acid concentrations within the samples. The methyl esters were quantified by GC (Agilent Technologies, 6890 N) One microliter was injected by an auto sampler into the chromatograph, equipped with a split/splitless injector and a Flame Ionization Detector (FID). The injector temperature was programmed at 250°C while the detector temperature was 300℃. The column temperature program was initiated and run at 100℃ for 2min, after that warmed to 170℃ @ 10℃ /min, then held for 2 min, again warmed to 220℃ @ 7.5℃ /min and held for 20 min to facilitate optimal separation. The group of the fatty acids analyzed included saturated acids (SFA), monounsaturated acids (MUFA) and polyunsaturated acids (PUFA). Methyl esters of fatty acids were identified by using standards (Sigma-Aldrich)

3.7.7 Protein profile

Each meat sample was subjected to SDS-PAGE analysis by following the basic method developed by Laemmli (1970) and modified by Singh and Shepherd (1985). The dried protein pellets were solubilized in 250 µL of a sample buffer. The detail of solutions prepared for running electrophoresis is given below;

- **30% Acrylamide solution**

29.2 g Acrylamide monomer, 0.8 g Bisacrylamide were dissolved in distilled water and final volume was made 100 mL with distilled water. The solution was filtered under vaccum using 0.45 mm membrane and stored at 4ºC in dark bottle.

- **Separating gel buffer (1.5 M, pH 8.8)**

18.20 g Tris base was dissolved in 80 mL water, the pH was adjusted to 8.8 with HCl and volume (100 mL) was made with distilled water.

- **Stacking gel buffer (0.5 M, pH 6.8)**

1 g Tris base was dissolved in 80 mL water, the pH was adjusted to 6.8 with HCl and volume was made to 100 mL with distilled water.

- **10% Sodium Dodecyl Sulphate (SDS) Solution**

2.0 g SDS was dissolved in 20 mL of distilled water.

- **10% Ammonium Per Sulphate (APS) Solution**

0.1 g APS was dissolved in 1 mL of distilled water.

- **Electrode buffer**

14.4 g Glycine, 3.0 g tris base and 1 g SDS were dissolved in distilled water to a final volume of 1000 mL.

- **Sample buffer**

62.5 mM tris-HCl pH 6.8, 10% Glycerol, 2% SDS, 0.002% Bromophenol blue, 5% Mercaptoethanol. (0.75 g tris in 50 mL water having pH 6.8 adjusted with HCl, 10 mL glycerol, 2 g SDS, 2 mg Bromophenol blue, 5 mL Mercaptoethanol were added to make 100 mL with distilled water.

- **Staining solution**

400 mL methanol, 100 mL acetic acid were dissolved in 500 mL distilled water. 1 g Coomassie Blue R 250 was dissolved in 40 mL water mixed and added to above solution. The final volume (1000 mL) was made with distilled water.

- **Destaining solution**

400 mL Methanol and 100 mL acetic acid were added in distilled water to make final volume up to 1000 mL.

- **Resolving gel solution (2 Gels)**

Lower gel buffer 1875 µL, 30% acrylamide solution 2500 µL, 10% SDS 300 µL, distilled water 2800 µL, 10% APS solution 50 µL, N,N,N’N’ Tetramethylethylene Diamine (TEMED) 5 µL.

- **Stacking gel solution (2 Gels)**

Upper gel buffer 1250 μL, 30% acrylamide Solution 875 μL, 10% SDS 200 μL, distilled water 2675 μL, 10% APS solution 50 μL, N,N,N'N' Tetramethylethylene Diamine (TEMED) 5 μL.

The electrophoresis was carried out using a 10% gel concentration (Laemmli, 1970). A 10-well, 0.75 mm comb was used in a Bio-Rad Mini Protein 3 System having gel size 8.3-7.3 cm. The SDS-gels contained 4% polyacrylamide stacking gel and a resolving gel of 10% polyacrylamide. Samples [30 µL aliquots from whole wheat flour (5 mg) extracted with 250 µL of sample buffer] were applied into precast application slots. Upon completion of electrophoresis, the proteins were fixed in methanol/acetic acid/water (40/10/50) and then stained with Coomassie Blue R-250.

3.8 Analysis of serum bio-chemical profile

The rabbit blood samples were collected for analysis of the following parameters:

3.8.1 Total cholesterol

The total cholesterol concentration was estimated by liquid cholesterol CHOD-POP method described by Stockbridge *et al*. (1989). For the preparation of reagent blank 1000 uL of working reagent was taken in a test tube. 100 uL of distilled water was added. Standard solution was prepared by adding 1000 uL working reagent 100 uL of standard supernatant in another test tube. Serum sample was prepared by the addition of 1000 uL working reagent 100 uL of serum supernatant. After mixing the contents of each test tube incubated for 5 min @37 ºC. Absorbance of sample and standard against reagent blank was recorded within 1hr through spectrophotometer (CESIL CE7200, England) at 546 nm.

3.8.2 High Density Lipoprotein (HDL) concentration

The high-density lipoprotein concentration in blood was estimated by using the HDL-cholesterol kits by the method described by Assmann (1979). In 200 µL serum, 500 µL diluted reagent was added allowing standing for 10 minutes at a room temperature. Final absorbance of sample, standard and blank was determined through spectrophotometer (CESIL CE7200, England) at wavelength of 546 nm.

3.8.3 Low Density Lipoprotein (LDL) concentration

The low density lipoprotein concentration in blood was determined by following the method described by McNamara *et al*. (1990)

3.8.4 Triglyceride concentration

The blood triglycerides concentration was estimated by liquid triglycerides GPO-PAP method described by Anoni *et al.* (1982). 10 µL standard solutions and 10 uL of sample were taken into test tubes along with one blank. Test tubes were incubated for 5 minutes at 37 ℃ and absorbance was recorded through spectrophotometer (CESIL CE7200, England).

3.8.5 Total protein Concentration

Total protein concentration was determined by the Biuret method described by Josephson and Gyllensward (1975). Absorption was recorded through spectrophotometer (CESIL CE7200, England) at 540nm.

3.9 Product development (Nuggets preparation)

Rabbit meat (Loin and hind legs) was utilized in the preparation of nuggets as method described by Perlo *et al.* (2006). Nuggets were stored for 30 days and analyses were done after every 10 days. The raw material in the preparation of the nuggets were cleaned and weighed according to the recipe. The rabbit meat (loin and hind leg) produced by feeding different feed (oat, linseed) was washed with tap water, deboned manually and minced by using electric mincer. The rabbit meat and onion were mixed in a meat mixer for five minutes, after that all other ingredients were added according to the recipe and mixed thoroughly to provide a uniform blend.

Table 3.3: Recipe of the nuggets

Sr.no	**Name of the ingredient**	**Quantity**
1	Rabbit boneless	½ kg
2	Egg	1
3	Oil	As required for frying
4	Black pepper	12 g
5	Garlic paste	1 tsp
6	Onion	1
7	Plain flour	120 g

8	Bread crumbs	70 g
9	Salt	20 g

The mixture was extended in a thin layer (10 mm thickness) and shaped into discs of 30 mm diameter (10±1 g/piece) in the Meat Technology Laboratory. These were dipped in plain flour and bread crumbs separately. The frying of the nuggets was done in canola oil at 180 ºC till golden brown color was appeared.

3.10 Physico-chemical analysis of nuggets:

The Physico-Chemical Analysis (pH, Water Activity, Crude Protein, Crude Fat and Texture) of nuggets were estimated at regular interval (0, 10, 20, 30 days) by their respective analytical methods.

3.10.1 Determination of water activity

The water activity of Nuggets was determined at regular storage intervals by using an electronic Hygropalm water activity meter (Model Aw-Win, Rotronic, equipped with a Karl-Fast probe) described by Cosenzaa *et al*. (2003). The sample was taken in plastic cup and the water activity was measured by water activity meter.

3.10.2 Texture analysis

The textural characteristics of nuggets were analyzed at different storage intervals by means of texture analyzer (Mod. TA-XT2, Stable Microsystems, surrey, UK) Texture was determined with the help of texture analyzer as described by Carlos *et al*. (2009). The nuggets were fried and compression test was performed to check the texture of the product.

3.10.3 Colour variations

Hunter color values (L, A and B) were determined according to CIE (1978) by a Minolta CR-200 Lovibond Tintometer (Minolta Co. Osaka, Japan). Observations were made at three different locations of the nuggets at regular storage intervals. The instrument was standardized with a white plate. L* values are a measure of darkness to lightness; a* values are a measure of redness and b* values for yellowness.

3.10.4 pH measurement

The pH of Nuggets was measured by using pH meter meter (InoLab PH720, WTW 82362) by 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.

3.10.5 Measurement of Thio Barbeturic Acid (TBA)

The TBA assay of nuggets was carried to determine the production of malonaldehyde per kg of the nuggets during storage by following the method as described by Schmedes and Holmer (1989). 10 g sample was mixed with 25 mL of trichloroacetic acid solution (200 g/L of TCA in 135 mL/L phosphoric acid solution) and homogenized for 30 seconds. Filtered the sample and 2 mL of the filtrate was added to 2 mL TBA solution (3 g/L) in a test tube. The test tubes were incubated at room temperature in the dark for 20 hour then the absorbance was measured at 532 nm by using UV–VIS spectrophotometer.

3.10.6 Peroxide value

The Peroxide value (POV) of nuggets were determined according to the method as described in AOAC (2000). 3 g sample was weighed in a 250-mL glass stoppered flask and heated in a water bath at 60 ºC for 3 min to melt the fat, then thoroughly agitated for 3 min with 30 mL acetic acid–chloroform solution (3:2 v/v) to dissolve the fat. The sample was filtered under vacuum through Whatman filter paper to remove meat particles. Saturated potassium iodide solution (0.5 mL) was added to the filtrate, which was transferred into the burette. The titration was allowed to run against standard solution of sodium thiosulfate (25 g/L) by using starch solution as indicator of end point. POV was calculated and expressed as milliequivalent peroxide per kg of sample:

$$POV\ (meq)/kg = \frac{S \times N}{W} \times 1000$$

Where S is the volume of titration (mL), N the normality of sodium thiosulfate solution that is 0.01 and W the sample weight (kg).

3.11 Sensory evaluation of nuggets

The sensory evaluation of fried nuggets was carried out for the different attributes like color, appearance, taste, texture and overall acceptability by using nine point hedonic scale after 0, 10, 20 and 30 days of storage by trained panelists according to the method described by Meilgaard *et al*. (2007).

3.12 Hypocholesterolemia study

In order to assess the impact of rabbit functional meat on human blood lipid profile, a study trial was conducted. Subjects were provided with rabbit meat in comparison with chicken meat by following the study design as given in the table.

Table 3.4: Detail of the design for hypocholesterolemia study

Treatments	Description
G1	**Control**
G2	**4% oat fed rabbit meat**
G3	**2% oat fed rabbit meat**
G4	**7% linseed fed rabbit meat**
G5	**3.5% linseed fed rabbit meat**
G6	**Chicken**

The detail of bio evaluation plan is as under. Twist a time blood samples were drawn initially in 12 hours fasting condition at 0day and 2nd time samples were collected after 4th week of bio evaluation study.

Table 3.5: Detail of bio-evaluation plan

Study Period	Enrolled males in study	Blood sampling	Total Groups	Individual /Group	Age	Meat (Minced) quantity provided
4 weeks	30	2 times	6 including Control	5	20-30 year	100 g/Day One time

3.13 Analysis of serum bio-chemical profile of subjects

The blood samples were collected at 0 day and 30 day for analysis of the following parameters:

3.13.1 Total cholesterol

The total cholesterol concentration was estimated by liquid cholesterol CHOD-POP method described by Stockbridge *et al*. (1989). For the preparation of reagent blank 1000 uL of working reagent was taken in a test tube. 100 uL of distilled water was added. Standard solution was prepared by adding 1000 uLworking reagent 100 uL of standard supernatant in another test tube. Serum sample was prepared by the addition of 1000 uL working reagent 100 uL of serum supernatant. After mixing the contents of each test tube incubated for 5 min @ 37ºC. Absorbance of sample and standard against reagent blank was recorded within 1hr through spectrophotometer (CESIL CE7200, England) at 546 nm.

3.13.2 High Density Lipoprotein (HDL) Concentration

The high-density lipoprotein concentration in blood was estimated by using the HDL-cholesterol kits by the method described by Assmann (1979). In 200 µL serum, 500 µL diluted reagent was added allowing standing for 10 minutes at a room temperature. Final absorbance of sample, standard and blank was determined through spectrophotometer (CESIL CE7200, England) at wavelength of 546 nm.

3.13.3 Low Density Lipoprotein (LDL) Concentration

The low density lipoprotein concentration in blood was determined by following the expression described by McNamara *et al*. (1990)

3.13.4 Triglyceride concentration

The blood triglycerides concentration was estimated by liquid triglycerides GPO-PAP method described by Anoni *et al.* (1982). 10 µL standard and sample was taken into test tubes along with one blank. Test tubes were incubated for 5 minutes at 37 °C and absorbance was recorded through spectrophotometer (CESIL CE7200, England).

3.13.5 Total protein concentration

Total protein concentration was determined by the Biuret method described by Josephson and Gyllensward (1975). Absorption was recorded through spectrophotometer (CESIL CE7200, England) at 540 nm.

3.14 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 (Mstat 5.4). The comparison of means was done by the Duncan Multiple Range test (Steel *et al.,* 1997).

CHAPTER 4

RESULTS AND DISCUSSION

The purpose of current study was to evaluate the effect of linseed as a source of poly unsaturated fatty acids enrichment and oat as a fat lowering in meat muscle tissues of rabbits. Further to assess the quality, shelf stability of PUFA enriched meat and meat products. The bio-evaluation of meat was also carried out in order to provide hypercholesterolemics a better choice of meat. In connection to this twenty five to thirty days old weaned rabbits were subjected to feed supplemented with different level of oat and linseed. The rabbits were reared for eight weeks on experimental feeds. Serum lipid profile of rabbits was measured to check the efficacy of oat and linseed on lipid profile. The physico-chemical analysis and lipid stability of meat was determined through chemical and biochemical assay. The poly unsaturated fatty acid enriched and low fat meat was used in nuggets preparation for physiochemical study, sensory evaluation and bio-evaluation study of human subjects. Blood serum lipid profile of human subjects was measured. The results obtained during the course of this experiment are presented here.

4.1 Physical parameters of the rabbits

4.1.1 Body weight gain

The statistical results regarding analysis of variance of body weight gain of rabbits fed on oat and linseed are depicted in Table 4.1. It is evident from the results that the experimental years have non-significant effect on the body weight gain of rabbits. The body weight gain of rabbits varied significantly during experimental weeks. The data explicated in Table 4.1 indicates that body weight gain was significantly affected by supplementation of oat and linseed in rabbits feed. However, the interactive effect of experimental years × weeks, experimental years × treatments, treatments × weeks and experimental years × treatments × weeks exhibited non-significant effect on the body weight gain of rabbits.

The data regarding mean values for rabbit's weight gain is presented in Tables 4.2, 4.3 and 4.4. It is obvious for data expressed in Table 4.2 that variation in body weight gain during the experimental years was non-significant; the average weight gain during 2012 was 234.35 g/week while during 2013 weekly body weight gain in rabbits was observed to be 234.39 g. The weekly weight gain of rabbits varied significantly as evident from data presented in Table 4.3. The rabbit body weight gain during experimental weeks varied significantly from

205.67 g to 265.60 g during different weeks of growth period. The highest body weight gain (265.60 g) was observed in fourth week (W4) of growth period while during 8^{th} week (W8) of growth period the rabbits gained lowest in their body weight (205.67 g). It is evident from results that rabbits fed on oat and linseed gained weight with the progression of growth period up to 4^{th} week because of the fattening period (35-65 days) of rabbits but later on reduction in weight gain of rabbits was observed. The results regarding impact of oat and linseed supplementation in feed on weight gain of rabbits are presented in Table 4.4. The body weight gain in rabbits as a function of different treatments varied significantly from 223.75 g to 248.75 g during the course of study. The highest body weight gain (248.75 g/week) was observed in rabbits fed on 7% linseed (T3) while lowest (223.75 g/week) body weight gain was noted in rabbits fed on control feed (T0). It is evident from results that linseed and oat supplementation in feed significantly improve the weight gain in rabbits. The interactive effect of experimental years × weeks, experimental years × treatments, treatments × weeks and experimental year's × treatments × weeks exhibited non-significant effect on the body weight gain of rabbits.

The results of current study are in line with Dal Bosco *et al.* (2014) who fed rabbits on alfalfa and observed lowest weight as compare to other feed. Ajuyah *et al.* (1993) fed chickens on a diet containing 15% whole linseed and observed reduction in live weight but in course of our study we observed increase in live weight by using 7% whole linseed in rabbit diet. Colin *et al.* (2005) used diets supplemented with extruded flaxseed stated a reduced growth and lower live weight at slaughter in rabbits fed flaxseed. 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. It is evident from the results of current study that supplementation of oat and linseed in feed significantly enhance the body weight gain of rabbits.

4.1.2 Feed intake

The statistical results concerning analysis of variance for feed intake of rabbits reared on oat and linseed are given in Table 4.5. It is evident from the results that the experimental years have non-significant effect on the feed intake of rabbits. The feed intake of rabbits varied significantly during experimental weeks. The data explicated in Table 4.5 indicates that feed

Table 4.1: Analysis of variance for weight gain of rabbits

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.1	0.1	0.00^{NS}
Error 1	4	512.3	128.1	
Week (W)	7	107427.8	15346.8	782.29**
Treatment (T)	4	18473.8	4618.4	235.42**
Year x W	7	0.3	0.0	0.00^{NS}
Year x T	4	0.2	0.0	0.00^{NS}
W x T	28	1.6	0.1	0.00^{NS}
Year x W x T	28	1.6	0.1	0.00^{NS}
Error	156	3060.4	19.6	
Total	239	129478.0		

NS = Non-significant (P>0.05); ** = Highly significant (P<0.01)

Table 4.2: Effect of oat and linseed supplementation on the weight gain (g) of rabbits during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	223.75	236.75	226.75	248.75	235.75	234.35
Y2	223.75	236.88	226.83	248.75	235.75	234.39

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.3: Effect of oat and linseed supplementation on weekly weight gain (g) of rabbits

Weak	Treatment					Weak Mean
	T0	T1	T2	T3	T4	
W1	240.00	253.00	243.00	265.00	252.00	250.60C
W2	210.00	223.00	213.00	235.00	222.00	220.60E
W3	245.00	258.00	248.00	270.00	257.00	255.60B
W4	255.00	268.00	258.00	280.00	267.00	265.60A
W5	235.00	248.00	238.00	260.00	247.00	245.60D
W6	210.00	223.50	213.00	235.00	222.00	220.70E
W7	200.00	213.00	203.00	225.00	212.00	210.60F
W8	195.00	208.00	198.33	220.00	207.00	205.67G

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.4: Effect of oat and linseed supplementation on weight gain (g) of rabbits

Years/ Weak	Treatment					Years x Weak Mean
	T0	T1	T2	T3	T4	
Y1 W1	239	254	244	263	250	250
W2	209	224	214	233	220	220
W3	244	259	249	268	255	255
W4	254	269	259	278	265	265
W5	234	249	239	258	245	245
W6	209	224	214	233	220	220
W7	199	214	204	223	210	210
W8	194	209	199	218	205	205
Y2 W1	241	252	242	267	254	251
W2	211	222	212	237	224	221
W3	246	257	247	272	259	256
W4	256	267	257	282	269	266
W5	236	247	237	262	249	246
W6	211	223	212	237	224	221
W7	201	212	202	227	214	211
W8	196	207	197.67	222	209	206
Mean	223.75D	236.81B	226.79C	248.75A	235.75B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05). Small letters represent comparison among interaction means and capital letters are used for overall mean.

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The data regarding mean values for rabbit's feed intake of is explicated in Tables 4.6, 4.7 and 4.8. It is evident from data depicted in Table 4.6 that variation in feed intake during the experimental years was non-significant; the average feed intake during 2012 was 705.57 g/week while during 2013 weekly feed intake in rabbits was observed to be 704.41 g. The weekly feed intake of rabbits varied significantly as evident from data presented in Table 4.7. The rabbits feed intake during experimental weeks varied significantly from 421.87 g to 864.83g during different weeks of growth period. The highest feed intake (864.83 g) was observed in 8th week (W8) of growth period while lowest feed intake (421.87 g) was observed in first week (W1) of growth period. The feed intake of rabbits increased with the increase in age of rabbits. The results regarding impact of oat and linseed supplementation in feed on the feed intake of rabbits are expressed in Table 4.8. The feed intake in rabbits as a function of different treatments varied non-significantly from 697.46 g to 709.60 g during the course of study. The highest feed intake (709.60 g/week) was observed in rabbits fed on 4% oat (T1) while lowest feed intake (697.46 g/week) were noted in rabbits fed on control diet (T0). It is evident from results that linseed and oat supplementation in feed had non-significant effect on feed intake of the growing rabbit. The interactive effect of experimental years × weeks, experimental years × treatments, treatments × weeks and experimental years × treatments × weeks also exhibited non-significant effect on the feed intake of rabbits.

It is evident from the results of current study that supplementation of oat and linseed in feed did not significantly enhance the feed intake of rabbits. These results are in agreement with Kouba *et al.* (2008) who used 6% linseed in the diet of rabbits and reported that feed supplementation did not affect the feed intake of rabbits. Maclean *et al. (*1994) and Brand and Vandermerwe (1996) also found no effect of naked oats on weight gain, feed efficiency or mortality in poultry and pigs, if diets are formulated on an isonutrient basis. Fernandez and Fraga (1996) investigated the influence of fat addition to fibrous diets and found non-significant effect on feed intake of rabbits.

4.1.3 Feed Conversion Ratio (FCR)

The statistical results concerning analysis of variance of FCR of rabbits fed on oat and linseed are given in Table 4.9. It is obvious from the results that experimental years have non-significant effect on FCR of rabbits. FCR of rabbits varied significantly during experimental weeks. The data presented in Table 4.9 showed that FCR significantly raised by

Table 4.5: Analysis of variance for feed intake of rabbits

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	81	81	0.04^{NS}
Error 1	4	7692	1923	
W	7	6954047	993435	668.58**
Treatment (T)	4	5994	1498	1.01^{NS}
Year x W	7	10406	1487	1.00^{NS}
Year x T	4	7105	1776	1.20^{NS}
W x T	28	41421	1479	1.00^{NS}
Year x W x T	28	42146	1505	1.01^{NS}
Error	156	231798	1486	
Total	239	7300689		

NS = Non-significant (P>0.05); ** = Highly significant (P<0.01)

Table 4.6: Effect of oat and linseed supplementation on feed intake (g) of rabbits during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	694.79	707.88	698.79	709.67	706.71	705.57
Y2	700.13	711.33	702.33	696.79	711.46	704.41

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.7: Effect of oat and linseed supplementation on weekly feed intake (g) of rabbits

Weak	Treatment					Weak Mean
	T0	T1	T2	T3	T4	
W1	412.50	425.67	415.67	431.83	423.67	421.87F
W2	448.50	465.17	450.17	473.83	458.83	459.30E
W3	608.83	618.00	611.33	634.17	621.50	618.77D
W4	762.50	773.50	767.50	686.50	770.83	752.17C
W5	809.50	821.67	812.50	836.50	827.83	821.60B
W6	844.50	856.67	847.67	865.67	854.00	853.70A
W7	837.50	850.00	841.83	860.83	848.17	847.67A
W8	855.83	866.17	857.83	876.50	867.83	864.83A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Table 4.8: Effect of oat and linseed supplementation on feed intake of (g) rabbits

Years/ Weak	Treatment					Years x Weak Mean
	T0	T1	T2	T3	T4	
Y1 W1	410.33	423.33	413.33	430.67	422.33	420.00
W2	447.33	462.67	448.67	472.67	457.67	457.80
W3	604.33	616.33	609.67	631.67	618.67	616.13
W4	760.33	771.33	765.00	785.33	768.67	770.13
W5	807.33	819.33	811.00	834.33	823.67	819.13
W6	842.33	856.67	845.33	865.33	850.67	852.07
W7	834.67	848.67	840.67	860.67	846.67	846.27
W8	851.67	864.67	856.67	876.67	865.33	863.00
Y2 W1	414.67	428.00	418.00	433.00	425.00	423.73
W2	449.67	467.67	451.67	475.00	460.00	460.80
W3	613.33	619.67	613.00	636.67	624.33	621.40
W4	764.67	775.67	770.00	587.67	773.00	734.20
W5	811.67	824.00	814.00	838.67	832.00	824.07
W6	846.67	856.67	850.00	866.00	857.33	855.33
W7	840.33	851.33	843.00	861.00	849.67	849.07
W8	860.00	867.67	859.00	876.33	870.33	866.67
Mean	697.46A	709.60A	700.56A	708.23A	709.08A	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05). Small letters represent comparison among interaction means and capital letters are used for overall mean.

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

supplementation of oat and linseed in rabbits feed. However, the interactive effect of experimental years × weeks, experimental years × treatments, treatments × weeks and experimental years × treatments × weeks exhibited non-significant effect on the FCR of rabbits.

The data regarding mean values for rabbit's FCR is presented in Tables 4.10, 4.11 and 4.12. It is obvious from data expressed in Table 4.10 that variation in FCR during the experimental years was non-significant; the average FCR during 2012 was 3.063 while during 2013 weekly FCR in rabbits was observed to be 3.062. The weekly FCR of rabbits varied significantly as evident from data presented in Table 4.11. The rabbit's FCR during experimental weeks varied significantly from 1.685 to 4.213 during different weeks of growth period. The highest FCR (4.213) was observed during eighth week (W8) of growth period while during first week (W1) of growth period the rabbits showed lowest (1.685) FCR. It is evident from the results that FCR increased continuously with the increase in rabbit growing period. The results regarding impact of oat and linseed supplementation in feed on FCR of rabbits are depicted in Table 4.12. FCR of rabbit as a function of different treatments varied significantly from 2.895 to 3.172 during the course of study. The highest FCR (3.172/week) was observed in rabbits fed on control feed (T0) while lowest FCR (2.895/week) was observed in rabbits fed on 7% linseed (T3). It is evident from the results that oat and linseed supplementation in feed result in significant reduction in the FCR of rabbits. The interactive effect of experimental years × weeks, experimental years × treatments, treatments × weeks and experimental years × treatments × weeks exhibited non-significant effect on the FCR of rabbits.

The results are in agreement with Bernardini *et al.* (1999); Dal Bosco *et al.* (2004); Kouba *et al.* (2008) and Bianchi *et al.* (2009) who proposed that diets high in n-3 PUFA significantly influence productive performances in rabbits. Bianchi *et al.* (2006) found that 8% of linseed supplementation determined a lower FCR, daily weight gain as well as lower final live weight of rabbits compared to the group without linseed addition. Differences occurred in feed intake and diet efficiency between the results because in this case supplementation of oat and linseed was carried out with alfalfa. These differences were expected because of the higher fat content in the linseed group of our experiment that ultimately reduces FCR in rabbits.

Table 4.9: Analysis of variance for FCR of rabbits

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.0001	0.0001	0.04^{NS}
Error 1	4	0.0117	0.0029	
W	7	189.6069	27.0867	1087.86**
Treatment (T)	4	2.2339	0.5585	22.43**
Year x W	7	0.1349	0.0193	0.77^{NS}
Year x T	4	0.0941	0.0235	0.94^{NS}
W x T	28	0.7952	0.0284	1.14^{NS}
Year x W x T	28	0.5412	0.0193	0.78^{NS}
Error	156	3.8843	0.0249	
Total	239	197.3023		

NS = Non-significant (P>0.05); ** = Highly significant (P<0.01)

Table 4.10: Effect of oat and linseed supplementation on FCR of rabbits during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	3.160	3.039	3.134	2.936	3.046	3.063
Y2	3.184	3.052	3.149	2.855	3.068	3.062

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Table 4.11: Effect of oat and linseed supplementation on weekly FCR of rabbits

Weak	Treatment					Weak Mean
	T0	T1	T2	T3	T4	
W1	1.719	1.683	1.711	1.630	1.681	1.685H
W2	2.136	2.086	2.113	2.017	2.067	2.084G
W3	2.486	2.396	2.466	2.349	2.419	2.423F
W4	2.991	2.887	2.976	2.452	2.887	2.838E
W5	3.445	3.314	3.414	3.218	3.353	3.349D
W6	4.024	3.833	3.980	3.685	3.847	3.874C
W7	4.189	3.996	4.147	3.827	4.005	4.033B
W8	4.389	4.168	4.326	3.986	4.196	4.213A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Table 4.12: Effect of oat and linseed supplementation on FCR of rabbits

Years/ Weak	Treatment					Years x Weak Mean
	T0	T1	T2	T3	T4	
Y1 W1	1.710	1.673	1.701	1.625	1.676	1.677
W2	2.130	2.075	2.106	2.011	2.062	2.077
W3	2.467	2.389	2.458	2.340	2.407	2.412
W4	2.982	2.878	2.965	2.805	2.879	2.902
W5	3.436	3.306	3.408	3.209	3.337	3.339
W6	4.016	3.842	3.969	3.683	3.832	3.868
W7	4.174	3.986	4.142	3.825	3.994	4.024
W8	4.368	4.161	4.327	3.986	4.184	4.205
Y2 W1	1.728	1.692	1.720	1.634	1.687	1.692
W2	2.142	2.098	2.121	2.023	2.073	2.091
W3	2.505	2.403	2.473	2.359	2.430	2.434
W4	2.999	2.896	2.986	2.099	2.895	2.775
W5	3.454	3.323	3.420	3.228	3.370	3.359
W6	4.033	3.825	3.991	3.686	3.862	3.879
W7	4.203	4.007	4.153	3.828	4.016	4.041
W8	4.410	4.175	4.326	3.985	4.208	4.221
Mean	3.172A	3.046B	3.142A	2.895C	3.057B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05). Small letters represent comparison among interaction means and capital letters are used for overall mean.

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

4.2 Physico-chemical analysis of rabbit meat

4.2.1 pH of rabbit meat

The statistical results regarding analysis of variance of pH of rabbit's meat (loin, hind leg) fed on oat and linseed are given in Table 4.13. It is evident from the results that experimental years have non-significant effect on the pH of rabbit's meat (loin, hind leg). The results explicated in Table 4.13 designated that the pH of rabbit's meat (loin, hind leg) was significantly affected by the supplementation of oat and linseed in rabbits feed. However, the interactive effect of experimental years × treatments exhibited non-significant effect on pH of rabbit's meat (loin, hind leg).

The data regarding mean values for pH of rabbit's meat (loin, hind leg) is expressed in Table 4.14. It is obvious from the data that variation in pH of meat (loin, hind leg) during the experimental years was non-significant; the average pH of loin meat during 2012 was 5.79 while during 2013 pH was observed to be 5.81. The average pH of hind leg meat during 2012 was 5.74 while during 2013 pH was observed to be 5.71. The results regarding impact of oat and linseed supplementation in feed on pH of rabbit's meat (loin, hind leg) are shown in Table 4.14. The pH of loin meat as a function of different treatments varied significantly from 5.64 to 5.99 while pH of the hind leg meat varied from 5.56 to 5.93. The highest pH values 5.99 was observed in loin and 5.93 in hind leg of rabbit's meat fed on 3.5% linseed (T4) while lowest pH values 5.64 in loin and 5.56 in hind leg were observed in rabbit's meat fed on control feed (T0). The interactive effect of experimental years × treatments exhibited non-significant effect on pH of rabbit's meat (loin, leg).

It is evident from the results that oat and linseed supplementation in feed significantly affects the pH of loin and hind leg of rabbit meat. The present investigation showed that supplementation of oat and linseed enhanced the ultimate pH of loin and hind leg muscles. These results are in agreement with the work of Poławska *et al.* (2012) who used 8% linseed in the feed of ostrich that raised pH of the muscle as compared to normal. These results are also supported by Bianchi *et al.* (2006) who used different level of linseed in the feed of rabbits that enhance ultimate pH 6.24 vs. 6.12 and 6.11 vs. 6.07 for L. *lumborum* and hamburgers respectively. Eiben *et al.* (2010) used sunflower and linseed oil in the feed of rabbits that increased ultimate pH values of the rabbit meat.

Table 4.13: Analysis of variance for pH of rabbit meat

Source of variation	Degrees of freedom	Mean squares	
		Loin	Hind leg
Year (Y)	1	0.003413^{NS}	0.006453^{NS}
Error-1	4		
Treatment	4	0.133920**	0.152317**
Y x Treatment	4	0.000013^{NS}	0.000053^{NS}
Error	16	0.002584	0.001613

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.14: Effect of oat and linseed supplementation on pH of rabbit meat

Treatment	Loin meat			Hind leg meat		
	Y1	Y2	Means	Y1	Y2	Means
T0	5.63	5.65	5.64d	5.57	5.54	5.56d
T1	5.69	5.71	5.70c	5.64	5.62	5.63c
T2	5.73	5.75	5.74c	5.66	5.63	5.65c
T3	5.91	5.93	5.92b	5.87	5.83	5.85b
T4	5.98	6.00	5.99a	5.95	5.91	5.93a
Mean	5.79	5.81		5.74	5.71	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05) Small letters represent comparison among interaction means and capital letters are used for overall mean.

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

4.2.2 Water activity (Aw) of rabbit meat

Water activity (Aw) is the most important property of water in food system as the microorganism cannot grow well below optimum water activity level (Roa and Tapia, 1998). The statistical results regarding analysis of variance of water activity of rabbit's meat (loin, hind leg) fed on oat and linseed are depicted in Table 4.15. It is evident from the results that experimental years have non-significant effect on the Aw of rabbit's meat (loin, hind leg). The results explicated in Table 4.15 designated that the Aw of rabbit's meat (loin, hind leg) was affected non-significantly by the supplementation of oat and linseed in rabbits feed. The interactive effect of experimental years × treatments also exhibited non-significant effect on Aw of loin and hind leg of rabbit meat.

The data regarding mean values for Aw of loin and hind leg of rabbit meat are expressed in Tables 4.16. It is obvious from the data expressed in Table 4.16 that variation in Aw of meat (loin, hind leg) during the experimental years was non-significant; The average Aw of loin meat during 2012 was 0.845 while during 2013 Aw of loin meat was observed to be 0.835. The average Aw of hind leg meat during 2012 was 0.868 while during 2013 Aw was observed to be 0.878. The results regarding impact of oat and linseed supplementation in feed on pH of rabbit's meat (loin, hind leg) are shown in Table 4.16. The Aw of loin meat as a function of different treatments varied non-significantly from 0.832 to 0.848 while Aw of the hind leg meat varied from 0.865 to 0.878. The highest Aw values 0.848 in loin and 0.878 in hind leg was observed in rabbit's meat fed on 3.5% linseed (T4) while lowest Aw values 0.832 in loin and 0.865 in hind leg were observed in rabbit's meat fed on control feed (T0). It is evident from the results that oat and linseed supplementation in feed did not affect the Aw of loin and hind leg of rabbit meat. These results are out of range of the critical water activity values for microbes that are determined by Troller and Christian (1978) in different foods for different microbes.

4.2.3 Protein contents of rabbit meat

The statistical results regarding analysis of variance of protein of rabbit's meat (loin, hind leg) fed on oat and linseed are given in Table 4.17. It is evident from the results that experimental years have non-significant effect on the protein contents of rabbit's meat (loin, hind leg). The results explicated in Table 4.17 designated that the protein of rabbit's meat

Table 4.15: Analysis of variance for water activity of rabbit meat

Source of variation	Degrees of freedom	Mean squares	
		Loin	Hind leg
Year (Y)	1	0.0007500^{NS}	0.0007500^{NS}
Error-1	4		
Treatment	4	0.0002867^{NS}	0.0001533^{NS}
Y x Treatment	4	0.0000000^{NS}	0.0000000^{NS}
Error	16	0.0006433	0.0002542

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.16: Effect of oat and linseed supplementation on water activity of rabbit meat

Treatment	Loin meat			Hind leg meat		
	Y1	Y2	Means	Y1	Y2	Means
T0	0.847	0.837	0.842a	0.867	0.877	0.872a
T1	0.840	0.830	0.835a	0.860	0.870	0.865a
T2	0.850	0.840	0.845a	0.870	0.880	0.875a
T3	0.853	0.843	0.848a	0.873	0.883	0.878a
T4	0.837	0.827	0.832a	0.870	0.880	0.875a
Mean	0.845	0.835		0.868	0.878	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05) Small letters represent comparison among interaction means and capital letters are used for overall mean.

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

(loin, hind leg) was significantly affected by the supplementation of oat and linseed in rabbits feed. However, the interactive effect of experimental years × treatments exhibited non-significant effect on protein of loin and hind leg of rabbit meat.

The data regarding mean values for protein contents of rabbit's meat (loin, leg) is expressed in Table 4.18. It is evident from the data that variation in protein contents of meat (loin, hind leg) during the experimental years was non-significant; the average protein contents of loin meat during 2012 were 22.70% while during 2013 protein contents were observed to be 22.64%. The average protein contents of leg meat during 2012 were 22.54% while during 2013 protein contents were observed to be 22.58%. The results regarding impact of oat and linseed supplementation in feed on protein of rabbit's meat (loin, hind leg) are shown in Table 4.18. The protein of loin meat as a function of different treatments varied significantly from 21.06 to 24.06% while protein of hind leg meat varied from 20.88 to 23.93%. The highest protein contents 24.06% in loin and 23.93% in hind leg were observed in rabbit meat fed on 7% linseed (T3) while lowest protein contents 21.06% in loin and 20.88% in hind leg were observed in rabbit meat fed on control feed (T0). The interactive effect of experimental years × treatments exhibited non-significant effect on protein contents of loin and hind leg of rabbit meat.

It is evident from the results that oat and linseed supplementation in feed result in significant increase in the protein contents of loin and hind leg of rabbit meat. The results of protein are similar with the findings of Pla *et al.* (2004) that loin meat showed high percentage of protein with respect to hind leg meat of rabbits. Supplementation of oat and linseed increased the overall protein contents as compared to control because addition of oat and linseed increased the concentration of biological protein in the feed. These results are correlated with the findings of Zsédely *et al.* (2006) who also used sunflower and linseed oil in the feed of rabbits that enhanced protein contents of rabbit meat.

4.2.4 Fat contents of rabbit meat

The statistical results regarding analysis of variance for fat contents of rabbit's meat (loin, hind leg) fed on oat and linseed are given in Table 4.19. It is evident from the results that experimental years have non-significant effect on the fat contents of rabbit's meat (loin, hind leg). The results explicated in Table 4.19 showed that the fat contents of meat of rabbit (loin, hind leg) were significantly affected by the supplementation of oat and linseed in rabbits feed

Table 4.17: Analysis of variance for protein of rabbit meat

Source of variation	Degrees of freedom	Mean squares	
		Loin	Hind leg
Year (Y)	1	0.0538^{NS}	0.0120^{NS}
Error-1	4		
Treatment	4	7.4312**	6.8949**
Y x Treatment	4	0.0084 ^{NS}	0.0140 ^{NS}
Error	16	0.1251	0.1298

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.18: Effect of oat and linseed supplementation on protein (%) of rabbit meat

Treatment	Loin meat			Hind leg meat		
	Y1	Y2	Means	Y1	Y2	Means
T0	21.11	21.02	21.06e	20.86	20.90	20.88e
T1	22.95	22.86	22.91c	22.43	22.47	22.45c
T2	22.07	21.99	22.03d	21.75	21.79	21.77d
T3	24.10	24.02	24.06a	23.90	23.95	23.93a
T4	23.27	23.29	23.65b	23.76	23.79	23.78b
Mean	22.70	22.64		22.54	22.58	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05) Small letters represent comparison among interaction means and capital letters are used for overall mean.

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

However, the interactive effect of experimental years × treatments exhibited non-significant effect on fat contents of loin and hind leg of rabbit meat.

The data regarding mean values for fat contents of rabbit's meat (loin, leg) is expressed in Table 4.20. It is evident from the data that variation in fat contents of meat (loin, hind leg) during the experimental years was non-significant; the average fat contents of loin meat during 2012 were 1.97% while during 2013 fat contents were observed to be 2.00%. The average fat contents of leg meat during 2012 were 3.92% while during 2013 fat contents were observed to be 3.91%. The results regarding impact of oat and linseed supplementation in feed on fat of rabbit's meat (loin, hind leg) are shown in Table 4.20. The fat of loin meat as a function of different treatments varied significantly from 1.63 to 2.31% while fat of hind leg meat varied from 3.40 to 4.56%. The highest fat contents 2.31% in loin and 4.56% in hind leg were observed in rabbit's meat fed on 7% linseed (T3) while lowest fat contents 1.63% in loin and 3.40% were observed in rabbit's meat fed on 4% oat (T1). The interactive effect of experimental years × treatments exhibited non-significant effect on fat contents of loin and hind leg of rabbit meat.

It is evident from the results that oat and linseed supplementation in feed significantly affects the fat contents of loin and hind leg of rabbit meat. According to Bianchi et al. (2006) 8% linseed diet fed to rabbits between 65 and 87 days of age resulted in a smaller and fatter carcass than the controls without supplementation that agrees with our results. Pla (2008) comparing the carcass value of 63-day-old rabbits on 3% sunflower oil or 3% linseed oil diets reported similar reference carcass weights but higher fat percentage with linseed oil diet. Dietary oat in rabbit diets equilibrated in digestible energy and protein did not affect carcass weight and fatness, as estimated by the percentage of perineal and scapular fat. The results of current study are in conformity with the findings of Pla *et al.* (2004) that leg meat showed high percentage of fat with respect to loin meat of rabbits.

4.2.5 Texture of rabbit meat

The statistical results regarding analysis of variance for texture of rabbit's meat (loin, hind leg) fed on oat and linseed are depicted in Table 4.21. It is evident from the results that experimental years have non-significant effect on the texture of rabbit's meat (loin, hind leg). The results explicated in Table 4.19 showed that the texture of rabbit's meat (loin, hind leg) was significantly affected by the supplementation of oat and linseed in rabbits feed. However

Table 4.19: Analysis of variance for fat content of rabbit meat

Source of variation	Degrees of freedom	Mean squares	
		Loin	Hind Leg
Year (Y)	1	0.01825^{NS}	0.00675^{NS}
Error-1	4		
Treatment	4	0.44381**	1.36208**
Y x Treatment	4	0.00385 ^{NS}	0.00563 ^{NS}
Error	16	0.01535	0.01579

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.20: Effect of oat and linseed supplementation on fat of rabbit meat

Treatment	Loin meat			Hind Leg meat		
	Y1	Y2	Means	Y1	Y2	Means
T0	1.95	2.00	1.97c	3.74	3.71	3.73c
T1	1.61	1.66	1.63e	3.41	3.38	3.40e
T2	1.81	1.86	1.84d	3.59	3.56	3.58d
T3	2.32	2.30	2.31a	4.55	4.57	4.56a
T4	2.14	2.17	2.16b	4.30	4.32	4.31b
Mean	1.97	2.00		3.92	3.91	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05) Small letters represent comparison among interaction means and capital letters are used for overall mean.

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

the interactive effect of experimental years × treatments exhibited non-significant effect on texture of rabbit's meat (loin, hind leg).

The data regarding mean values for texture of rabbit's meat (loin, leg) is expressed in Table 4.22. It is evident from the data that variation in texture of meat (loin, hind leg) during the experimental years was non-significant; the average texture value of loin meat during 2012 was 2.45 while during 2013 texture value was observed to be 2.50. The average texture value of hind leg meat during 2012 was 2.19 while during 2013 texture value was observed to be 2.16.The results regarding impact of oat and linseed supplementation in feed on texture of rabbit's meat (loin, hind leg) are shown in Table 4.22. The texture of loin meat as a function of different treatments varied significantly from 2.19 to 2.87 while texture of hind leg meat varied from 1.78 to 2.63. The highest texture value 2.87 in loin and 2.63 in hind leg was observed in rabbit's meat fed on 4% oat while lowest texture value 2.19 in loin and 1.78 in hind leg was observed in rabbit's meat fed on 7% linseed (T3). The interactive effect of experimental years × treatments exhibited non-significant effect on texture of rabbit's meat (loin, hind leg).

It is evident from the results that oat and linseed supplementation in feed significantly affects the fat contents of loin and hind leg of rabbit meat. These results are in agreement with Pla *et al.* (2004) who stated that as the increase in fat contents of the meat ultimately retards the texture shear force values of the meat. Hind leg portion of rabbit meat had more fat contents and less texture values as compared to loin meat. The results showed that enriching rabbit meat with long-chain PUFA through diet has a significant effect on instrumental texture properties. Results agreed with the work of Hernández and Pla (2007) who found similar results when fed rabbits with dietary n-3 and n-6 fatty acids and determined lower textural values of rabbit meat.

4.2.6 Fatty acids Profile

Fatty acids composition of loin meat of rabbits

The degree of unsaturation and chain length of fatty acids are considered one of the important quality attributes of fats and oils. All the fatty acids were broken down into saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and Polyunsaturated (PUFA). The data regarding the fatty acid profile of rabbit loin meat is presented in the Table

Table 4.21: Analysis of variance for texture of rabbit meat

Source of variation	Degrees of freedom	Mean squares	
		Loin	Hind Leg
Year (Y)	1	0.01875*	0.00675^{NS}
Error-1	4		
Treatment	4	0.47629**	0.70781**
Y x Treatment	4	0.00000^{NS}	0.00000^{NS}
Error	16	0.00337	0.00409

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.22: Effect of oat and linseed supplementation on texture of rabbit meat

Treatment	Loin meat			Hind leg meat		
	Y1	**Y2**	**Means**	**Y1**	**Y2**	**Means**
T0	2.38	2.43	2.40c	2.13	2.10	2.12c
T1	2.84	2.89	2.87a	2.64	2.61	2.63a
T2	2.64	2.69	2.67b	2.41	2.38	2.40b
T3	2.16	2.21	2.19e	1.79	1.76	1.78e
T4	2.25	2.30	2.28d	1.96	1.93	1.94d
Mean	2.45	2.50		2.19	2.16	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05) Small letters represent comparison among interaction means and capital letters are used for overall mean.

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

4.23. It is obvious from the results that the experimental year has non-significant effect on the fatty acid profile of rabbit's loin meat. Rabbits reared on control feed (T0) had a significantly higher percentage of saturated fatty acids (35.95%) in 2012 while (35.92%) in 2013 in loin meat of rabbits. Lowest saturated fatty acids (34.01%) in 2012 while (33.98%) in 2013 were observed in the loin meat of rabbits receiving 4% supplementation of oat in feed. Rabbits reared on feed supplemented with 7% linseed had a significantly higher amount of unsaturated fatty acids (62.77%) in 2012 while (62.45%) in 2013 including MUFA (29.42%) in 2012 while (29.45%) in 2013 and Poly unsaturated fatty acid (33.36%) in 2012 and (33.21%) in 2013 in the loin meat of rabbits. Lowest unsaturated fatty acids (45.62%) in 2012 and (45.53%) in 2013 were observed in loin meat of rabbits receiving 4% supplementation of oat in feed. The highest ratio of SFA/UFA (0.746) in 2012 and (0.745) in 2013 was seen in rabbit's loin meat fed on 4% oat supplemented feed while lowest ratio of SFA/UFA (0.567) in 2012 and (0.570) in 2013 was observed in loin meat of rabbits receiving 7% supplementation of linseed in feed. Highest PUFA/SFA (0.937) in 2012 and (0.933) in 2013 was observed in loin meat of rabbits fed on 7% linseed supplementation in feed (T3) while lowest PUFA/SFA (0.615) in 2012 and (0.612) in 2013 was observed in loin meat of rabbits fed on 4% oat supplementation in feed (T1).

The results regarding composition of fatty acids in loin meat of rabbits fed on oat and linseed are presented in Table 4.24. It is obvious from the results that the composition of saturated and unsaturated fatty acids in loin meat of rabbits was significantly affected by oat and linseed supplementation. The results with respect to fatty acids composition indicate that palmitic acid ranged from 25.79 to 27.93% in loin meat during the experimental years. Highest concentration (27.93%) of palmitic acid was observed in loin meat of rabbits fed on 7% linseed (T3) whereas lowest (25.79%) was observed in loin meat of rabbits fed on 4% oat (T1). However highest level of stearic acid (7.32%) existed in rabbit's meat fed on control feed (T0) while lowest level (6.23%) was observed in loin meat of rabbits fed on 7% linseed (T3). The results also indicates that highest concentration of oleic (25.48), linoleic (24.13) and linolenic acid (5.38) present in loin meat of rabbits fed on 7% linseed in the feed (T3).

It is evident from the results that oat and linseed supplementation in feed significantly affects the fatty acid composition of loin meat of rabbit. The dietary use of linseed strongly influenced the overall fatty acid composition of the meat resulting in lower content of total

SFA and a higher content of total PUFA. The higher PUFA were due to the higher contents of a-linolenic acid that results in a more favorable PUFA/SFA ratio in the meat of rabbit's fed on diets containing linseed. Bernardini *et al.* (1999) and Dal Bosco *et al.* (2004) stated that the whole linseed in the feed of rabbits is much effective in increasing the PUFA and a-linolenic acid contents in the meat of rabbits. Colin *et al*. (2005) proposed that use of commercial feed ingredient (Tradi-Lin®) containing extruded linseed increase the a-linolenic acid contents of rabbit meat. The increased content of n-3 PUFA in rabbit meat are mainly due to the higher content of α-linolenic acid, which represents the main fatty acid of linseed (Petracci *et al.,* 2009). Feeding oats to rabbits also improved fatty acid composition of the meat. The results are in agreement with the work of Lopez-Bote *et al.* (1998) who used 300g oat/Kg feed and found favourable PUFA/SFA ratio. Tarasewicz *et al*. (2001) stated that broiler birds receiving 7% supplementation with linseed had a significantly higher amount of unsaturated fatty acids (UFA), including MUFA, and a decreased amount of SFA. The consumption of loin guarantees a lower intake of n-3 PUFA because of the lower total lipid content. The enrichment of rabbit meat has the potential to provide a useful contribution intake of n-3 PUFA in rabbit meat products (Petracci *et al.*, 2009). The results of current finding are in consistent with Anjum *et al*. (2013) who stated that highest PUFA fatty acids were found in broilers muscles fed on diet containing highest level of extruded flaxseed while lowest were observed in broilers chicks fed on control feed.

Fatty acids composition of hind leg meat of rabbits

The degree of unsaturation and chain length of fatty acids are considered one of the important quality attributes of fats and oils. All the fatty acids were broken down into saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and Polyunsaturated (PUFA). The data regarding the fatty acid profile of rabbit hind leg meat is presented in Table 4.25. It is obvious from the results that the experimental year has non-significant effect on the fatty acid profile of hind leg meat of rabbits. Rabbits reared on control feed (T0) had a significantly higher percentage of saturated fatty acids (33.98%) in 2012 and (33.96%) in 2013 in hind leg meat of rabbits. Lowest saturated fatty acids (32.44%) in 2012 and (32.42%) in 2013 were observed in hind leg meat of rabbits receiving 4% supplementation of oat in feed. Rabbits reared on feed supplemented with 7% linseed had a significantly higher amount of unsaturated fatty acids (66.37%) in 2012 while (66.23%) in 2013 having MUFA (30.85%)

Table 4.23 Fatty acid profile % of loin meat of rabbits

	Experimental year (2012)					Experimental year (2013)				
	Treatments					Treatments				
Fatty acids	**T0**	**T1**	**T2**	**T3**	**T4**	**T0**	**T1**	**T2**	**T3**	**T4**
SFA	35.95	34.01	34.16	35.62	35.06	35.92	33.98	34.13	35.59	35.03
MUFA	23.71	24.72	24.96	29.42	27.62	23.71	24.73	24.97	29.45	27.63
PUFA	26.69	20.90	21.90	33.36	29.34	26.54	20.80	22.00	33.21	29.19
UFA	50.4	45.62	46.86	62.77	56.96	50.25	45.53	46.97	62.45	56.82
SFA/UFA	0.713	0.746	0.729	0.567	0.616	0.715	0.745	0.727	0.570	0.617
PUFA/SFA	0.742	0.615	0.641	0.937	0.837	0.739	0.612	0.645	0.933	0.833

SFA: Saturated fatty acids **MUFA**: Monounsaturated fatty acids **PUFA**: Polyunsaturated fatty acids **UFA:** Unsaturated Fatty acids **SFA/UFA:** Ratio of saturated fatty acids and unsaturated fatty acids **PUFA/SFA:** Ratio of poly unsaturated fatty acid and saturated fatty acids

Table 4.24: Fatty acid composition of loin meat of rabbits

	Experimental year (2012)					Experimental year (2013)				
	Fatty acid % in loin meat tissues					Fatty acid % in loin meat tissues				
Fatty acids	**T0**	**T1**	**T2**	**T3**	**T4**	**T0**	**T1**	**T2**	**T3**	**T4**
C14,0	1.84	1.21	1.64	1.22	1.96	1.81	1.18	1.61	1.19	1.93
C16,0	26.79	25.83	26.28	27.93	26.87	26.75	25.79	26.24	27.89	26.83
C18,0	7.32	6.97	6.24	6.47	6.23	7.36	7.01	6.28	6.51	6.27
C14,1	0.07	0.02	0.02	0.20	0.03	0.06	0.02	0.02	0.02	0.03
C16,1	0.61	0.95	1.01	3.73	2.86	0.64	0.98	1.04	3.76	2.89
C18,1	23.03	23.75	23.93	25.48	24.73	23.01	23.73	23.91	25.46	24.71
C18,2	22.82	18.04	18.20	24.13	23.06	22.79	18.02	18.22	24.10	23.03
C18,3	2.98	1.04	1.19	5.38	3.55	2.95	1.02	1.21	5.35	3.52
C20,3	0.30	1.75	1.81	2.44	1.96	0.27	1.73	1.83	2.41	1.93
C22,5	0.40	0.03	0.09	1.18	0.62	0.37	0.01	0.11	1.15	0.59
C22,6	0.19	0.04	0.61	0.23	0.15	0.16	0.02	0.63	0.20	0.12

in 2012 while (30.86%) in 2013 and PUFA (35.52%) in 2012 while (35.37%) in hind leg meat. Lowest unsaturated fatty acids (51.99%) in 2012 and (51.90%) in 2013 were observed in hind leg of rabbit's meat receiving 4% supplementation of oat in feed. The highest ratio of SFA/UFA (0.624) in 2012 and (0.625) in 2013 was seen in hind leg meat of rabbits fed on 4% oat supplemented feed while lowest ratio of SFA/UFA (0.516) in 2012 and (0.517) in 2013 was observed in rabbits hind leg meat receiving 7% supplementation of linseed in feed. Highest PUFA/SFA (1.062) in 2012 and (1.057) in 2013 was observed in hind leg meat of rabbits fed on 7% linseed supplementation in feed (T3) while lowest PUFA/SFA (0.756) in 2012 and (0.753) in 2013 was observed in hind leg meat of rabbits fed on 4% oat supplementation in feed (T1).

The results regarding composition of fatty acids in hind leg meat of rabbits fed on oat and linseed are presented in Table 4.26. It is obvious from the results that the composition of saturated and unsaturated fatty acids in hind leg meat of rabbits were significantly affected by oat and linseed supplementation. The results regarding fatty acids composition indicate that fatty acid such as palmitic acid ranged from 25.87 to 26.74% in hind leg meat of rabbits during the experimental years. Highest percentage (26.74) of palmitic acid was observed in hind leg meat of rabbits fed on 7% linseed (T3) during the experimental year 2012 whereas lowest (25.87) was observed in hind leg meat of rabbits fed on 4% oat (T1) during the experimental year 2013. However highest level of stearic acid (6.83%) found in hind leg meat of rabbits fed on control feed (T0) during the experimental year 2012 while lowest level (5.17%) was observed in hind leg meat of rabbits fed on 3.5% linseed (T4) during the experimental year 2013. The results also indicate that highest concentration of oleic (27.27%), linoleic (26.95%) and linolenic acid (8.13%) were present in hind leg meat of rabbits fed on 7% linseed in the feed (T3).

These findings correlates with Petracci *et al.* (2009) showed that administration of n-3 enriched diets during the last 3-4 weeks of the growing period is sufficient to achieve substantial fatty acid modification in loin and leg meat increasing the n- 3 PUFA content to demanded values, thus reducing the feed cost in comparison with a longer treatment. The results are in agreement with Petracci *et al.* (2009) who used 6% dietary linseed in the feed of rabbits and concluded that it corresponds to n-3 PUFA content of 8.5% of the total fatty acids. The results of current finding are in consistent with Anjum *et al.* (2013) who described highest fatty acid contents were found in broilers muscles fed on diet containing highest level of extruded flaxseed while lowest level of fatty acid were observed in broilers chicks fed on control feed. 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 linseed (Bianchi *et al.*, 2009). Oil seeds, such as linseed and rapeseed are also high in a-linolenic acid, and therefore the meat of animals reared on feeds containing these also contained higher levels of n-3 PUFAs (Givens, 2005). The results are in agreement with the work of Lopez-Bote *et al.* (1999) who used 300g oat/Kg feed and found favourable PUFA/SFA ratio. Tarasewicz *et al.* (2001) stated that broiler birds receiving 7% supplementation with linseed had a significantly higher amount of unsaturated fatty acids (UFA), including MUFA, and a decreased amount of SFA. The consumption of hind leg meat guarantees a higher intake of n-3 PUFA because of the higher total lipid contents in the meat.

4.2.7 SDS-PAGE characterization of rabbit proteins

The myofibrillar proteins (high molecular weight myofibrillar subunits and low molecular weight myofibrillar subunits) fractions in different rabbit meats produced during the experimental year 2012 and 2013 were determined through SDS-polyacrylamide gel electrophoresis (SDS-PAGE). The results interpreted from their electrophoretograms are shown in Figure 4.1. The high molecular weight myofibrillar subunits (HMW-GS) and low molecular weight myofibrillar subunits (LMW-GS) fractions have been identified as two major classes of myofibrillar polypeptides in different meat of rabbits. These two classes of myofibrillar polypeptides occur in meat as crossed-linked proteins resulting from inter-polypeptide disulphide linkages. These HMW-GS and LMW-GS were identified by comparing with the standards of molecular weight subunits (21-200 kDa) run in the same gel. The polypeptides detected in the present study can be divided into two major molecular weight regions. The polypeptides present at 28.23 kDa to 69.81 kDa are known low molecular weight myofibrillar subunits (LMW-GS) while those which are present in the region above 70 kDa are high molecular weight myofibrillar subunits (HMW-GS) as already reported by Beitz and Wall (1972). It is evident from the electrophorogram that more number of polypeptides were observed in the region falling under low molecular weight myofibrillar subunits.

Table 4.25: Fatty acid profile % of hind leg meat of rabbits

	Experimental year (2012)					Experimental year (2013)				
	Treatments					Treatments				
Fatty acids	T0	T1	T2	T3	T4	T0	T1	T2	T3	T4
SFA	33.98	32.44	32.64	33.46	32.85	33.96	32.42	32.62	33.45	32.87
MUFA	26.47	27.47	27.58	30.85	30.35	26.48	27.48	27.59	30.86	30.36
PUFA	30.44	24.52	24.94	35.52	32.36	30.29	24.42	25.04	35.37	32.21
UFA	56.91	51.99	52.52	66.37	62.71	56.77	51.90	52.63	66.23	62.57
SFA/UFA	0.597	0.624	0.621	0.516	0.520	0.598	0.625	0.620	0.517	0.521
PUFA/SFA	0.896	0.756	0.764	1.062	0.985	0.892	0.753	0.768	1.057	0.980

SFA: Saturated fatty acids **MUFA**: Monounsaturated fatty acids **PUFA**: Polyunsaturated fatty acids **UFA:** Unsaturated Fatty acids **SFA/UFA:** Ratio of saturated fatty acids and unsaturated fatty acids **PUFA/SFA:** Ratio of poly unsaturated fatty acid and saturated fatty acids

Table 4.26: Fatty acid composition of hind leg meat of rabbits

	Experimental year (2012)					Experimental year (2013)				
	Fatty acid % in loin meat tissues					Fatty acid % in loin meat tissues				
Fatty acids	T0	T1	T2	T3	T4	T0	T1	T2	T3	T4
C14,0	0.94	1.25	0.93	1.34	1.15	0.92	1.23	0.91	1.32	1.16
C16,0	26.21	25.91	26.03	26.74	26.52	26.17	25.87	25.99	26.71	26.54
C18,0	6.83	5.28	5.68	5.38	5.18	6.87	5.32	5.72	5.42	5.17
C14,1	0.13	0.07	0.08	0.06	0.08	0.13	0.07	0.08	0.06	0.08
C16,1	1.77	2.27	2.33	3.52	4.18	1.8	2.3	2.36	3.55	4.21
C18,1	24.57	25.13	25.17	27.27	26.09	24.55	25.11	25.15	27.25	26.07
C18,2	24.02	19.65	19.45	26.95	25.47	23.99	19.63	19.47	26.92	25.44
C18,3	5.1	2.95	3.76	8.13	6.57	5.07	2.93	3.78	8.1	6.54
C20,3	0.33	1.8	1.66	0.16	0.12	0.3	1.78	1.68	0.13	0.09
C22,5	0.74	0.04	0.01	0.11	0.09	0.71	0.02	0.03	0.08	0.06
C22,6	0.25	0.08	0.06	0.17	0.11	0.22	0.06	0.08	0.14	0.08

The SDS-PAGE patterns of molecular weight of myofibrillar subunits showed the presence of myofibrillar subunits in the range of 28.23 to 110.89kDa and 28.29 to 114.51 kDa during the experimental years 2012 and 2013 respectively. The highest molecular weight myofibrillar subunit α-actinin (110.89-114.51kDa) was observed in meat of rabbits fed on 4% oat (T1) while the lowest molecular weight subunit myosin light chain 1 (MLC-1) (28.23-28.29 kDa) was expounded by meat of rabbits fed on 2% oat (T2) during the experimental year 2012 and 2013 respectively. Myosin light chain 2 (MLC-2) (18 kDa), and myosin light chain 3 (MLC-3) (16 kDa) bands did not significantly change by varying the feed. A wide variation with respect to high molecular weight subunits in rabbits fed on different level of oat and linseed supplementation occurred. Our results are in consistent with the findings of Claeys *et al*. (1995) who reported the range from 70 kDa to 130 kDa for HMW-GS and results for HMW-GS identified in present study fall within these ranges. The highest numbers of polypeptide bands were identified in meat of rabbits fed on 2% oat (T2) and 7% linseed during experimental year 2012 and 2013. Bandman, (1992) reported that myofibrillar polymers are made up of high molecular weight (100 kDa) and low molecular weight (31-45 kDa) myofibrillar subunits linked together by disulfides bonds which support to the present electorphoretic bands influenced for LMW-GS.

4.3 Analysis of serum bio-chemical profile of rabbits

4.3.1 Total serum cholesterol

Total serum cholesterol is an important factor in the determination of bio-chemical profile. The statistical results regarding serum cholesterol of rabbits fed on oat and linseed are given in Table 4.27. It is evident from the results that the experimental years have non-significant effect on the serum cholesterol of rabbits. The data presented in Table 4.27 indicates that the serum cholesterol concentration was significantly affected by the supplementation of oat and linseed in rabbits feed. However, the interactive effect of experimental years × treatments exhibited non-significant effect on serum cholesterol of rabbits.

The data regarding mean values for serum cholesterol is expressed in Table 4.28. It is obvious from the data expressed in Table 4.28 that the variation in serum cholesterol during the experimental years was non-significant; the average concentration of serum cholesterol during 2012 was 126.04 mg/dl while during 2013 it was observed to be 126.11 mg/dl. The results regarding impact of oat and linseed supplementation in a feed on serum cholesterol of

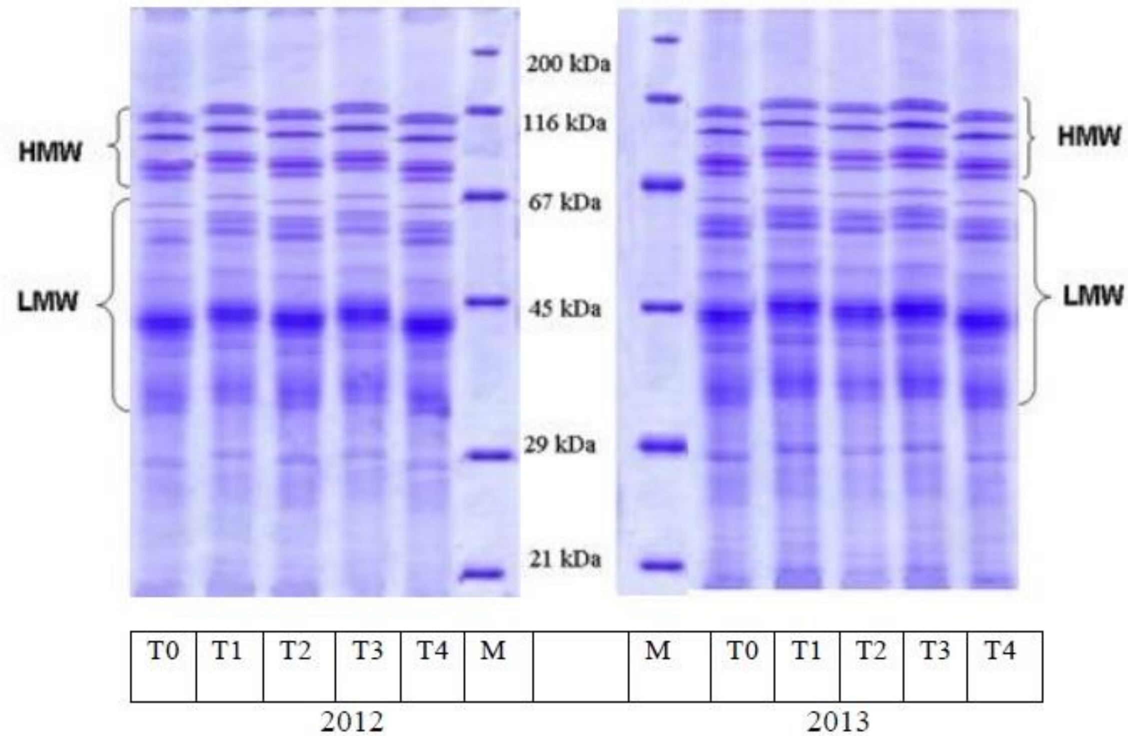

Fig 4.1: Electrophoregrams of HMW-MS and LMW-MS of rabbit meat

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

rabbits are shown in Table 4.28. The serum cholesterol of rabbits as a function of different treatments varied significantly from 105.66 mg/dl to 141.21 mg/dl during the course of study. The highest serum cholesterol (141.21 mg/dl) were observed in rabbits fed on control feed (T0) while lowest serum cholesterol (105.27 mg/dl) was noted in rabbits fed on 4% oat (T1). The interactive effect of experimental years × treatments exhibited non-significant effect on serum cholesterol of rabbits.

It is evident from the results that oat and linseed supplementation in feed significantly affects the total serum cholesterol in rabbits. Linseed contains biologically active substances such as lignans, fibre and linoleic acid that have cardioprotective effects. The lignan compounds, when ingested, are capable of promoting reductions in serum cholesterol because of their modulatory function through the cholesterol acyltransferase enzyme (acyl CoA) and 7-a-hydroxylase involved in their metabolism (Kris-Etherton *et al.,* 2003). Some reports recorded that linseed (12.5g/day) prevented the rise in plasma triglyceride levels over a 16-week feeding period in a hypercholesterolemic rabbit model but had no effect on triglycerides levels in low density lipoprotein receptor (LDLr) mice supplemented with 0.04g/day of flaxseed during 24 weeks.

Dupasquier *et al.* (2006) and (Dupasquier *et al.* (2007) reported that dietary linseed even low doses (0.04-0.2g/day) significantly reduce plasma cholesterol levels in the LDL in mice. The total cholesterol contents of rabbits were lowered when they fed on diets supplemented with 4% oat. These results correlated with many studies indicating the efficacy of oat and oat bran in reducing total cholesterol (TC) and LDL-C concentrations while either increasing or having no effect on plasma HDL-C concentrations in humans (Kerckhoffs *et al.,* 2003; Charlton *et al.,* 2011; Othman *et al.,* 2011). A number of studies indicate that beta-glucan is the major active cholesterol-reducing component of oats. When beta-glucans are fed in a dose-dependent manner, significantly greater reductions in blood cholesterol are observed as beta-glucan content increases (Behall *et al.,* 1997). Oats lowers blood cholesterol levels via the formation of a viscous gel by the oat soluble fiber. This binds bile acids and increases their excretion within the feces (Judd and Trusswell, 1981; Marlett *et al.,* 1994).

4.3.2 Total serum triglycerides

High serum triglycerides (TG) concentration is recognized as an independent risk factor for The atherosclerosis as it is closely correlated with the increase of the risk of coronary heart

Table 4.27: Analysis of variance for total serum cholesterol of rabbits

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year (Y)	1	0.00	0.00	0.00[NS]
Error-1	4	37.07	9.27	
Treatment	4	5307.20	1326.80	91.66**
Y x Treatment	4	10.04	2.51	0.20[NS]
Error	16	231.60	14.48	

NS = Non-significant (P>0.05), ** = Highly significant (P<0.01)

Table 4.28: Effect of oat and linseed supplementation on total serum cholesterol (mg/dl) of rabbits

Treatments	**Year**		**Years x Treatment**
	Y1	**Y2**	**Mean**
T0	142.33	140.08	141.21a
T1	105.27	106.05	105.66e
T2	117.78	117.30	116.04d
T3	129.53	132.00	130.77c
T4	135.31	135.12	135.22b
Total	126.04	126.11	

Means sharing similar letter in a column is statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

diseases (Smith *et al.*, 2004). The statistical results regarding serum triglycerides of rabbits fed on oat and linseed are given in Table 4.29. It is evident from the results that the experimental years have non-significant effect on the serum triglycerides of rabbits. The data presented in Table 4.29 indicates that the serum triglycerides concentration was significantly affected by the supplementation of oat and linseed in rabbits feed. However, the interactive effect of experimental years × treatments exhibited non-significant effect on serum triglycerides of rabbits.

The data regarding mean values for serum triglycerides are expressed in Table 4.30. It is obvious from the data expressed in Table 4.30 that variation in serum triglycerides during the experimental years was non-significant; the average concentration of serum triglycerides during 2012 was 76.03 mg/dl while during 2013 it was observed to be 76.02 mg/dl. The results regarding impact of oat and linseed supplementation in feed on serum triglycerides of rabbits are shown in Table 4.30. The serum triglycerides of rabbits as a function of different treatments varied significantly from 66.23 mg/dl to 85.93 mg/dl. The highest serum triglycerides (85.93 mg/dl) were observed in rabbits fed on control feed (T0) while lowest serum triglycerides (66.23 mg/dl) was noted in rabbits fed on 4% oat (T1). The interactive effect of experimental years × treatments exhibited non-significant effect on serum triglycerides of rabbits.

The results of present study indicated a significant reduction in triglycerides content of rabbits fed on diet supplemented with 4% oat. These results are in agreement with the work of El Rabey *et al.* (2013) who determined the efficiency of oat in ameliorating blood lipid profile and the adverse histological changes in hypercholesterolemic male rats. Total triglycerides were remarkably reduced in rats fed on oat bran as compared to control and other group. Flaxseed (12.5g/day) prevented the rise in plasma triglyceride levels over a 16-week feeding period in a hypercholesterolemic rabbit model but had no effect on triglycerides levels in low density lipoprotein receptor (LDLr) mice supplemented with 0.04g/day of flaxseed during 24 weeks (Dupasquier *et al.,* 2006; Dupasquier *et al.,* 2007).

4.3.3 Serum high density lipoprotein

The statistical results regarding serum High Density Lipoprotein (HDL) of rabbits fed on oat and linseed are given in Table 4.31. It is evident from the results that the experimental years have non-significant effect on the serum HDL of rabbits.

Table 4.29: Analysis of variance for serum triglycerides of rabbits

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year (Y)	1	3.33	3.33	0.56^{NS}
Error-1	4	40.53	10.13	
Treatment	4	1433.87	358.47	60.50**
Y x Treatment	4	13.33	3.33	0.56^{NS}
Error	16	94.80	5.92	

NS = Non-significant (P>0.05), ** = Highly significant (P<0.01)

Table 4.30: Effect of oat and linseed supplementation on serum triglycerides (mg/dl) of rabbits

Treatments	**Year**		**Years x Treatment Mean**
	Y1	**Y2**	
T0	85.33	86.52	85.93a
T1	66.67	65.79	66.23d
T2	71.37	73.23	72.30c
T3	82.10	83.32	82.71b
T4	74.67	71.25	72.96c
Total	76.03a	76.02a	

Means sharing similar letter in a column is statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The data presented in Table 4.31 indicates that the serum HDL concentration was significantly affected by the supplementation of oat and linseed in rabbits feed. However, the interactive effect of experimental years × treatments exhibited non-significant effect on serum HDL of rabbits. The data regarding mean values for serum HDL are expressed in Table 4.32. It is obvious from the data expressed in Table 4.32 that the variation in serum HDL during the experimental years was non-significant; the average concentration of serum HDL concentration during 2012 was 46.90 mg/dl while during 2013 it was observed to be 46.79 mg/dl. The results regarding impact of oat and linseed supplementation in feed on serum HDL of rabbits are shown in Table 4.32. The serum HDL of rabbits as a function of different treatments varied significantly from 41.00 mg/dl to 48.00 mg/dl. The highest serum HDL concentration (48.00 mg/dl) was observed in rabbits fed on 7% linseed (T3) while lowest serum HDL concentration was observed in rabbits fed on 2% oat (T2). The interactive effect of experimental years × treatments exhibited non-significant effect on serum HDL of rabbits. Supplementation of oat and linseed to the rabbits increased HDL concentration in serum of rabbits. In several studies, oats improved lipid profiles by significantly increasing blood concentrations of HDL cholesterol as well as apolipoprotein A-I, a major component of HDL (Turnbull and Reeds, 1989; Bremer *et al.,* 1991). The results of present study indicated a significant increase in HDL content of rabbits fed on diet supplemented with 7% linseed. Our findings are correlated with the work of Nounou *et al*. (2012) who found a significant increase of high density lipoprotein (HDL) 34.3±1.9 mg/dl in group of rabbits which were fed on linseed supplementation with increase up to 129.4% as compared to the control. The significant increase in HDL due to linseed supplementation may be explained by stimulation of lipid oxidation during activity. Alterations in the transport of blood lipids, with a higher ratio of HDL to LDL increased lipoprotein lipase activity, which increases the use of circulating triglycerides as fuel and increases their clearance. Activation of this enzyme also speeds up the conversion of the very low density lipoproteins (VLDL) to HDL (Press *et al.*, 2003; Lee and Prasad, 2003).

4.3.4 Serum low density lipoprotein

The statistical results regarding serum Low Density Lipoprotein (LDL) of rabbits fed on oat and linseed are given in Table 4.33. It is evident from the results that the experimental years have non-significant effect on the serum LDL of rabbits.

Table 4.31: Analysis of variance for serum HDL of rabbits

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year (Y)	1	0.033	0.033	0.01^{NS}
Error-1	4	10.933	2.733	
Treatment	4	512.667	128.167	53.40**
Y x Treatment	4	0.133	0.033	0.01^{NS}
Error	16	38.400	2.400	

NS = Non-significant (P>0.05), ** = Highly significant (P<0.01)

Table 4.32: Effect of oat and linseed supplementation on serum HDL (mg/dl) of rabbits

Treatments	**Year**		**Years x Treatment**
	Y1	**Y2**	**Mean**
T0	44.33	44.00	44.17c
T1	47.67	47.60	47.67b
T2	41.00	41.13	41.00d
T3	53.33	53.19	53.33a
T4	48.19	48.05	48.00b
Total	46.90	46.79	

Means sharing similar letter in a column is statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The data presented in Table 4.33 indicates that the serum LDL concentration was significantly affected by the supplementation of oat and linseed in rabbits feed. However, the interactive effect of experimental years × treatments exhibited non-significant effect on serum LDL of rabbits. The data regarding mean values for serum LDL are expressed in Table 4.34. It is obvious from the data expressed in Table 4.34 that the variation in serum LDL during the experimental years was non-significant; the average concentration of serum LDL during 2012 was 29.81 mg/dl while during 2013 it was observed to be 29.83 mg/dl. The results regarding impact of oat and linseed supplementation in feed on serum LDL of rabbits are shown in Table 4.34. The serum LDL of rabbits as a function of different treatments varied significantly from 24.33 mg/dl to 35.33 mg/dl. The highest serum LDL (35.33 mg/dl) was observed in rabbits fed on control feed (T0) while lowest serum LDL concentration was observed in rabbits fed on 7% linseed (T3). The interactive effect of experimental years × treatments exhibited non-significant effect on serum LDL of rabbits.

It can be observed in the present study that there was a decrease in LDL-C in feed supplemented groups of oat and linseed. This potential reducing effect of linseed is noteworthy, because it is known that the reduction of 10mg/l in LDL-C results in a decrease of approximately 1–2% in the relative risk for cardiovascular morbidity (Lee and Prasad, 2003; Klag *et al.* 1993; Prasad, 2005; Cunanne *et al.* 1995). The results of present study indicated a significant decrease in LDL content of rabbits fed on diet supplemented with 7% linseed. There are reports that the hypocholesterolaemic effects of linseed may be attributed to the functional components present in its composition of lignans, soluble fibres and linolenic acid. Kitts *et al.* (1999) and Foti *et al.* (1996) reported that the lignans act positively in plasma lipids, by modulating the enzymes involved in cholesterol metabolism, and by reducing oxidative stress and the antagonistic properties of platelet aggregation. Soluble fibres within the linseed are potentially effective in regulating plasma levels of TC and LDL-C. In previous studies (Ruberfroid 1993; Sawashita *et al.* 2006), both in human subjects and in animals, the action of lipid-lowering soluble fibres has been reported.

4.3.5 Total serum protein

The statistical results regarding serum protein of rabbits fed on oat and linseed are given in Table 4.35. It is evident from the results that the experimental years have non-significant effect on the serum protein of rabbits.

Table 4.33: Analysis of variance for serum LDL of rabbits

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year (Y)	1	0.0000	0.0000	0.00^{NS}
Error-1	4	7.6000	1.9000	
Treatment	4	418.1330	104.5330	35.54**
Y x Treatment	4	0.0128	0.0032	0.01^{NS}
Error	16	47.067	2.9420	

NS = Non-significant (P>0.05), ** = Highly significant (P<0.01)

Table 4.34: Effect of oat and linseed supplementation on serum LDL (mg/dl) of rabbits

Treatments	**Year**		**Years x Treatment**
	Y1	**Y2**	**Mean**
T0	35.33	35.25	35.33a
T1	27.29	27.36	31.33b
T2	31.52	31.45	27.33c
T3	24.26	24.37	24.33d
T4	30.67	30.73	30.67b
Total	29.81	29.83	

Means sharing similar letter in a column is statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The data presented in Table 4.35 indicates that the serum protein concentration was significantly affected by the supplementation of oat and linseed in rabbits feed. However, the interactive effect of experimental years × treatments exhibited non-significant effect on serum protein of rabbits. The data regarding mean values for serum protein is expressed in Table 4.36. It is obvious from the data expressed in Table 4.36 that the variation in serum protein during the experimental years was non-significant; the average concentration of serum total protein during 2012 was 8.24 g/dl while during 2013 it was observed to be 8.23 g/dl. The results regarding impact of oat and linseed supplementation in feed on serum protein of rabbits are shown in Table 4.36. The serum protein of rabbits as a function of different treatments varied significantly from 8.18 g/dl to 8.37 g/dl. The highest serum total protein concentration (8.37) was observed in rabbits fed on 7% linseed (T3) while lowest serum total protein concentration (8.18 g/dl) was observed in rabbits fed on 4% oat (T1).

4.4 Physico-chemical analysis of nuggets

4.4.1 Water activity of loin nuggets

The statistical results regarding analysis of variance of Aw of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.37. It is evident from the results that experimental years have non-significant effect on Aw of loin nuggets. Water activity of loin nuggets varied significantly during storage. The data explicated in Table 4.37 indicates that water activity of loin nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant on water activity of loin nuggets.

The data regarding mean values for water activity of loin nuggets is explicated in Tables 4.38, 4.39 and 4.40. It is evident from results presented in Table 4.38 that variation in water activity values during the experimental years was non-significant; the average water activity values of loin nuggets during 2012 was 0.826 while during 2013 it was observed to be 0.827. The water activity values of loin nuggets during storage varied significantly as presented in Table 4.39. The water activity values of loin nuggets during storage varied significantly from 0.789 to 0.858 during different storage period. The highest water activity value (0.858) was observed at 0day of storage period while during 30th day of storage period loin nuggets showed lowest water activity value (0.789). It is evident from the results that the nuggets prepared from loin meat of rabbits fed on oat and linseed decrease water activity values with

Table 4.35: Analysis of variance for serum total protein of rabbits

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year (Y)	1	0.0000	0.0000	0.00^{NS}
Error-1	4	0.0335	0.0084	0.71^{NS}
Treatment	4	120.1959	30.0490	2539.89**
Y x Treatment	4	0.0153	0.0038	0.01^{NS}
Error	16	0.1893	0.0118	

NS = Non-significant (P>0.05), ** = Highly significant (P<0.01)

Table 4.36: Effect of oat and linseed supplementation on serum total protein (g/dl) of rabbits

Treatments	**Year**		**Years x Treatment Mean**
	Y1	**Y2**	
T0	8.24	8.15	8.20c
T1	8.15	8.20	8.18c
T2	8.19	8.18	8.19c
T3	8.36	8.38	8.37a
T4	8.27	8.31	8.29b
Total	8.24	8.23	

Means sharing similar letter in a column is statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on water activity of loin nuggets are presented in Table 4.40. The water activity of loin nuggets as a function of different treatments varied significantly from 0.783 to 0.843 during the course of storage period. The highest water activity value (0.843) was observed in loin nuggets of rabbit's meat fed on 7% linseed (T3) while lowest water activity value (0.783) was noted in loin nuggets of rabbit's meat fed on control feed (T0).The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant on water activity of loin nuggets.

It is evident from results that linseed and oat supplementation in feed significantly reduce the water activity values of the nuggets. The results correlate with the findings of Ruiz *et al.* (1999) who studied that water activity of crusted dry-cured loin and non-crusted dry-cured loin decrease and the texture of the product go towards hardness with advancement of the storage period. Anjum *et al. (*2013) prepared nuggets and stored for 30day and found the decreasing trend in water activity. The results of my study are in contrast with the findings of Ca´ceres *et al.* (2008) observed no change in water activity in omega enriched sausage during storage. This variation in results may be due to the different level of enrichment or different storage conditions.

4.4.2 Aw of hind leg nuggets

The statistical results regarding analysis of variance of Aw of hind leg nuggets of the rabbits fed on oat and linseed are given in Table 4.41. It is evident from the results that experimental years have non-significant effect on Aw of hind leg nuggets. Water activity of hind leg nuggets varied significantly during storage. The data explicated in Table 4.41 indicates that water activity of hind leg nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant on water activity of hind leg nuggets.

The data regarding mean values for water activity of hind leg nuggets is explicated in Tables 4.42, 4.43 and 4.44. It is evident from results presented in Table 4.42 that variation in water activity values during the experimental years was non-significant; the average water activity values of hind leg nuggets during 2012 were 0.846 while during 2013 it was observed to be 0.847. The water activity values of hind leg nuggets during the storage varied significantly as

Table 4.37: Analysis of variance for Aw of loin nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.004323	0.004323	0.993^{NS}
Error 1	4	0.017396	0.004329	
Storage	3	0.107413	0.035804	66.078**
Treat	4	1.059907	0.399767	279.442**
Year x Storage	3	0.000023	0.000008	0.014^{NS}
Year x Treat	4	0.000450	0.000113	0.118 ^{NS}
Storage x Treat	12	0.011687	0.000974	1.027 ^{NS}
Year x Storage x Treat	12	0.001371	0.000114	0.120 ^{NS}
Error	76	0.067189	0.000884	

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.38: Effect of oat and linseed supplementation on Aw of loin nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	0.782	0.843	0.834	0.843	0.831	0.826
Y2	0.783	0.843	0.834	0.843	0.832	0.827

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Table 4.39: Effect of oat and linseed supplementation on Aw of loin nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	0.822	0.864	0.858	0.883	0.865	0.858a
10	0.810	0.849	0.838	0.860	0.863	0.844b
20	0.776	0.831	0.827	0.833	0.813	0.816c
30	0.725	0.828	0.812	0.796	0.784	0.789d

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.40: Effect of oat and linseed supplementation on Aw of loin nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	0.821	0.863	0.857	0.882	0.864	0.857
10	0.809	0.847	0.836	0.858	0.861	0.842
20	0.775	0.832	0.828	0.834	0.814	0.817
30	0.724	0.829	0.813	0.797	0.785	0.790
Y2 0	0.823	0.865	0.859	0.884	0.866	0.859
10	0.811	0.851	0.840	0.862	0.865	0.846
20	0.777	0.830	0.826	0.832	0.812	0.815
30	0.726	0.827	0.811	0.795	0.783	0.788
Mean	0.783c	0.842a	0.834b	0.843a	0.831b	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

presented in Table 4.43. The water activity values of hind leg nuggets during storage varied significantly from 0.809 to 0.878 during different storage period. The highest water activity value (0.878) was observed at 0day of storage period while during 30^{th} day of storage period hind leg nuggets showed lowest water activity value (0.809). It is evident from the results that the nuggets prepared from hind meat of rabbits fed on oat and linseed decrease water activity values with the progression of storage period up to 30^{th} day. The results regarding impact of oat and linseed supplementation in feed on water activity of hind leg nuggets are presented in Table 4.44. The water activity of hind leg nuggets as a function of different treatments varied significantly from 0.803 to 0.863 during the course of storage period. The highest water activity value (0.863) was observed in hind leg nuggets of rabbit's meat fed on 7% linseed (T3) while lowest water activity value (0.803) was noted in hind leg nuggets of rabbit's meat fed on control feed (T0). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant on water activity of hind leg nuggets.

It is evident from results that linseed and oat supplementation in feed significantly reduce the water activity values of the nuggets. During storage the leg meat nuggets showed the same behavior as the loin meat nuggets. The results correlate with the findings of Ruiz *et al.* (1999) who studied that water activity of crusted dry-cured loin and non-crusted dry-cured loin decrease and the texture of the product go towards hardness with advancement of the storage period. Anjum *et al. (*2013) prepared nuggets and stored for 30day and found the decreasing trend in water activity. The results of my study are in contrast with the findings of Ca´ceres *et al.* (2008) observed no change in water activity in omega enriched sausage during storage. This variation in results may be due to the different level of enrichment or different storage conditions.

4.4.3 Texture of loin nuggets

The statistical results regarding analysis of variance for texture of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.45. It is evident from the results that experimental years have non-significant effect on texture of loin nuggets. Texture of loin nuggets varied significantly during storage. The data explicated in Table 4.45 indicates that texture of loin nuggets was significantly affected by supplementation of oat and linseed.

Table 4.41: Analysis of variance for Aw of hind leg nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.004430	0.004430	0.997^{NS}
Error 1	4	0.017403	0.004350	
Storage	3	0.107520	0.035840	66.097**
Treat	4	1.051014	0.262753	378.377**
Year x Storage	3	0.000130	0.000043	0.019^{NS}
Year x Treat	4	0.000557	0.000139	0.234 ^{NS}
Storage x Treat	12	0.011794	0.000983	1.765 ^{NS}
Year x Storage x Treat	12	0.001478	0.000123	0.165 ^{NS}
Error	76	0.067296	0.000885	
	119			

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.42: Effect of oat and linseed supplementation on Aw of hind leg nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	0.802	0.863	0.854	0.863	0.851	0.846
Y2	0.803	0.863	0.854	0.863	0.852	0.847

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Table 4.43: Effect of oat and linseed supplementation on Aw of hind leg nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	0.842	0.884	0.878	0.903	0.885	0.878a
10	0.830	0.869	0.858	0.880	0.883	0.864b
20	0.796	0.851	0.847	0.853	0.833	0.836c
30	0.745	0.848	0.832	0.816	0.804	0.809d

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.44: Effect of oat and linseed supplementation on Aw of hind leg nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	0.841	0.883	0.877	0.902	0.884	0.877
10	0.829	0.867	0.856	0.878	0.881	0.862
20	0.795	0.852	0.848	0.854	0.834	0.837
30	0.744	0.849	0.833	0.817	0.805	0.810
Y2 0	0.843	0.885	0.879	0.904	0.886	0.879
10	0.831	0.871	0.860	0.882	0.885	0.866
20	0.797	0.850	0.846	0.852	0.832	0.835
30	0.746	0.847	0.831	0.815	0.803	0.808
Mean	0.803c	0.862a	0.854b	0.863a	0.851b	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant effect while storage x treatment showed significant effect on texture of loin nuggets.

The data regarding mean values for texture of loin nuggets is explicated in Tables 4.46, 4.47 and 4.48. It is evident from results presented in Table 4.46 that variation in texture values during the experimental years was non-significant; the average texture values of loin nuggets during 2012 was 4.73 while during 2013 it was observed to be 4.69. The texture values of loin nuggets during storage varied significantly as presented in Table 4.47. The texture values of loin nuggets during storage varied significantly from 4.62 to 4.77 during different storage period. The highest texture value (4.77) was observed at 30th day of storage period while during 0day of storage period loin nuggets showed lowest texture value (4.62). It is evident from the results that the nuggets prepared from loin meat of rabbits fed on oat and linseed increase texture values with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on texture of loin nuggets are presented in Table 4.48. The texture of loin nuggets as a function of different treatments varied significantly from 4.20 to 5.23 during the course of storage period. The highest texture value (5.23) was observed in loin nuggets of rabbit's meat fed on 7% linseed (T3) while lowest texture value (4.20) was noted in loin nuggets of rabbit's meat fed on control feed (T0). The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant effect while storage x treatment showed significant effect on texture of loin nuggets.

It is evident from results that linseed and oat supplementation in feed significantly increase the texture values of the nuggets. These results are in correlation with the findings of Ruiz *et al.* (1999**)** who observed significant effect of storage on texture of patties. The results of present study are in agreement of Sohaib *et al*. (2012) stated that the increase in hardness may be associated with the decrease in water activity of the nuggets as the advancement of storage period. Similarly, in chevon patties with oat bran, the shear force values were found to be lower than the control due to the decrease in cohesion resulting from the increase in the fiber content which was attributed to the good binding capacity of the proteins (Dawkins *et al.,* 1990). Contrary to this, Talukder and Sharma (2010) stated that the incorporation of oat bran increased the shear press values of the chicken meat patties.

Table 4.45: Analysis of variance for texture of loin nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.00208	0.00208	3.33^{NS}
Error 1	4	0.01278	0.00320	
Storage	3	0.47644	0.15881	10.16**
Treat	4	20.98375	5.24594	335.56**
Year x Storage	3	0.07225	0.02408	1.54^{NS}
Year x Treat	4	0.09633	0.02408	1.54^{NS}
Storage x Treat	12	2.76825	0.23069	14.76**
Year x Storage x Treat	12	0.28900	0.02408	1.54^{NS}
Error	76	1.18815	0.01563	
Total	119	25.93904		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.46: Effect of oat and linseed supplementation on texture of loin nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	4.23	4.59	4.42	5.27	5.13	4.73
Y2	4.16	4.52	4.35	5.20	5.20	4.69

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Table 4.47: Effect of oat and linseed supplementation on texture of loin nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	4.33hi	4.54ef	4.42fgh	5.01c	4.81d	4.62B
10	4.16j	4.50efg	4.37gh	5.14bc	5.63a	4.76A
20	4.19ij	4.55ef	4.32hi	5.28b	5.03c	4.67B
30	4.13j	4.61e	4.43fgh	5.51a	5.20b	4.77A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.48: Effect of oat and linseed supplementation on texture of loin nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	**T1**	**T2**	**T3**	**T4**	
Y1 0	4.36	4.58	4.45	5.04	4.84	4.65
10	4.19	4.54	4.40	5.17	5.38	4.74
20	4.23	4.59	4.35	5.31	5.07	4.71
30	4.16	4.65	4.46	5.54	5.23	4.81
Y2 0	4.29	4.51	4.38	4.97	4.77	4.58
10	4.12	4.47	4.33	5.10	5.88	4.78
20	4.16	4.52	4.28	5.24	5.00	4.64
30	4.09	4.58	4.39	5.47	5.16	4.74
Mean	4.20D	4.55B	4.38C	5.23A	5.17A	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

4.4.4 Texture of hind leg nuggets

The statistical results regarding analysis of variance of the texture of hind leg nuggets of the rabbits fed on oat and linseed are given in Table 4.49. It is evident from the results that experimental years have non-significant effect on texture of hind leg nuggets. Texture of hind leg nuggets varied significantly during storage. The data explicated in Table 4.49 indicates that texture of hind leg nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant effect while storage x treatment showed significant effect on texture of hind leg nuggets.

The data regarding mean values for texture of hind leg nuggets is explicated in Tables 4.50, 4.51 and 4.52. It is evident from results presented in Table 4.50 that variation in texture values during the experimental years was non-significant; the average texture values of hind leg nuggets during 2012 were 4.67 while during 2013 it was observed to be 4.62. The texture values of hind leg nuggets during storage varied significantly as presented in Table 4.51. The texture values of hind leg nuggets during storage varied significantly from 4.55 to 4.71 during different storage period. The highest texture value (4.71) was observed at 30th day of storage period while during 0day of storage period hind leg nuggets showed lowest texture value (4.55). It is evident from the results that the nuggets prepared from hind leg meat of rabbits fed on oat and linseed increase texture values with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on texture of hind leg nuggets are presented in Table 4.52. The texture of hind leg nuggets as a function of different treatments varied significantly from 4.09 to 5.08 during the course of storage period. The highest texture value (5.08) was observed in hind leg nuggets of rabbit's meat fed on 7% linseed (T3) while lowest texture value (4.09) was noted in hind leg nuggets of rabbit's meat fed on control feed (T0). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant on texture of hind leg nuggets.

It is evident from results that linseed and oat supplementation in feed significantly increase the texture values of the nuggets The results correlate with the findings of Ruiz *et al.*, (1999) who studied that water activity of crusted dry-cured loin and non-crusted dry-cured loin decrease and the texture of the product go towards hardness with advancement of the storage period. Similarly, in chevon patties with oat bran, the shear force values were found to be lower than the control due to the decrease in cohesion resulting from the increase in the fiber content which was attributed to the good binding capacity of the proteins (Dawkins *et al.*, 1990).

4.4.5 Lightness L* of loin nuggets

The statistical results regarding analysis of variance for lightness L* of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.53. It is evident from the results that experimental years have non-significant effect on lightness L* of loin nuggets. Lightness L* of loin nuggets varied significantly during storage. The data explicated in Table 4.53 indicates that lightness L* of loin nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant effect while storage x treatment showed significant effect on lightness L* of loin nuggets.

The data regarding mean values for water activity of loin nuggets is explicated in Tables 4.54, 4.55 and 4.56. It is evident from results presented in Table 4.54 that variation in lightness L* values during the experimental years was non-significant; the average lightness L* values of loin nuggets during 2012 was 61.09 while during 2013 it was observed to be 61.04.The lightness L* values of loin nuggets during storage varied significantly as presented in Table 4.55. The lightness L* values of loin nuggets during storage varied significantly from 57.60 to 65.05 during different storage period. The highest lightness L* value (65.05) was observed at 30th day of storage period while during 0day of storage period loin nuggets showed lowest lightness L* value (57.60). It is evident from the results that the nuggets prepared from loin meat of rabbits fed on oat and linseed increase lightness L* values with the progression of storage period up to 30th day.

The results regarding impact of oat and linseed supplementation in feed on lightness L* of loin nuggets are presented in Table 4.56. The lightness L* of loin nuggets as a function of different treatments varied significantly from 53.34 to 66.37 during the course of storage period. The highest lightness L* value (66.37) was observed in loin nuggets of rabbit’s meat fed on 7% linseed (T3) while lowest lightness L* value (53.34) was noted in loin nuggets of rabbit’s meat fed on control feed (T0).

Table 4.49: Analysis of variance for texture of hind leg nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.02533	0.02533	1.76^{NS}
Error 1	4	0.26041	0.06510	
Storage	3	0.54636	0.18212	7.89**
Treat	4	17.00837	4.25209	184.12**
Year x Storage	3	0.02500	0.00833	0.36^{NS}
Year x Treat	4	0.03333	0.00833	0.36^{NS}
Storage x Treat	12	2.41067	0.20089	8.70**
Year x Storage x Treat	12	0.10000	0.00833	0.36^{NS}
Error	76	1.75519	0.02309	
Total	119	22.36467		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.50: Effect of oat and linseed supplementation on texture of hind leg nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	4.81	4.34	4.12	5.15	4.93	4.67
Y2	4.76	4.29	4.08	5.10	4.89	4.62

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Table 4.51: Effect of oat and linseed supplementation on texture of hind leg nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	4.93bcd	4.30ghi	4.12ij	4.81cde	4.58f	4.55B
10	4.75def	4.26ghi	4.07j	5.11b	5.35a	4.71A
20	4.76def	4.31gh	4.02j	5.08b	4.80cde	4.59B
30	4.69ef	4.37g	4.13hij	5.31a	4.97bc	4.69A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.52: Effect of oat and linseed supplementation on texture of hind leg nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	4.96	4.33	4.16	4.84	4.61	4.58
10	4.78	4.29	4.10	5.31	5.38	4.77
20	4.79	4.34	4.05	5.11	4.83	4.63
30	4.72	4.40	4.17	5.35	5.00	4.73
Y2 0	4.89	4.26	4.09	4.77	4.54	4.51
10	4.71	4.22	4.03	4.90	5.31	4.64
20	4.72	4.27	3.98	5.04	4.76	4.56
30	4.65	4.33	4.10	5.28	4.93	4.66
Mean	4.78C	4.31D	4.09E	5.08A	4.92B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

It is evident from results that linseed and oat supplementation in feed significantly increase the lightness L* values of the nuggets. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant effect while storage x treatment showed significant effect on lightness L* of loin nuggets.

The results are in line with work of Bianchi *et al*. (2006) who stated the effect of linseed, the meat (L. lumborum) from rabbits fed on diets containing linseed (8%) exhibited higher a* values. Moreover, the hamburgers prepared with the linseed (8%) meat, exhibited a lower pH and higher L* values.

4.4.6 Lightness L* of hind leg nuggets

The statistical results regarding analysis of variance for lightness L* of hind leg nuggets of the rabbits fed on oat and linseed are given in Table 4.57. It is evident from the results that experimental years have non-significant effect on lightness L* of hind leg nuggets. Lightness L* of hind leg nuggets varied significantly during storage. The data explicated in Table 4.57 indicates that lightness L* of hind leg nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant effect while storage x treatment showed significant effect on lightness L*of hind leg nuggets.

The data regarding mean values for water activity of hind leg nuggets is explicated in Tables 4.58, 4.59 and 4.60. It is evident from results presented in Table 4.58 that variation in lightness L* values during the experimental years was non-significant; the average lightness L* values of hind leg nuggets during 2012 was 61.08 while during 2013 it was observed to be 61.02. The lightness L* values of hind leg nuggets during storage varied significantly as presented in Table 4.59. The lightness L* values of hind leg nuggets during storage varied significantly from 57.58 to 65.04 during different storage period. The highest lightness L* value (65.04) was observed at 30th day of storage period while during 0day of storage period hind leg nuggets showed lowest lightness L* value (57.58). It is evident from the results that the nuggets prepared from hind leg meat of rabbits fed on oat and linseed increase lightness L* values with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on lightness L* of hind leg nuggets are presented in Table 4.60.

Table 4.53: Analysis of variance for lightness L* of loin nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.075	0.075	0.16^{NS}
Error 1	4	2.876	0.719	
Storage	3	867.721	289.240	617.58**
Treat	4	2750.971	687.743	1468.46**
Year x Storage	3	0.000	0.000	0.00^{NS}
Year x Treat	4	0.000	0.000	0.00^{NS}
Storage x Treat	12	175.693	14.641	31.26**
Year x Storage x Treat	12	0.000	0.000	0.00^{NS}
Error	76	35.594	0.468	
Total	119	3832.929		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.54: Effect of oat and linseed supplementation on lightness L* of loin nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	53.36	60.66	59.18	66.40	65.88	61.09
Y2	53.31	60.61	59.13	66.35	65.83	61.04

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Table 4.55: Effect of oat and linseed supplementation on lightness L* of loin nuggets during different storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	48.49m	57.69i	56.04j	63.06de	62.72e	57.60D
10	49.70l	60.17g	58.96h	66.15bc	65.78c	60.15C
20	54.13k	60.93fg	59.34h	66.93b	66.04c	61.47B
30	61.03f	63.73d	62.29e	69.35a	68.87a	65.05A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.56: Effect of oat and linseed supplementation on lightness L* of loin nuggets

Years/ Storage	Treatment					Years x S
	T0	**T1**	**T2**	**T3**	**T4**	**Mean**
Y1 0	48.52	57.72	56.06	63.08	62.75	57.62
10	49.72	60.20	58.98	66.18	65.80	60.18
20	54.15	60.96	59.36	66.95	66.06	61.50
30	61.06	63.75	62.32	69.37	68.89	65.08
Y2 0	48.47	57.67	56.01	63.03	62.70	57.57
10	49.67	60.15	58.93	66.13	65.75	60.13
20	54.10	60.91	59.31	66.90	66.01	61.45
30	61.01	63.70	62.27	69.32	68.84	65.03
Mean	53.34E	60.63C	59.16D	66.37A	65.85B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The lightness L* of hind leg nuggets as a function of different treatments varied significantly from 53.32 to 66.35 during the course of storage period. The highest lightness L* value (66.35) was observed in hind leg nuggets of the rabbit's meat fed on 7% linseed (T3) while lowest lightness L* value (53.32) was noted in hind leg nuggets of rabbit's meat fed on control feed (T0). The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant effect while storage x treatment showed significant effect on lightness L* of hind leg nuggets.

It is evident from results that linseed and oat supplementation in feed significantly increase the lightness L* values of the nuggets. The results are in line with work of Bianchi *et al.* (2006) who stated the effect of linseed; the meat (L. lumborum) from rabbits fed on diets containing linseed (8%) exhibited higher A values. Moreover, the hamburgers prepared with the linseed (8%) meat, exhibited a lower pH and higher L* values.

4.4.7 Redness a* of loin nuggets

The statistical results regarding analysis of variance for Redness a* of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.61. It is evident from the results that experimental years have non-significant effect on Redness a* of loin nuggets. Redness a* of loin nuggets varied significantly during storage. The data explicated in Table 4.61 indicates that Redness a* of loin nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on Redness a* of loin nuggets.

The data regarding mean values for Redness a* of loin nuggets is explicated in Tables 4.62, 4.63 and 4.64. It is evident from results presented in Table 4.62 that variation in Redness a* values during the experimental years was non-significant; the average Redness a* values of loin nuggets during 2012 was 12.36 while during 2013 it was observed to be 12.30. The Redness a* values of loin nuggets during storage varied significantly as presented in Table 4.63. The Redness a* values of loin nuggets during storage varied significantly from 9.25 to 14.62 during different storage period. The highest Redness a* value (14.62) was observed at 30^{th} day of storage period while during 20^{th} day of storage period loin nuggets showed lowest Redness a* value (9.25). It is evident from the results that the nuggets prepared from loin meat of the rabbits fed on oat and linseed increase Redness a* values with the progression of

Table 4.57: Analysis of variance for lightness L* of hind leg nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.080	0.080	0.26^{NS}
Error 1	4	0.269	0.067	
Storage	3	869.238	289.746	947.03**
Treat	4	2750.076	687.519	2247.15**
Year x Storage	3	0.000	0.000	0.00^{NS}
Year x Treat	4	0.001	0.000	0.00^{NS}
Storage x Treat	12	175.431	14.619	47.78**
Year x Storage x Treat	12	0.002	0.000	0.00^{NS}
Error	76	23.252	0.306	
Total	119	3818.350		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.58: Effect of oat and linseed supplementation on lightness L* of hind leg nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	53.34	60.65	59.16	66.38	65.85	61.08A
Y2	53.29	60.59	59.11	66.33	65.81	61.02A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.59: Effect of oat and linseed supplementation on lightness L* of hind leg nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	48.47n	57.67j	56.01k	63.04e	62.71ef	57.58D
10	49.68m	60.16h	58.94i	66.14c	65.75c	60.13C
20	54.10l	60.91g	59.31i	66.89b	66.01c	61.44B
30	61.02g	63.73d	62.28f	69.34a	68.85a	65.04A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.60: Effect of oat and linseed supplementation on lightness L* of hind leg nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	**T1**	**T2**	**T3**	**T4**	
Y1 0	48.50	57.70	56.03	63.07	62.73	57.61
10	49.70	60.20	58.97	66.17	65.77	60.16
20	54.13	60.93	59.33	66.90	66.03	61.47
30	61.03	63.77	62.30	69.37	68.87	65.07
Y2 0	48.45	57.65	55.99	63.01	62.68	57.55
10	49.65	60.13	58.91	66.11	65.73	60.11
20	54.07	60.88	59.28	66.87	65.98	61.42
30	61.00	63.69	62.26	69.31	68.83	65.02
Mean	53.32E	60.62C	59.13D	66.35A	65.83B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on Redness a* of loin nuggets are presented in Table 4.64. The Redness a* of loin nuggets as a function of different treatments varied significantly from 11.97 to 12.79 during the course of storage period. The highest Redness a* value (12.79) was observed in loin nuggets of rabbit's meat fed on control feed (T0) while lowest Redness a* value (11.97) was noted in loin nuggets of rabbit's meat fed on 7% linseed (T3). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on Redness a* of loin nuggets.

It is evident from results that linseed and oat supplementation in feed significantly decrease the Redness a* values of the nuggets. The results are in line with work of Bianchi *et al.* (2006) who stated the effect of linseed, the meat (L. lumborum) from rabbits fed on diets containing linseed (8%) exhibited higher a* values. Results are in agreement Betti *et al.* (2009) to redness (a*) was greater than the control after 16d of feeding flaxseed 8.02 vs. 6.58 control. The results of my study are in close collaboration with the finding of Hoz *et al.* (2004) who studied the color characteristics of omega enriched sausages and found that the color become dark with the passage of time.

4.4.8 Redness a* of hind leg nuggets

The statistical results regarding analysis of variance for Redness a* of hind leg nuggets of the rabbits fed on oat and linseed are given in Table 4.65. It is evident from the results that experimental years have non-significant effect on Redness a* of hind leg nuggets. Redness a* of hind leg nuggets varied significantly during storage. The data explicated in Table 4.65 indicates that Redness a* of hind leg nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on Redness a* of hind leg nuggets.

The data regarding mean values for Redness a* of hind leg nuggets is explicated in Tables 4.66, 4.67 and 4.68. It is evident from results presented in Table 4.66 that variation in Redness a* values during the experimental years was non-significant; the average Redness a* values of hind leg nuggets during 2012 was 12.32 while during 2013 it was observed to be 12.27.

Table 4.61: Analysis of variance for Redness a* of loin nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.114	0.114	3.37^{NS}
Error 1	4	0.598	0.149	
Storage	3	581.619	193.873	5726.90**
Treat	4	9.309	2.327	68.75**
Year x Storage	3	0.000	0.000	0.00^{NS}
Year x Treat	4	0.000	0.000	0.00^{NS}
Storage x Treat	12	0.672	0.056	1.65^{NS}
Year x Storage x Treat	12	0.001	0.000	0.00^{NS}
Error	76	2.573	0.034	
Total	119	594.387		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.62: Effect of oat and linseed supplementation on Redness a* of loin nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	12.82	12.29	12.49	12.01	12.19	12.36A
Y2	12.76	12.23	12.43	11.94	12.13	12.30A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.63: Effect of oat and linseed supplementation on Redness a* of loin nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	11.68	11.23	11.40	10.90	11.04	11.25C
10	14.75	14.15	14.33	13.84	13.94	14.20B
20	9.63	9.10	9.30	8.92	9.31	9.25D
30	15.10	14.58	14.81	14.23	14.36	14.62A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.64: Effect of oat and linseed supplementation on Redness a* of loin nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	11.71	11.26	11.43	10.95	11.07	11.28
10	14.78	14.18	14.36	13.87	13.97	14.23
20	9.66	9.13	9.33	8.95	9.34	9.28
30	15.13	14.61	14.84	14.26	14.39	14.65
Y2 0	11.65	11.20	11.37	10.85	11.01	11.22
10	14.72	14.12	14.30	13.81	13.91	14.17
20	9.60	9.07	9.27	8.89	9.28	9.22
30	15.07	14.55	14.78	14.20	14.33	14.59
Mean	12.79A	12.26C	12.46B	11.97D	12.16C	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The Redness a* values of hind leg nuggets during storage varied significantly as presented in Table 4.67. The Redness a* values of hind leg nuggets during storage varied significantly from 9.19 to 14.60 during different storage period. The highest Redness a* value (14.60) was observed at 30th day of storage period while during 20th day of storage period hind leg nuggets showed lowest Redness a* value (9.19). It is evident from the results that the nuggets prepared from hind leg meat of rabbits fed on oat and linseed increase Redness a* values with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on Redness a* of hind leg nuggets are presented in Table 4.68. The Redness a* of hind leg nuggets as a function of different treatments varied significantly from 11.95 to 12.76 during the course of storage period. The highest Redness a* value (12.76) was observed in hind leg nuggets of rabbit's meat fed on control feed (T0) while lowest Redness a* value (11.95) was noted in hind leg nuggets of rabbit's meat fed on 7% linseed (T3). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on Redness a* of hind leg nuggets.

It is evident from results that linseed and oat supplementation in feed significantly decrease the Redness a* values of the nuggets. The results are in line with work of Bianchi *et al.* (2006) who stated the effect of linseed, the meat (L. lumborum) from rabbits fed on diets containing linseed (8%) exhibited higher a* values. Results are in agreement with Betti *et al.* (2009*)* to redness (a*) was greater than the control after 16d of feeding flaxseed 8.02 vs. 6.58 control. The results of my study are in close collaboration with the finding of Hoz *et al.* (2004) who studied the color characteristics of omega enriched sausages and found that the color become dark with the passage of time.

4.4.9 Yellowness b* of loin nuggets

The statistical results regarding analysis of variance for Yellowness b* of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.69. It is evident from the results that experimental years have non-significant effect on Yellowness b* of loin nuggets. Yellowness b* of loin nuggets varied significantly during storage. The data explicated in Table 4.69 indicates that Yellowness b* of loin nuggets was significantly affected by supplementation of oat and linseed.

Table 4.65: Analysis of variance for Redness a* of hind leg nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.052	0.052	2.48^{NS}
Error 1	4	0.568	0.142	
Storage	3	589.427	196.476	9343.19**
Treat	4	9.569	2.392	113.76**
Year x Storage	3	0.024	0.008	0.37^{NS}
Year x Treat	4	0.040	0.010	0.48^{NS}
Storage x Treat	12	0.302	0.025	1.20^{NS}
Year x Storage x Treat	12	0.094	0.008	0.37^{NS}
Error	76	1.598	0.021	
Total	119	601.175		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.66: Effect of oat and linseed supplementation on Redness a* of hind leg nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	12.79	12.27	12.46	11.98	12.08	12.32A
Y2	12.73	12.21	12.40	11.92	12.11	12.27A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.67: Effect of oat and linseed supplementation on Redness a* of hind leg nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	11.65	11.20	11.37	10.89	11.01	11.22C
10	14.72	14.12	14.30	13.81	13.91	14.17B
20	9.60	9.07	9.27	8.89	9.12	9.19D
30	15.08	14.56	14.79	14.21	14.36	14.60A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.68: Effect of oat and linseed supplementation on Redness a* of hind leg nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	**T1**	**T2**	**T3**	**T4**	
Y1 0	11.68	11.23	11.40	10.92	11.04	11.25
10	14.75	14.15	14.33	13.84	13.94	14.20
20	9.63	9.10	9.30	8.92	8.98	9.18
30	15.11	14.59	14.82	14.24	14.37	14.63
Y2 0	11.62	11.17	11.34	10.86	10.98	11.19
10	14.69	14.09	14.27	13.78	13.88	14.14
20	9.57	9.04	9.24	8.86	9.25	9.19
30	15.05	14.53	14.76	14.18	14.34	14.57
Mean	12.76A	12.24C	12.43B	11.95E	12.10D	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant effect while storage x treatment showed significant effect on Yellowness b* of loin nuggets.

The data regarding mean values for Yellowness b* of loin nuggets is explicated in Tables 4.70, 4.71 and 4.72. It is evident from results presented in Table 4.70 that variation in Yellowness b* values during the experimental years was non-significant; the average Yellowness b* values of loin nuggets during 2012 was 10.99 while during 2013 it was observed to be 10.94. The Yellowness b* values of loin nuggets during storage varied significantly as presented in Table 4.71. The Yellowness b* values of loin nuggets during storage varied significantly from 8.93 to 12.61 during different storage period. The highest Yellowness b* value (12.61) was observed at 30^{th} day of storage period while during 0day of storage period loin nuggets showed lowest Yellowness b* value (8.93). It is evident from the results that the nuggets prepared from loin meat of rabbits fed on oat and linseed increase Yellowness b* values with the progression of storage period up to 30^{th} day. The results regarding impact of oat and linseed supplementation in feed on Yellowness b* of loin nuggets are presented in Table 4.72. The Yellowness b* of loin nuggets as a function of different treatments varied significantly from 8.99 to 12.15 during the course of storage period. The highest Yellowness b* value (12.15) was observed in loin nuggets of rabbit's meat fed on 7% linseed (T3) while lowest Yellowness b* value (8.99) was noted in loin nuggets of rabbit's meat fed on control feed (T0). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on Yellowness b* of loin nuggets.

It is evident from results that linseed and oat supplementation in feed significantly increase the Yellowness b* values of the nuggets. Changes in colour values might be due to oxidation of fat content that decreased the brightness of nuggets and colour goes towards yellowness. The results are in agreement with Naveena *et al.* (2008) who observed the color value of the chicken patties that declined with passage of the time and color of the patties change from red to brown which could be due to the formation of metmyoglobin in treatments.

4.4.10 Yellowness b* of hind leg nuggets

The statistical results regarding analysis of variance for Yellowness b* of hind leg nuggets of

Table 4.69: Analysis of variance for Yellowness b* of loin nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.056	0.056	2.49^{NS}
Error 1	4	0.118	0.030	
Storage	3	215.072	71.691	3960.79**
Treat	4	150.124	37.531	2073.52**
Year x Storage	3	0.001	0.000	0.01^{NS}
Year x Treat	4	0.001	0.000	0.01^{NS}
Storage x Treat	12	182.503	15.209	840.25**
Year x Storage x Treat	12	0.002	0.000	0.01^{NS}
Error	76	1.376	0.018	
Total	119	549.272		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.70: Effect of oat and linseed supplementation on Yellowness b* of loin nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	9.01	11.07	10.78	12.18	11.93	10.99
Y2	8.96	11.02	10.73	12.12	11.89	10.94

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.71: Effect of oat and linseed supplementation on Yellowness b* of loin nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	9.31n	8.42o	8.12p	9.53m	9.27n	8.93D
10	11.23j	10.34k	10.03l	11.41i	11.16j	10.83C
20	8.13p	11.92g	11.63h	13.03e	12.78f	11.50B
30	7.29q	13.49c	13.23d	14.63a	14.43b	12.61A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.71: Effect of oat and linseed supplementation on Yellowness b* of loin nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	9.33	8.44	8.14	9.55	9.29	8.95
10	11.25	10.36	10.06	11.45	11.18	10.86
20	8.15	11.94	11.66	13.05	12.79	11.52
30	7.31	13.52	13.25	14.65	14.46	12.64
Y2 0	9.28	8.39	8.09	9.50	9.24	8.90
10	11.20	10.31	10.01	11.36	11.13	10.80
20	8.10	11.89	11.61	13.00	12.77	11.47
30	7.26	13.47	13.20	14.60	14.41	12.59
Mean	8.99E	11.04C	10.75D	12.15A	11.91B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

the rabbits fed on oat and linseed are given in Table 4.73. It is evident from the results that experimental years have non-significant effect on Yellowness b* of hind leg nuggets. Yellowness b* of hind leg nuggets varied significantly during storage.

The data explicated in Table 4.73 indicates that Yellowness b* of hind leg nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant effect while storage x treatment showed significant effect on Yellowness b* of hind leg nuggets.

The data regarding mean values for Yellowness b* of hind leg nuggets is explicated in Tables 4.74, 4.75 and 4.76. It is evident from results presented in Table 4.74 that variation in Yellowness b* values during the experimental years was non-significant; the average Yellowness b* values of hind leg nuggets during 2012 was 10.97 while during 2013 it was observed to be 10.92. The Yellowness b* values of hind leg nuggets during storage varied significantly as presented in Table 4.75. The Yellowness b* values of hind leg nuggets during storage varied significantly from 8.90 to 12.59 during different storage period. The highest Yellowness b* value (12.59) was observed at 30th day of storage period while during 0day of storage period hind leg nuggets showed lowest Yellowness b* value (8.90). It is evident from the results that the nuggets prepared from hind leg meat of rabbits fed on oat and linseed increase Yellowness b* values with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on Yellowness b* of hind leg nuggets are presented in Table 4.76. The Yellowness b* of hind leg nuggets as a function of different treatments varied significantly from 8.96 to 12.12 during the course of storage period. The highest Yellowness b* value (12.12) was observed in hind leg nuggets of rabbit's meat fed on 7% linseed (T3) while lowest Yellowness b* value (8.96) was noted in hind leg nuggets of rabbit's meat fed on control feed (T0). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on Yellowness b* of hind leg nuggets.

It is evident from results that linseed and oat supplementation in feed significantly increase the Yellowness b* values of the nuggets. Changes in colour values might be due to oxidation of fat content that decreased the brightness of nuggets and colour goes towards yellowness. The results are in agreement with (Naveena *et al.*, 2008) who observed the color value of the

Table 4.73: Analysis of variance for Yellowness b* of hind leg nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.051	0.051	2.47^{NS}
Error 1	4	0.513	0.128	
Storage	3	216.125	72.042	5107.07**
Treat	4	150.312	37.578	2663.93**
Year x Storage	3	0.000	0.000	0.01^{NS}
Year x Treat	4	0.000	0.000	0.01^{NS}
Storage x Treat	12	182.284	15.190	1076.85**
Year x Storage x Treat	12	0.001	0.000	0.01^{NS}
Error	76	1.072	0.014	
Total	119	549.988		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.74: Effect of oat and linseed supplementation on Yellowness b* of hind leg nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	8.99	11.04	10.75	12.15	11.91	10.97A
Y2	8.94	10.99	10.70	12.09	11.86	10.92A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.75: Effect of oat and linseed supplementation on Yellowness b* of hind leg nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	9.28n	8.39o	8.09p	9.50m	9.24n	8.90D
10	11.20j	10.31k	10.00l	11.39i	11.13j	10.80C
20	8.11p	11.89g	11.61h	13.01e	12.78f	11.48B
30	7.27q	13.47c	13.21d	14.59a	14.41b	12.59A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.76: Effect of oat and linseed supplementation on Yellowness b* of hind leg nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	9.30	8.41	8.11	9.52	9.26	8.92
10	11.22	10.33	10.03	11.42	11.15	10.83
20	8.13	11.92	11.64	13.03	12.80	11.50
30	7.29	13.50	13.23	14.63	14.44	12.62
Y2 0	9.25	8.36	8.06	9.47	9.21	8.87
10	11.17	10.28	9.98	11.37	11.10	10.78
20	8.08	11.87	11.59	12.98	12.75	11.45
30	7.24	13.45	13.18	14.55	14.39	12.56
Mean	8.96E	11.01C	10.73D	12.12A	11.89B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

chicken patties that declined with passage of the time and color of the patties change from red to brown which could be due to the formation of metmyoglobin in treatments.

4.4.11 pH of loin nuggets

pH is an important factor in the determination of the shelf life and storage stability of the meat. The statistical results regarding analysis of variance for pH of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.77. It is evident from the results that experimental years have non-significant effect on pH of loin nuggets. pH of loin nuggets varied significantly during storage. The data explicated in Table 4.77 indicates that pH of loin nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant effect while storage x treatment showed significant effect on pH of loin nuggets.

The data regarding mean values for pH of loin nuggets is explicated in Tables 4.78, 4.79 and 4.80. It is evident from results presented in Table 4.78 that variation in pH values during the experimental years was non-significant; the average pH values of loin nuggets during 2012 was 6.01 while during 2013 it was observed to be 5.96. The pH values of loin nuggets during storage varied significantly as presented in Table 4.79. The pH values of loin nuggets during storage varied significantly from 5.84 to 6.10 during different storage period. The highest pH value (6.10) was observed at 30th day of storage period while during 0day of storage period loin nuggets showed lowest pH value (5.84). It is evident from the results that the nuggets prepared from loin meat of rabbits fed on oat and linseed increase pH values with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on pH of loin nuggets are presented in Table 4.80. The pH of loin nuggets as a function of different treatments varied significantly from 5.87 to 6.25 during the course of storage period. The highest pH value (6.25) was observed in loin nuggets of rabbit's meat fed on 7% linseed (T3) while lowest PH value (5.87) was noted in loin nuggets of rabbit's meat fed on control feed (T0). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on pH of loin nuggets.

It is evident from results that linseed and oat supplementation in feed significantly increase the pH values of the nuggets.

Table 4.77: Analysis of variance for pH of loin nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.003508	0.003508	1.33^{NS}
Error 1	4	0.018610	0.004652	
Storage	3	1.128029	0.376010	345.45**
Treat	4	2.637047	0.659262	605.68**
Year x Storage	3	0.000022	0.000007	0.01^{NS}
Year x Treat	4	0.000030	0.000008	0.01^{NS}
Storage x Treat	12	0.149833	0.012486	11.47**
Year x Storage x Treat	12	0.000090	0.000007	0.01^{NS}
Error	76	0.082723	0.001088	
Total	119	4.075892		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.78: Effect of oat and linseed supplementation on pH of loin nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	5.89	5.89	5.92	6.27	6.09	6.01A
Y2	5.84	5.84	5.87	6.22	6.04	5.96A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.79: Effect of oat and linseed supplementation on pH of loin nuggets during storage

Storage Days	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	5.67m	5.75l	5.80k	6.11d	5.89ij	5.84D
10	5.79k	5.87j	5.91hij	6.22b	6.00f	5.96C
20	5.96g	5.91hi	5.93ghi	6.32a	6.16c	6.05B
30	6.05e	5.94gh	5.96g	6.34a	6.20b	6.10A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.80: Effect of oat and linseed supplementation on pH of loin nuggets

Years/	Treatment					Years x S
Storage	T0	T1	T2	T3	T4	Mean
Y1 0	5.70	5.78	5.82	6.13	5.92	5.87
10	5.82	5.90	5.93	6.24	6.03	5.98
20	5.98	5.94	5.95	6.34	6.18	6.08
30	6.07	5.96	5.98	6.37	6.22	6.12
Y2 0	5.65	5.73	5.77	6.08	5.87	5.82
10	5.77	5.85	5.88	6.19	5.98	5.93
20	5.93	5.89	5.90	6.29	6.13	6.03
30	6.02	5.91	5.93	6.32	6.18	6.07
Mean	5.87D	5.88D	5.90C	6.25A	6.06B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The results of present study are in agreement with Yadav and Sanyal (1996) and Devendra and Tanwar (2011) who also observed increase in pH with the storage of nuggets. As storage period extends breakdown of protein increases that results in pH increase in the nuggets.

4.4.12 pH of hind leg nuggets

pH is an important factor in the determination of the shelf life and storage stability of the meat. The statistical results regarding analysis of variance for pH of hind leg nuggets of the rabbits fed on oat and linseed are given in Table 4.81. It is evident from the results that experimental years have non-significant effect on pH of hind leg nuggets. pH of hind leg nuggets varied significantly during storage. The data explicated in Table 4.81 indicates that pH of hind leg nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant effect while storage x treatment showed significant effect on pH of hind leg nuggets.

The data regarding mean values for pH of hind leg nuggets is explicated in Tables 4.82, 4.83 and 4.84. It is evident from results presented in Table 4.82 that variation in pH values during the experimental years was non-significant; the average pH values of hind leg nuggets during 2012 was 5.96 while during 2013 it was observed to be 5.91. The pH values of hind leg nuggets during storage varied significantly as presented in Table 4.83. The pH values of hind leg nuggets during storage varied significantly from 5.79 to 6.05 during different storage period. The highest pH value (6.05) was observed at 30th day of storage period while during 0day of storage period hind leg nuggets showed lowest pH value (5.79). It is evident from the results that the nuggets prepared from hind leg meat of rabbits fed on oat and linseed increase pH values with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on pH of hind leg nuggets are presented in Table 4.84. The pH of hind leg nuggets as a function of different treatments varied significantly from 5.81 to 6.17 during the course of storage period. The highest pH value (6.17) was observed in hind leg nuggets of rabbit’s meat fed on 7% linseed (T3) while lowest pH value (5.81) was noted in hind leg nuggets of rabbit’s meat fed on control feed (T0). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on pH of hind leg nuggets. It is evident from results that linseed and oat supplementation in feed significantly increase the pH values of the nuggets. The results of present study are in agreement with Yadav and Sanyal (1996) and Devendra and Tanwar (2011) who also observed increase in pH with the storage of nuggets. As storage period extends breakdown of protein increases that results in pH increase in the nuggets.

4.4.13 TBA of loin nuggets

TBA values represent the content of secondary lipid oxidation products, such as aldehydes, carbonyls, and hydrocarbons, which are considered to be responsible for the off flavors in meat (St. Angelo, 1996). The statistical results regarding analysis of variance for TBA of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.85. It is evident from the results that experimental years have non-significant effect on TBA of loin nuggets. TBA of loin nuggets varied significantly during storage. The data explicated in Table 4.85 indicates that TBA of loin nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on TBA of loin nuggets.

The data regarding mean values for TBA of loin nuggets is explicated in Tables 4.86, 4.87 and 4.88. It is evident from results presented in Table 4.86 that variation in TBA values during the experimental years was non-significant; the average TBA values of loin nuggets during 2012 was 0.63mgMD/kg while during 2013 it was observed to be 0.62mgMD/kg. The TBA values of loin nuggets during storage varied significantly as presented in Table 4.87. The TBA values of loin nuggets during storage varied significantly from 0.56 to 0.71mgMD/kg during different storage period. The highest TBA value (0.71mgMD/kg) was observed at 30th day of storage period while during 0day of storage period loin nuggets showed lowest TBA value (0.56mgMD/kg). It is evident from the results that the nuggets prepared from loin meat of rabbits fed on oat and linseed increase TBA values with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on TBA of loin nuggets are presented in Table 4.88. The TBA of loin nuggets as a function of different treatments varied significantly from 0.57 to 0.71mgMD/kg during the course of storage period. The highest TBA value (0.71mgMD/kg) was observed in the loin nuggets of rabbit’s meat fed on 7% linseed (T3) while lowest TBA

Table 4.81: Analysis of variance for pH of hind leg nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.005000	0.005000	1.31^{NS}
Error 1	4	0.024047	0.006012	
Storage	3	1.134547	0.378182	273.85**
Treat	4	2.770947	0.692737	501.63**
Year x Storage	3	0.000000	0.000000	0.00^{NS}
Year x Treat	4	0.000000	0.000000	0.00^{NS}
Storage x Treat	12	0.151853	0.012654	9.16**
Year x Storage x Treat	12	0.000000	0.000000	0.00^{NS}
Error	76	0.104953	0.001381	
Total	119	4.261347		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.82: Effect of oat and linseed supplementation on pH of hind leg nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	5.84	5.84	5.85	6.20	6.09	5.96
Y2	5.79	5.79	5.80	6.15	6.04	5.91

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.83: Effect of oat and linseed supplementation on pH of hind leg nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	5.62k	5.70j	5.72j	6.00e	5.93f	5.79D
10	5.74j	5.82i	5.83i	6.11d	6.04e	5.91C
20	5.91fg	5.86hi	5.85hi	6.27b	6.13cd	6.00B
30	6.00e	5.88fgh	5.88gh	6.32a	6.16c	6.05A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.84: Effect of oat and linseed supplementation on pH of hind leg nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	5.65	5.72	5.74	6.03	5.95	5.82
10	5.77	5.84	5.86	6.14	6.06	5.93
20	5.93	5.88	5.88	6.29	6.16	6.03
30	6.02	5.91	5.90	6.34	6.18	6.07
Y2 0	5.60	5.67	5.69	5.98	5.90	5.77
10	5.72	5.79	5.81	6.09	6.01	5.88
20	5.88	5.83	5.83	6.24	6.11	5.98
30	5.97	5.86	5.85	6.29	6.13	6.02
Mean	5.81C	5.83C	5.82C	6.17A	6.06B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

value (0.57mgMD/kg) was noted in loin nuggets of rabbit's meat fed on 4% oat (T1). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on TBA of loin nuggets.

It is evident from results that linseed and oat supplementation in feed significantly affect the TBA values of the nuggets. This result is in agreement to that reported by Cave and Burrows (1993), who found lower lipid oxidation in broiler thighs when fed a diet containing oats. Some other factors may also be involved in the antioxidant effect of dietary oat, such as differences in the concentration of pro-oxidants (e.g., transition metals) or some specific fatty acids. Rossanderhulthen *et al.* (1990) showed that oat bran markedly inhibited the absorption of non-haem iron due to the high phytate content of oat products. The TBA values for the control as well as the functional rabbit nuggets significantly increased with the storage period. This could be due to increased lipid oxidation and production of volatile metabolites in the presence of oxygen during aerobic storage. Other workers also reported a progressive increase in lipid oxidation during storage period (Kumar and Sharma, 2003; Modi *et al.*, 2003). Similarly, Brannan (2008) reported an increase in the TBARS values of chicken meat during refrigerated storage. The TBA did not exceed the maximum limit (0.9mgMD/kg) recommended by ES (2005) at 30 days storage in all the nuggets.

4.4.14 TBA of hind leg nuggets

The statistical results regarding analysis of variance for TBA of hind leg nuggets of the rabbits fed on oat and linseed are given in Table 4.89. It is evident from the results that experimental years have non-significant effect on TBA of hind leg nuggets. TBA of hind leg nuggets varied significantly during storage. The data explicated in Table 4.89 indicates that TBA of hind leg nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on TBA of hind leg nuggets.

The data regarding mean values for TBA of hind leg nuggets is explicated in Tables 4.90, 4.91 and 4.92. It is evident from results presented in Table 4.90 that variation in TBA values during the experimental years was non-significant; the average TBA values of hind leg nuggets during 2012 was 0.67mgMD/kg while during 2013 it was observed to be 0.66mgMD/kg.

Table 4.85: Analysis of variance for TBA of loin nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.000735	0.000735	0.853 NS
Error 1	4	0.00461	0.001153	
Storage	3	1.128029	0.37601	345.45**
Treat	4	2.637047	0.659262	605.68**
Year x Storage	3	0.000022	0.000007	0.01 NS
Year x Treat	4	0.000030	0.000008	0.01 NS
Storage x Treat	12	0.021833	0.001819	1.14 NS
Year x Storage x Treat	12	0.00009	0.000007	0.01 NS
Error	76	0.082723	0.001088	
Total	119	4.075892		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.86: Effect of oat and linseed supplementation on TBA (mgMD/kg) of loin nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	0.63	0.57	0.60	0.71	0.64	0.63
Y2	0.62	0.57	0.60	0.71	0.64	0.62

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.87: Effect of oat and linseed supplementation on TBA (mgMD/kg) of loin nuggets during different years

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	0.54	0.52	0.55	0.61	0.58	0.56D
10	0.60	0.54	0.57	0.66	0.60	0.60C
20	0.65	0.58	0.63	0.72	0.65	0.65B
30	0.72	0.62	0.66	0.83	0.73	0.71A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.88: Effect of oat and linseed supplementation on TBA (mgMD/kg) of loin nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	0.54	0.52	0.55	0.61	0.58	0.56
10	0.60	0.54	0.57	0.66	0.60	0.60
20	0.65	0.58	0.63	0.72	0.65	0.65
30	0.72	0.62	0.66	0.83	0.73	0.71
Y2 0	0.54	0.52	0.55	0.61	0.58	0.56
10	0.60	0.54	0.57	0.66	0.60	0.60
20	0.65	0.58	0.63	0.72	0.65	0.65
30	0.72	0.62	0.66	0.83	0.73	0.71
Mean	0.63B	0.57D	0.60C	0.71A	0.64B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The TBA values of hind leg nuggets during storage varied significantly as presented in Table 4.91. The TBA values of hind leg nuggets during storage varied significantly from 0.60 to 0.75mgMD/kg during different storage period. The highest TBA value (0.75mgMD/kg) was observed at 30th day of storage period while during 0day of storage period hind leg nuggets showed lowest TBA value (0.60mgMD/kg).

It is obvious from the results that the nuggets prepared from hind leg meat of rabbits fed on oat and linseed increase TBA values with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on TBA of hind leg nuggets are presented in Table 4.92. The TBA of hind leg nuggets as a function of different treatments varied significantly from 0.61 to 0.75mgMD/kg during the course of storage period. The highest TBA value (0.75mgMD/kg) was observed in hind leg nuggets of rabbit's meat fed on 7% linseed (T3) while lowest TBA value (0.61) was noted in hind leg nuggets of rabbit's meat fed on 4% oat (T1). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on TBA of hind leg nuggets.

It is evident from results that linseed and oat supplementation in feed significantly affect the TBA values of the nuggets. This result is in agreement to that reported by Cave and Burrows (1993), who found lower lipid oxidation in broiler thighs when fed a diet containing oats. Some other factors may also be involved in the antioxidant effect of dietary oat, such as differences in the concentration of pro-oxidants (e.g., transition metals) or some specific fatty acids. Rossanderhulthen *et al.* (1990) showed that oat bran markedly inhibited the absorption of non-haem iron due to the high phytate content of oat products. The TBA values for the control as well as the functional rabbit nuggets significantly increased with the storage period. This could be due to increased lipid oxidation and production of volatile metabolites in the presence of oxygen during aerobic storage. Other workers also reported a progressive increase in lipid oxidation during storage period (Kumar and Sharma, 2003; Modi *et al.*, 2003). Similarly, Brannan (2008) reported an increase in the TBARS values of chicken meat during refrigerated storage. The TBA did not exceed the maximum limit (0.9mgMD/kg) recommended by ES (2005) at 30 days storage in all the nuggets.

Table 4.89: Analysis of variance for TBA of hind leg nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.000750	0.000750	0.931^{NS}
Error 1	4	0.024047	0.006012	
Storage	3	1.134547	0.378182	273.85**
Treat	4	2.770947	0.692737	501.63**
Year x Storage	3	0.000000	0.000000	0.00 ^{NS}
Year x Treat	4	0.000000	0.000000	0.00 ^{NS}
Storage x Treat	12	0.021853	0.001821	1.16 ^{NS}
Year x Storage x Treat	12	0.000000	0.000000	0.00 ^{NS}
Error	76	0.104953	0.001381	
Total	119	4.261347		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.90: Effect of oat and linseed supplementation on TBA (mgMD/kg) of hind leg nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	0.67	0.61	0.64	0.75	0.68	0.67
Y2	0.67	0.61	0.64	0.75	0.68	0.66

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.91: Effect of oat and linseed supplementation on TBA (mgMD/kg) of hind leg nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	0.59	0.56	0.59	0.65	0.62	0.60
10	0.64	0.58	0.61	0.70	0.64	0.64
20	0.69	0.62	0.67	0.76	0.69	0.69
30	0.76	0.66	0.70	0.87	0.77	0.75

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.92: Effect of oat and linseed supplementation on TBA (mgMD/kg) of hind leg nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	0.59	0.56	0.59	0.65	0.62	0.60
10	0.64	0.58	0.61	0.70	0.64	0.64
20	0.69	0.62	0.67	0.76	0.69	0.69
30	0.76	0.66	0.70	0.87	0.77	0.75
Y2 0	0.59	0.56	0.59	0.65	0.62	0.60
10	0.64	0.58	0.61	0.70	0.64	0.64
20	0.69	0.62	0.67	0.76	0.69	0.69
30	0.76	0.66	0.70	0.87	0.77	0.75
Mean	0.67	0.61	0.64	0.75	0.68	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

4.4.15 POV of loin nuggets

Hydroperoxides are the primary products of lipid oxidation (Sun *et al.*, 2011). The statistical results regarding analysis of variance for POV of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.93. It is evident from the results that experimental years have non-significant effect on POV of loin nuggets. POV of loin nuggets varied significantly during storage. The data explicated in Table 4.93 indicates that POV of the loin nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on POV of loin nuggets.

The data regarding mean values for POV of loin nuggets is explicated in Tables 4.94, 4.95 and 4.96. It is evident from results presented in Table 4.94 that variation in POV values during the experimental years was non-significant; the average POV values of loin nuggets during 2012 was 8.05mEq/kg while during 2013 it was observed to be 8.06mEq/kg. The POV values of loin nuggets during storage varied significantly as presented in Table 4.95. The POV values of loin nuggets during storage varied significantly from 6.70 to 9.54mEq/kg during different storage period. The highest POV value (09.54mEq/kg) was observed at 30th day of storage period while during 0day of storage period loin nuggets showed lowest POV value (6.70mEq/kg). It is evident from the results that the nuggets prepared from loin meat of rabbits fed on oat and linseed increase POV values with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on POV of loin nuggets are presented in Table 4.96. The POV of loin nuggets as a function of different treatments varied significantly from 7.31 to 9.09mEq/kg during the course of storage period. The highest POV value (9.09mEq/kg) was observed in loin nuggets of rabbit's meat fed on 7% linseed (T3) while lowest POV value (7.31mEq/kg) was noted in loin nuggets of rabbit's meat fed on 4% oat (T1). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on POV of loin nuggets. It is evident from results that linseed and oat supplementation in feed significantly affect the POV values of the nuggets. It was noticed that after one month of storage the peroxide value of the nuggets did not exceed the maximum limit recommended by Codex Standard (1999) (max. 12.5mEq/kg).

Table 4.93: Analysis of variance for POV of loin nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.00533	0.00533	0.26^{NS}
Error 1	4	0.26041	0.06510	
Storage	3	0.54636	0.18212	7.89**
Treat	4	17.00837	4.25209	184.12**
Year x Storage	3	0.02500	0.00833	0.36 ^{NS}
Year x Treat	4	0.03333	0.00833	0.36 ^{NS}
Storage x Treat	12	0.41067	0.03422	1.70 ^{NS}
Year x Storage x Treat	12	0.10000	0.00833	0.36 ^{NS}
Error	76	1.75519	0.02309	
Total	119	22.36467		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.94: Effect of oat and linseed supplementation on POV (mEq/kg) of loin nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	8.10	7.31	7.57	9.09	8.16	8.05
Y2	8.10	7.32	7.57	9.09	8.16	8.06

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.95: Effect of oat and linseed supplementation on POV (mEq/kg) of loin nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	6.77	6.45	6.53	6.93	6.84	6.70D
10	7.77	7.04	7.33	8.06	7.79	7.60C
20	8.24	7.69	7.95	9.58	8.29	8.35B
30	9.62	8.08	8.45	11.80	9.73	9.54A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.96: Effect of oat and linseed supplementation on POV (mEq/kg) of loin nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	6.77	6.45	6.53	6.93	6.84	6.70
10	7.77	7.04	7.33	8.06	7.79	7.60
20	8.24	7.69	7.95	9.58	8.29	8.35
30	9.62	8.08	8.45	11.80	9.73	9.54
Y2 0	6.77	6.45	6.53	6.93	6.84	6.70
10	7.77	7.04	7.33	8.06	7.79	7.60
20	8.24	7.69	7.95	9.58	8.29	8.35
30	9.62	8.08	8.45	11.80	9.73	9.54
Mean	8.10C	7.31E	7.57D	9.09A	8.16B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The increased POVs of the samples indicated that the samples were in the propagation stage of lipid oxidation and that the formed hydroperoxide decomposed at a lower rate. The values obtained in this study are consistent with those obtained by Conchillo *et al.* (2005), who observed that POVs reached 38 to 40mEq/kg in frozen samples stored for 3 months. The acceptable limit for human consumption is 10mEq/kg with reference to the European Pharmacopoeia and Norwegian Medicinal Standard (Cagdas and Kumcuoglu, 2014). Thus, POVs for all treatments were in the acceptable range at the end of storage.

4.4.16 POV of hind leg nuggets

The statistical results regarding analysis of variance for POV of hind leg nuggets of the rabbits fed on oat and linseed are given in Table 4.97. It is evident from the results that experimental years have non-significant effect on POV of hind leg nuggets. POV of hind leg nuggets varied significantly during storage. The data explicated in Table 4.97 indicates that POV of hind leg nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on POV of hind leg nuggets.

The data regarding mean values for POV of hind leg nuggets is explicated in Tables 4.98, 4.99 and 4.100. It is evident from results presented in Table 4.98 that variation in POV values during the experimental years was non-significant; the average POV values of hind leg nuggets during 2012 was 8.03mEq/kg while during 2013 it was observed to be 8.02mEq/kg. The POV values of hind leg nuggets during storage varied significantly as presented in Table 4.99. The POV values of hind leg nuggets during storage varied significantly from 6.74 to 9.57mEq/kg during different storage period. The highest POV value (9.57mEq/kg) was observed at 30th day of storage period while during 0day of storage period hind leg nuggets showed lowest POV value (6.74mEq/kg). It is evident from the results that the nuggets prepared from hind leg meat of rabbits fed on oat and linseed increase POV values with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on POV of hind leg nuggets are presented in Table 4.100. The POV of hind leg nuggets as a function of different treatments varied significantly from 7.35 to 8.87mEq/kg during the course of storage period. The highest POV value (8.87mEq/kg) was observed in hind leg nuggets of rabbit’s meat fed on 7% linseed (T3) while lowest POV value (7.35mEq/kg) was noted in hind leg nuggets of rabbit's meat fed on 4% oat (T1). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on POV of hind leg nuggets.

It is evident from results that linseed and oat supplementation in feed significantly affect the POV values of the nuggets. It was noticed that after one month of storage the peroxide value of the nuggets did not exceed the maximum limit recommended by Codex Standard (1999) (max. 12.5mEq/kg). The increased POVs of the samples indicated that the samples were in the propagation stage of lipid oxidation and that the formed hydroperoxide decomposed at a lower rate. The values obtained in this study are consistent with those obtained by Conchillo *et al.* (2005), who observed that POVs reached 38 to 40mEq/kg in frozen samples stored for 3 months. The acceptable limit for human consumption is 10mEq/kg with reference to the European Pharmacopoeia and Norwegian Medicinal Standard. Thus, POVs for all treatments were in the acceptable range at the end of storage.

4.5 Sensory evaluation of nuggets

Sensory evaluation of food has been defined as a scientific method used to evoke, measure, analyze and interpret responses to products as perceived through the senses of sight, touch, smell, taste, and hearing (Sohaib *et al.*, 2012)

4.5.1 Colour of loin nuggets

The statistical results regarding analysis of variance for colour of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.101. It is evident from the results that experimental years have non-significant effect on colour of loin nuggets. colour of loin nuggets varied significantly during storage. The data explicated in Table 4.101 indicates that colour of loin nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant while storage x treatment showed significant effect on colour of loin nuggets.

The data regarding mean score for colour of loin nuggets is explicated in Tables 4.102, 4.103 and 4.104. It is evident from results presented in Table 4.102 that variation in colour score during the experimental years was non-significant; the average colour score of loin nuggets during 2012 was 6.0 while during 2013 it was observed to be 5.8. The colour score of loin nuggets during storage varied significantly as presented in Table 4.103.

Table 4.97: Analysis of variance for POV of hind leg nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.00533	0.00533	3.36^{NS}
Error 1	4	0.26041	0.06510	
Storage	3	0.54636	0.18212	7.89**
Treat	4	17.00837	4.25209	184.12**
Year x Storage	3	0.025	0.00833	0.36 ^{NS}
Year x Treat	4	0.03333	0.00833	0.36 ^{NS}
Storage x Treat	12	0.41067	0.03422	1.70 ^{NS}
Year x Storage x Treat	12	0.1	0.00833	0.36 ^{NS}
Error	76	1.75519	0.02309	
Total	119	22.36467		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.98: Effect of oat and linseed supplementation on POV (mEq/kg) of hind leg nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	8.14	7.35	7.61	8.87	8.20	8.03
Y2	8.14	7.35	7.60	8.87	8.20	8.02

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.99: Effect of oat and linseed supplementation on POV (mEq/kg) of hind leg nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	6.81	6.49	6.57	6.97	6.88	6.74D
10	7.81	7.07	7.36	8.10	7.83	7.64C
20	8.28	7.73	7.99	8.62	8.33	8.19B
30	9.66	8.12	8.49	11.80	9.77	9.57A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.100: Effect of oat and linseed supplementation on POV (mEq/kg) of hind leg nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	6.81	6.49	6.57	6.97	6.88	6.74
10	7.81	7.07	7.36	8.10	7.83	7.64
20	8.28	7.73	7.99	8.62	8.33	8.19
30	9.66	8.12	8.49	11.80	9.77	9.57
Y2 0	6.81	6.49	6.57	6.97	6.88	6.74
10	7.81	7.07	7.36	8.10	7.83	7.64
20	8.28	7.73	7.99	8.62	8.33	8.19
30	9.66	8.12	8.49	11.80	9.77	9.57
Mean	8.14C	7.35E	7.61D	8.87A	8.20B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The colour score of loin nuggets during storage varied significantly from 5.5 to 6.0 during different storage period. The highest colour score (6.0) was observed at 30th day of storage period while during 0day of storage period loin nuggets showed lowest colour score (5.5). It is evident from the results that the nuggets prepared from loin meat of rabbits fed on oat and linseed increase colour score with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on colour of loin nuggets are presented in Table 4.104. The colour of loin nuggets as a function of different treatments varied significantly from 4.9 to 7.1 during the course of storage period. The highest colour score (7.1) was observed in loin nuggets of rabbit's meat fed on 7% linseed (T3) while lowest colour score (4.9) was noted in loin nuggets of rabbit's meat fed on 2% oat (T2). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on colour of loin nuggets.

It is evident from results that linseed and oat supplementation in feed significantly affect the colour score of the nuggets. Colour score decreased due to oxidation of the lipids that retarded the shining of nuggets (Sohaib *et al.,* 2013). The lower colour scores for T1 were due to dark brownish colour of the oats, which significantly deteriorated the consumer acceptance. The colour scores with linseed flour were better because linseed had lighter appearance than product with oats (Jeun-Hornga *et al.*, 2002).

4.5.2 Colour of hind leg nuggets

The statistical results regarding analysis of variance for colour of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.105. It is evident from the results that experimental years have non-significant effect on colour of hind leg nuggets. colour of hind leg nuggets varied significantly during storage. The data explicated in Table 4.105 indicates that colour of hind leg nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant while storage x treatment showed significant effect on colour of hind leg nuggets.

The data regarding mean score for colour of hind leg nuggets is explicated in Tables 4.106, 4.107 and 4.108. It is evident from results presented in Table 4.106 that variation in colour score during the experimental years was non-significant; the average colour score of hind leg

Table 4.101: Analysis of variance for colour of lion nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.0700	0.0700	1.43^{NS}
Error 1	4	0.1537	0.0384	
Storage	3	1.8520	0.6173	8.79**
Treat	4	70.2953	17.5738	250.13**
Year x Storage	3	0.0000	0.0000	0.00^{NS}
Year x Treat	4	0.0000	0.0000	0.00^{NS}
Storage x Treat	12	16.2780	1.3565	19.31**
Year x Storage x Treat	12	0.0000	0.0000	0.00^{NS}
Error	76	5.3397	0.0703	
Total	119	96.5187		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.102: Effect of oat and linseed supplementation on colour of loin nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	5.9	5.3	5.1	7.2	6.3	6.0
Y2	5.6	5.0	4.8	6.9	6.0	5.8

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.103: Effect of oat and linseed supplementation on colour of loin nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	6.0de	5.3h	3.8k	6.9b	6.2c	5.5B
10	5.8ef	5.0i	4.5j	7.0b	6.2c	5.6B
20	5.6fg	4.8i	5.7f	7.1ab	6.1cd	5.9A
30	5.4gh	5.6fg	5.6fg	7.3a	6.0de	6.0A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.104: Effect of oat and linseed supplementation on colour of loin nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	6.2	5.5	4.1	7.1	6.5	5.8
10	6.0	5.2	4.6	7.2	6.4	5.8
20	5.8	5.0	5.9	7.3	6.3	6.0
30	5.6	5.8	5.8	7.5	6.2	6.1
Y2 0	5.9	5.2	3.8	6.8	6.2	5.5
10	5.7	4.9	4.3	6.9	6.1	5.5
20	5.5	4.7	5.6	7.0	6.0	5.7
30	5.3	5.5	5.5	7.2	5.9	5.8
Mean	5.7C	5.2D	4.9E	7.1A	6.2B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

nuggets during 2012 was 6.4 while during 2013 it was observed to be 6.2. The colour score of hind leg nuggets during storage varied significantly as presented in Table 4.107. The colour score of hind leg nuggets during storage varied significantly from 6.0 to 6.6 during different storage period. The highest colour score (6.6) was observed at 30th day of storage period while during 0day of storage period hind leg nuggets showed lowest colour score (6.0). It is evident from the results that the nuggets prepared from hind leg meat of rabbits fed on oat and linseed increase colour score with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on colour of hind leg nuggets are presented in Table 4.108. The colour of hind leg nuggets as a function of different treatments varied significantly from 5.3 to 7.5 during the course of storage period. The highest colour score (7.5) was observed in hind leg nuggets of rabbit's meat fed on 7% linseed (T3) while lowest colour score (5.3) was noted in hind leg nuggets of rabbit's meat fed on 2% oat (T2). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on colour of hind leg nuggets.

It is evident from results that linseed and oat supplementation in feed significantly affect the colour score of the nuggets. Colour score decreased due to oxidation of the lipids that retarded the shining of nuggets (Sohaib *et al.*, 2013). The lower colour scores for T1 were due to dark brownish colour of the oats, which significantly deteriorated the consumer acceptance. The colour scores with linseed flour were better because linseed had lighter appearance than product with oats (Jeun-Hornga *et al.*, 2002).

4.5.3 Appearance of loin nugget

The statistical results regarding analysis of variance for appearance of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.109. It is evident from the results that experimental years have non-significant effect on appearance of loin nuggets. Appearance of loin nuggets varied significantly during storage. The data explicated in Table 4.109 indicates that appearance of loin nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant while storage x treatment showed significant effect on appearance of loin nuggets.

Table 4.105: Analysis of variance for colour of hind leg nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.0643	0.0643	1.25 NS
Error 1	4	0.1987	0.0496	
Storage	3	1.8520	0.6173	9.43**
Treat	4	70.2953	17.5738	268.48**
Year x Storage	3	0.0000	0.0000	0.00NS
Year x Treat	4	0.0000	0.0000	0.00NS
Storage x Treat	12	16.2780	1.3565	20.72**
Year x Storage x Treat	12	0.0000	0.0000	0.00NS
Error	76	4.9747	0.0655	
Total	119	96.1987		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.106: Effect of oat and linseed supplementation on colour of hind leg nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	6.3	5.7	5.5	7.6	6.7	6.4
Y2	6.0	5.4	5.2	7.3	6.4	6.2

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.107: Effect of oat and linseed supplementation on colour of hind leg nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	6.4de	5.7h	4.3k	7.3b	6.6c	6.0B
10	6.2ef	5.4i	4.9j	7.4b	6.6cd	6.1B
20	6.0fg	5.2i	6.1f	7.5ab	6.7cd	6.5A
30	5.8gh	6.0fg	6.1fg	7.7a	6.5de	6.6A

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.108: Effect of oat and linseed supplementation on colour of hind leg nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	**T1**	**T2**	**T3**	**T4**	
Y1 0	6.6	5.9	4.5	7.5	6.9	6.2
10	6.4	5.6	5.0	7.6	6.8	6.2
20	6.2	5.4	6.3	7.7	6.7	6.4
30	6.0	6.2	6.2	7.9	6.6	6.5
Y2 0	6.3	5.6	4.2	7.2	6.6	5.9
10	6.1	5.3	4.7	7.3	6.5	5.9
20	5.9	5.1	6.0	7.4	6.4	6.1
30	5.7	5.9	5.9	7.6	6.3	6.2
Mean	6.1C	5.6D	5.3E	7.5A	6.6B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The data regarding mean score for appearance of loin nuggets is explicated in Tables 4.110, 4.111 and 4.112. It is evident from results presented in Table 4.110 that variation in appearance score during the experimental years was non-significant; the average appearance score of loin nuggets during 2012 was 6.7 while during 2013 it was observed to be 6.5. The appearance score of loin nuggets during storage varied significantly as presented in Table 4.111. The appearance score of loin nuggets during storage varied significantly from 6.2 to 7.1 during different storage period. The highest appearance score (7.1) was observed at 0day of storage period while during 30th day of storage period loin nuggets showed lowest appearance score (6.2). It is evident from the results that the nuggets prepared from loin meat of rabbits fed on oat and linseed decrease appearance score with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on appearance of loin nuggets are presented in Table 4.112. The appearance of loin nuggets as a function of different treatments varied significantly from 6.3 to 6.9 during the course of storage period. The highest appearance score (6.9) was observed in loin nuggets of rabbit's meat fed on 7% linseed (T3) while lowest appearance score (6.3) was noted in loin nuggets of rabbit's meat fed on 2% oat (T2). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on appearance of loin nuggets. It is evident from results that linseed and oat supplementation in feed significantly affect the appearance score of the nuggets. The results are in correlation with Sohaib *et al.* (2013) who reported that the appearance of the nuggets and patties decreases with passage of the time.

4.5.4 Appearance of hind leg nuggets

The statistical results regarding analysis of variance for appearance of hind leg nuggets of the rabbits fed on oat and linseed are given in Table 4.113. It is evident from the results that experimental years have non-significant effect on appearance of hind leg nuggets. Appearance of hind leg nuggets varied significantly during storage. The data explicated in Table 4.113 indicates that appearance of hind leg nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant while storage x treatment showed significant effect on appearance of hind leg nuggets.

Table 4.109: Analysis of variance for appearance of lion nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.02000	0.02000	2.70 NS
Error 1	4	0.34517	0.08629	
Storage	3	13.70867	4.56956	204.51**
Treat	4	9.50833	2.37708	106.38**
Year x Storage	3	0.00000	0.00000	0.00NS
Year x Treat	4	0.00000	0.00000	0.00NS
Storage x Treat	12	1.67633	0.13969	6.25**
Year x Storage x Treat	12	0.00000	0.00000	0.00NS
Error	76	1.69817	0.02234	
Total	119	28.13667		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.110: Effect of oat and linseed supplementation on appearance of loin nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	7.0	6.4	6.4	7.0	6.8	6.7
Y2	6.8	6.2	6.2	6.8	6.6	6.5

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.111: Effect of oat and linseed supplementation on appearance of loin nuggets storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	7.4a	6.7c	6.7c	7.5a	7.2b	7.1A
10	7.2b	6.4d	6.4de	7.1b	6.8c	6.8B
20	6.8c	6.2fg	6.0g	6.7c	6.6c	6.5C
30	6.3def	5.8h	6.3def	6.4de	6.2efg	6.2D

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.112: Effect of oat and linseed supplementation on appearance of loin nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	7.5	6.8	6.8	7.6	7.3	7.2
10	7.3	6.5	6.5	7.2	6.9	6.9
20	6.9	6.3	6.1	6.8	6.7	6.6
30	6.4	5.9	6.4	6.5	6.3	6.3
Y2 0	7.3	6.6	6.6	7.4	7.1	7.0
10	7.1	6.3	6.3	7.0	6.7	6.7
20	6.7	6.1	5.9	6.6	6.5	6.4
30	6.2	5.7	6.2	6.3	6.1	6.1
Mean	6.8A	6.4C	6.3C	6.9A	6.7B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The data regarding mean score for appearance of hind leg nuggets is explicated in Tables 4.114, 4.115 and 4.116. It is evident from results presented in Table 4.114 that variation in appearance score during the experimental years was non-significant; the average appearance score of hind leg nuggets during 2012 was 6.3 while during 2013 it was observed to be 6.1.The appearance score of hind leg nuggets during storage varied significantly as presented in Table 4.115. The appearance score of hind leg nuggets during the storage varied significantly from 6.1 to 6.7 during different storage period. The highest appearance score (6.7) was observed at 0day of storage period while during 30th day of storage period hind leg nuggets showed lowest appearance score (5.8). It is evident from the results that the nuggets prepared from hind leg meat of rabbits fed on oat and linseed decrease appearance score with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on appearance of hind leg nuggets are presented in Table 4.116. The appearance of hind leg nuggets as a function of different treatments varied significantly from 5.8 to 6.6 during the course of storage period. The highest appearance score (6.6) was observed in hind leg nuggets of rabbit's meat fed on 7% linseed (T3) while lowest appearance score (5.8) was noted in hind leg nuggets of rabbit's meat fed on 2% oat (T2). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on appearance of hind leg nuggets. It is evident from results that linseed and oat supplementation in feed significantly affect the appearance score of the nuggets. The results are in correlation with Sohaib *et al.* (2013) who reported that the appearance of the nuggets and patties decreases with passage of the time.

4.5.5 Taste of loin nuggets

The statistical results regarding analysis of variance for taste of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.117. It is evident from the results that experimental years have non-significant effect on taste of loin nuggets. Taste of loin nuggets varied significantly during storage. The data explicated in Table 4.117 indicates that taste of loin nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant while storage x treatment showed significant effect on taste of loin nuggets.

The data regarding mean score for taste of loin nuggets is explicated in Tables 4.118, 4.119 and 4.120.

Table 4.113: Analysis of variance for Appearance of leg nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.02000	0.02000	2.70 NS
Error 1	4	0.35931	0.08983	
Storage	3	13.70867	4.56956	204.67**
Treat	4	9.50833	2.37708	106.47**
Year x Storage	3	0.00000	0.00000	0.00NS
Year x Treat	4	0.00000	0.00000	0.00NS
Storage x Treat	12	1.67633	0.13969	6.26**
Year x Storage x Treat	12	0.00000	0.00000	0.00NS
Error	76	1.69683	0.02233	
Total	119	28.14947		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.114: Effect of oat and linseed supplementation on appearance of hind leg nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	6.6	6.0	6.0	6.4	6.6	6.3
Y2	6.4	5.8	5.8	6.2	6.4	6.1

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.115: Effect of oat and linseed supplementation on appearance of hind leg nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	7.0a	6.3c	6.3c	7.1a	6.8b	6.7A
10	6.8b	6.0d	6.0de	6.7b	6.4c	6.4B
20	6.4c	5.8fg	5.6g	6.3c	6.2c	6.1C
30	5.9def	5.4h	5.9def	6.0de	5.8efg	5.8D

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.116: Effect of oat and linseed supplementation on appearance of hind leg n nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	**T1**	**T2**	**T3**	**T4**	
Y1 0	7.1	6.4	6.4	7.2	6.9	6.8
10	6.9	6.1	6.1	6.8	6.5	6.5
20	6.5	5.9	5.7	6.4	6.3	6.2
30	6.0	5.5	6.0	6.1	5.9	5.9
Y2 0	6.9	6.2	6.2	7.0	6.7	6.6
10	6.7	5.9	5.9	6.6	6.3	6.3
20	6.3	5.7	5.5	6.2	6.1	6.0
30	5.8	5.3	5.8	5.9	5.7	5.7
Mean	6.5A	5.9C	5.8C	6.6A	6.3B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

It is evident from results presented in Table 4.118 that variation in taste score during the experimental years was non-significant; the average taste score of loin nuggets during 2012 was 6.1 while during 2013 it was observed to be 6.0. The taste score of loin nuggets during storage varied significantly as presented in Table 4.119. The taste score of loin nuggets during storage varied significantly from 5.8 to 6.2 during different storage period. The highest taste score (6.2) was observed at 10th day of storage period while during 30th day of storage period loin nuggets showed lowest taste score (5.8). It is evident from the results that the nuggets prepared from loin meat of rabbits fed on oat and linseed affect taste score with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on taste of loin nuggets are presented in Table 4.120. The taste of loin nuggets as a function of different treatments varied significantly from 5.4 to 6.6 during the course of storage period. The highest taste score (6.6) was observed in loin nuggets of rabbit's meat fed on 7% linseed (T3) while lowest taste score (5.4) was noted in loin nuggets of rabbit's meat fed on control feed (T0). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on taste of loin nuggets.

It is evident from results that linseed and oat supplementation in feed significantly increase the taste score of the nuggets. The decrease in flavor value with the storage is due to the peroxidation of PUFA which results in off flavors and bad odours (Woods and Fearon, 2009). Our findings are in agreement with the results of Devendra and Tanwar (2011) and Biswas *et al.,* 2006). They observed highly significant effect of taste in nuggets with storage periods.

4.5.6 Taste of hind leg nuggets

The statistical results regarding analysis of variance for taste of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.121. It is evident from the results that experimental years have non-significant effect on taste of hind leg nuggets. Taste of hind leg nuggets varied significantly during storage. The data explicated in Table 4.121 indicates that taste of hind leg nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant while storage x treatment showed significant effect on taste of hind leg nuggets.

Table 4.117: Analysis of variance for taste of lion nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.05769	0.05769	2.87 NS
Error 1	4	0.33739	0.08435	
Storage	3	2.94206	0.98069	55.19**
Treat	4	20.38279	5.09570	286.77**
Year x Storage	3	0.00000	0.00000	0.00NS
Year x Treat	4	0.00000	0.00000	0.00NS
Storage x Treat	12	4.49471	0.37456	21.08**
Year x Storage x Treat	12	0.00000	0.00000	0.00NS
Error	76	1.35048	0.01777	
Total	119	39.67368		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.118: Effect of oat and linseed supplementation on taste of loin nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	5.3g	6.2cd	5.9e	6.7a	6.5b	6.1
Y2	5.5f	6.1d	5.9e	6.5b	6.2c	6.0

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.119: Effect of oat and linseed supplementation on taste of loin nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	5.7d	6.2c	6.2c	6.2c	6.1c	6.0B
10	5.3e	6.4b	6.1c	6.8a	6.6a	6.2A
20	5.3e	6.2c	5.8d	6.8a	6.4b	6.1B
30	5.1f	5.7d	5.4e	6.6a	6.2c	5.8C

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.120: Effect of oat and linseed supplementation on taste of loin nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	5.6	6.7	6.5	6.9	6.9	6.5
10	5.2	6.3	6.0	6.7	6.5	6.1
20	5.2	6.1	5.7	6.7	6.3	6.0
30	5.0	5.6	5.3	6.5	6.1	5.7
Y2 0	5.8	5.7	5.9	5.4	5.3	5.6
10	5.4	6.5	6.2	6.9	6.7	6.3
20	5.4	6.3	5.9	6.9	6.5	6.2
30	5.2	5.8	5.5	6.7	6.3	5.9
Mean	5.4E	6.1C	5.9D	6.6A	6.3B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The data regarding mean score for taste of hind leg nuggets is explicated in Tables 4.122, 4.123 and 4.124. It is evident from results presented in Table 4.122 that variation in taste score during the experimental years was non-significant; the average taste score of hind leg nuggets during 2012 was 5.8 while during 2013 it was observed to be 6.0. The taste score of hind leg nuggets during storage varied significantly as presented in Table 4.123. The taste score of hind leg nuggets during storage varied significantly from 5.6 to 6.4 during different storage period. The highest taste score (6.4) was observed at 0day of storage period while during 30th day of storage period hind leg nuggets showed lowest taste score (5.6). It is evident from the results that the nuggets prepared from hind leg meat of rabbits fed on oat and linseed affect taste score with the progression of storage period up to 30th day.

The results regarding impact of oat and linseed supplementation in feed on taste of hind leg nuggets are presented in Table 4.124. The taste of hind leg nuggets as a function of different treatments varied significantly from 5.1 to 6.5 during the course of storage period. The highest taste score (6.5) was observed in hind leg nuggets of rabbit's meat fed on 7% linseed (T3) while lowest taste score (5.1) was noted in hind leg nuggets of rabbit's meat fed on control feed (T0).The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on taste of hind leg nuggets. It is evident from results that linseed and oat supplementation in feed significantly increase the taste score of the nuggets. The decrease in flavor value with the storage is due to the peroxidation of PUFA which results in off flavors and bad odours (Woods and Fearon, 2009). 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.

4.5.7 Texture of loin nuggets

The statistical results regarding analysis of variance for texture of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.125. It is evident from the results that experimental years have non-significant effect on texture of loin nuggets. Texture of loin nuggets varied significantly during storage. The data explicated in Table 4.125 indicates that texture of loin nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant while storage x treatment showed significant effect on texture of loin nuggets.

Table 4.121: Analysis of variance for taste of hind leg nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.02000	0.02000	2.70 NS
Error 1	4	0.13911	0.03478	
Storage	3	10.18092	3.39364	765.27**
Treat	4	28.96383	7.24096	1632.85**
Year x Storage	3	0.00000	0.00000	0.00NS
Year x Treat	4	0.00000	0.00000	0.00NS
Storage x Treat	12	1.69283	0.14107	31.81**
Year x Storage x Treat	12	0.00000	0.00000	0.00NS
Error	76	0.33703	0.00443	
Total	119	42.51372		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.122: Effect of oat and linseed supplementation on taste of hind leg nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	5.0	5.6	5.9	6.4	6.2	5.8
Y2	5.2	5.8	6.1	6.6	6.4	6.0

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.123: Effect of oat and linseed supplementation on taste of hind leg nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	5.5g	6.3c	6.6b	6.7a	6.7a	6.4A
10	5.1h	5.8f	6.2d	6.5b	6.4c	6.0B
20	5.1h	5.5g	5.9e	6.5b	6.2d	5.8C
30	4.9i	5.2h	5.4g	6.4c	6.0e	5.6D

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.124: Effect of oat and linseed supplementation on taste of hind leg nuggets during different years

Years/ Storage	Treatment					Years x S Mean
	T0	**T1**	**T2**	**T3**	**T4**	
Y1 0	5.4	6.2	6.5	6.6	6.6	6.3
10	5.0	5.7	6.1	6.4	6.3	5.9
20	5.0	5.4	5.8	6.4	6.1	5.7
30	4.8	5.1	5.3	6.3	5.9	5.5
Y2 0	5.6	6.4	6.7	6.8	6.8	6.5
10	5.2	5.9	6.3	6.6	6.5	6.1
20	5.2	5.6	6.0	6.6	6.3	5.9
30	5.0	5.3	5.5	6.5	6.1	5.7
Mean	5.1E	5.7D	6.0C	6.5A	6.3B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The data regarding mean score for texture of loin nuggets is explicated in Tables 4.126, 4.127 and 4.128. It is evident from results presented in Table 4.126 that variation in texture score during the experimental years was non-significant; the average texture score of loin nuggets during 2012 was 6.0 while during 2013 it was observed to be 6.1. The texture score of loin nuggets during storage varied significantly as presented in Table 4.127. The texture score of loin nuggets during storage varied significantly from 5.7 to 6.3 during different storage period. The highest texture score (6.3) was observed at 0day of storage period while during 30th day of storage period loin nuggets showed lowest texture score (5.7). It is evident from the results that the nuggets prepared from loin meat of rabbits fed on oat and linseed affect texture score with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on texture of loin nuggets are presented in Table 4.128. The texture of loin nuggets as a function of different treatments varied significantly from 5.4 to 6.5 during the course of storage period. The highest texture score (6.5) was observed in loin nuggets of rabbit's meat fed on 7% linseed (T3) while lowest texture score (5.4) was noted in loin nuggets of rabbit's meat fed on control feed (T0). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on texture of loin nuggets.

It is obvious from results that linseed and oat supplementation in feed significantly increase the texture score of the nuggets. The increase in hardness may be associated with the decrease in water activity of the nuggets with the advancement of storage period. The results of present study are in close collaboration with (Sohaib *et al.,* 2012) who stated that the texture value varied significantly with the advancement of storage period.

4.5.8 Texture of hind leg nuggets

The statistical results regarding analysis of variance for texture of hind leg nuggets of the rabbits fed on oat and linseed are given in Table 4.129. It is evident from the results that experimental years have non-significant effect on texture of hind leg nuggets. Texture of hind leg nuggets varied significantly during storage. The data explicated in Table 4.129 indicates that texture of hind leg nuggets was significantly affected by supplementation of oat and linseed.

Table 4.125: Analysis of variance for texture of lion nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.03000	0.03000	2.96 NS
Error 1	4	0.13761	0.03440	
Storage	3	6.16733	2.05578	573.30**
Treat	4	13.28117	3.32029	925.94**
Year x Storage	3	0.00000	0.00000	0.00NS
Year x Treat	4	0.00000	0.00000	0.00NS
Storage x Treat	12	0.51683	0.04307	12.01**
Year x Storage x Treat	12	0.00000	0.00000	0.00NS
Error	76	0.27253	0.00359	
Total	119	20.67547		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.126: Effect of oat and linseed supplementation on texture of loin nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	5.4	6.0	6.0	6.4	6.1	6.0
Y2	5.5	6.1	6.1	6.5	6.2	6.1

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.127: Effect of oat and linseed supplementation on texture of loin nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	5.7ij	6.3d	6.2d	6.8a	6.5b	6.3A
10	5.6k	6.1f	6.1ef	6.7a	6.2de	6.2B
20	5.3l	5.9g	5.9g	6.4c	6.1f	5.9C
30	5.2m	5.8h	5.8hi	6.1f	5.7j	5.7D

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.128: Effect of oat and linseed supplementation on texture of loin nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	**T1**	**T2**	**T3**	**T4**	
Y1 0	5.7	6.2	6.2	6.7	6.5	6.3
10	5.6	6.1	6.1	6.6	6.2	6.1
20	5.2	5.9	5.9	6.3	6.0	5.9
30	5.1	5.8	5.8	6.0	5.7	5.7
Y2 0	5.8	6.3	6.3	6.8	6.6	6.4
10	5.7	6.2	6.2	6.7	6.3	6.2
20	5.3	6.0	6.0	6.4	6.1	6.0
30	5.2	5.9	5.9	6.1	5.8	5.8
Mean	5.4D	6.0C	6.0C	6.5A	6.1B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant while storage x treatment showed significant effect on texture of hind leg nuggets.

The data regarding mean score for texture of hind leg nuggets is explicated in Tables 4.130, 4.131 and 4.132. It is evident from results presented in Table 4.130 that variation in texture score during the experimental years was non-significant; the average texture score of hind leg nuggets during 2012 was 5.8 while during 2013 it was observed to be 5.9. The texture score of hind leg nuggets during storage varied significantly as presented in Table 4.131. The texture score of hind leg nuggets during storage varied significantly from 5.6 to 6.2 during different storage period. The highest texture score (6.2) was observed at 0day of storage period while during 30th day of storage period hind leg nuggets showed lowest texture score (5.6). It is obvious from the results that the nuggets prepared from hind leg meat of rabbits fed on oat and linseed affect texture score with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on texture of hind leg nuggets are presented in Table 4.132. The texture of hind leg nuggets as a function of different treatments varied significantly from 5.3 to 6.3 during the course of storage period. The highest texture score (6.3) was observed in hind leg nuggets of rabbit's meat fed on 7% linseed (T3) while lowest texture score (5.3) was noted in hind leg nuggets of rabbit's meat fed on control feed (T0). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on texture of hind leg nuggets.

It is evident from results that linseed and oat supplementation in feed significantly increase the texture score of the nuggets. The increase in hardness may be associated with the decrease in water activity of the nuggets with the advancement of storage period. The results of present study are in close collaboration with (Sohaib *et al.,* 2012) who stated that the texture value varied significantly with the advancement of storage period.

4.5.9 Overall acceptability of loin nuggets

The statistical results regarding analysis of variance for texture of loin nuggets of the rabbits fed on oat and linseed are given in Table 4.133. It is evident from the results that experimental years have non-significant effect on overall acceptability of loin nuggets.

Table 4.129: Analysis of variance for texture of hind leg nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.03000	0.03000	2.98 ^{NS}
Error 1	4	0.13345	0.03336	
Storage	3	6.16733	2.05578	582.36**
Treat	4	13.28117	3.32029	940.57**
Year x Storage	3	0.00000	0.00000	0.00 ^{NS}
Year x Treat	4	0.00000	0.00000	0.00 ^{NS}
Storage x Treat	12	0.51683	0.04307	12.20**
Year x Storage x Treat	12	0.00000	0.00000	0.00 ^{NS}
Error	76	0.26829	0.00353	
Total	119	20.66707		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.130: Effect of oat and linseed supplementation on texture of hind leg nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	5.8	5.2	5.8	5.9	6.3	5.8
Y2	5.9	5.3	5.9	6.0	6.4	5.9

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.131: Effect of oat and linseed supplementation on texture of hind leg nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	5.6ij	6.1d	6.1d	6.6a	6.4b	6.2A
10	5.5k	6.0f	6.0ef	6.5a	6.1de	6.0B
20	5.1l	5.8g	5.8g	6.2c	5.9f	5.8C
30	5.0m	5.7h	5.7hi	5.9f	5.6j	5.6D

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.132: Effect of oat and linseed supplementation on texture of hind leg nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	5.5	6.1	6.0	6.6	6.3	6.1
10	5.4	5.9	5.9	6.5	6.0	6.0
20	5.1	5.7	5.7	6.2	5.9	5.7
30	5.0	5.6	5.6	5.9	5.5	5.5
Y2 0	5.6	6.2	6.1	6.7	6.4	6.2
10	5.5	6.0	6.0	6.6	6.1	6.1
20	5.2	5.8	5.8	6.3	6.0	5.8
30	5.1	5.7	5.7	6.0	5.6	5.6
Mean	5.3D	5.9C	5.9C	6.3A	6.0B	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Overall acceptability of loin nuggets varied significantly during storage. The data explicated in Table 4.133 indicates that overall acceptability of loin nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant while storage x treatment showed significant effect on overall acceptability of loin nuggets.

The data regarding mean score for overall acceptability of loin nuggets is explicated in Tables 4.134, 4.135 and 4.136. It is evident from results presented in Table 4.134 that variation in overall acceptability score during the experimental years was non-significant; the average overall acceptability score of loin nuggets during 2012 was 6.8 while during 2013 it was observed to be 6.7. The overall acceptability score of loin nuggets during storage varied significantly as presented in Table 4.135. The texture score of loin nuggets during storage varied significantly from 6.5 to 7.0 during different storage period. The highest overall acceptability score (7.0) was observed at 0day of storage period while during 30th day of storage period loin nuggets showed lowest overall acceptability score (6.5). It is evident from the results that the nuggets prepared from loin meat of rabbits fed on oat and linseed decrease overall acceptability score with the progression of storage period up to 30th day. The results regarding impact of oat and linseed supplementation in feed on overall acceptability of loin nuggets are presented in Table 4.136. The overall acceptability of loin nuggets as a function of different treatments varied significantly from 6.1 to 7.2 during the course of storage period. The highest overall acceptability score (7.2) was observed in loin nuggets of rabbit's meat fed on 7% linseed (T3) while lowest overall acceptability score (6.1) was noted in loin nuggets of rabbit's meat fed on control feed (T0). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on overall acceptability of loin nuggets. It is evident from results that linseed and oat supplementation in feed significantly increase the overall acceptability score of the nuggets.

4.5.10 Overall acceptability of hind leg nuggets

The statistical results regarding analysis of variance for texture of hind leg nuggets of the rabbits fed on oat and linseed are given in Table 4.137. It is evident from the results that experimental years have non-significant effect on overall acceptability of hind leg nuggets. Overall acceptability of hind leg nuggets varied significantly during storage.

Table 4.133: Analysis of variance for overall acceptability of lion nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.03000	0.03000	2.98 ^{NS}
Error 1	4	0.06017	0.01504	
Storage	3	4.25492	1.41831	425.77**
Treat	4	17.43000	4.35750	1308.11**
Year x Storage	3	0.00000	0.00000	0.00^{NS}
Year x Treat	4	0.00000	0.00000	0.00^{NS}
Storage x Treat	12	0.47467	0.03956	11.87**
Year x Storage x Treat	12	0.00000	0.00000	0.00^{NS}
Error	76	0.25317	0.00333	
Total	119	22.77292		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.134: Effect of oat and linseed supplementation on overall acceptability of loin nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	6.2	7.0	7.1	7.2	hind leg	6.8
Y2	6.1	6.9	7.0	7.1	6.5	6.7

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.135: Effect of oat and linseed supplementation on overall acceptability of loin nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	6.5k	7.2b	7.2b	7.4a	6.9gh	7.0A
10	6.3l	7.0de	7.1c	7.2b	6.7j	6.9B
20	6.1m	6.9fg	7.0ef	7.1cd	6.4k	6.7C
30	5.8n	6.8i	6.8hi	7.1cd	6.2l	6.5D

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.136: Effect of oat and linseed supplementation on overall acceptability of loin nuggets

Years/ Storage	Treatment					Years x S Mean
	T0	T1	T2	T3	T4	
Y1 0	6.5	7.3	7.3	7.5	6.9	7.1
10	6.3	7.1	7.2	7.2	6.7	6.9
20	6.1	7.0	7.0	7.1	6.5	6.7
30	5.8	6.8	6.9	7.1	6.3	6.6
Y2 0	6.4	7.2	7.2	7.4	6.8	7.0
10	6.2	7.0	7.1	7.1	6.6	6.8
20	6.0	6.9	6.9	7.0	6.4	6.6
30	5.7	6.7	6.8	7.0	6.2	6.5
Mean	6.1E	7.0C	7.0B	7.2A	6.5D	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The data explicated in Table 4.137 indicates that overall acceptability of hind leg nuggets was significantly affected by supplementation of oat and linseed. The interactive effect of year x storage, year x treatment and year x storage x treatment showed non-significant while storage x treatment showed significant effect on overall acceptability of hind leg nuggets.

The data regarding mean score for overall acceptability of hind leg nuggets is explicated in Tables 4.138, 4.139 and 4.140. It is evident from results presented in Table 4.138 that variation in overall acceptability score during the experimental years was non-significant; the average overall acceptability score of hind leg nuggets during 2012 was 6.6 while during 2013 it was observed to be 6.5. The overall acceptability score of hind leg nuggets during storage varied significantly as presented in Table 4.139. The texture score of hind leg nuggets during storage varied significantly from 6.1 to 7.0 during different storage period. The highest overall acceptability score (7.0) was observed at 0day of storage period while during 30^{th} day of storage period hind leg nuggets showed lowest overall acceptability score (6.1). The results regarding impact of oat and linseed supplementation in feed on overall acceptability of hind leg nuggets are presented in Table 4.140. The overall acceptability of hind leg nuggets as a function of different treatments varied significantly from 5.9 to 6.9 during the course of storage period. The highest overall acceptability score (6.9) was observed in hind leg nuggets of rabbit's meat fed on 7% linseed (T3) while lowest overall acceptability score (5,9) was noted in hind leg nuggets of rabbit's meat fed on control feed (T0). The interactive effect of year x storage, year x treatment, storage x treatment and year x storage x treatment showed non-significant effect on overall acceptability of hind leg nuggets. It is evident from the results that the nuggets prepared from hind leg meat of rabbits fed on oat and linseed decrease overall acceptability score with the progression of storage period up to 30^{th} day.

4.6 Serum Lipid Profile (Human Bio-Evaluation Study)

4.6.1 Total serum cholesterol

The statistical results regarding analysis of variance for total serum cholesterol of human subjects are given in Table 4.141. It is evident from the results that experimental years have non-significant effect on serum cholesterol of human subjects. Total serum cholesterol of human subjects varied significantly during different time period.

Table 4.137: Analysis of variance for overall acceptability of hind leg nuggets

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.03000	0.03000	2.98 NS
Error 1	4	0.08724	0.02181	
Storage	3	13.41167	4.47056	1011.91**
Treat	4	17.17050	4.29263	971.64**
Year x Storage	3	0.00000	0.00000	0.00NS
Year x Treat	4	0.00000	0.00000	0.00NS
Storage x Treat	12	0.49750	0.04146	9.38**
Year x Storage x Treat	12	0.00000	0.00000	0.00NS
Error	76	0.33576	0.00442	
Total	119	31.80267		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01)

Table 4.138: Effect of oat and linseed supplementation on overall acceptability of hind leg nuggets during different years

Year	Treatment					Year Mean
	T0	T1	T2	T3	T4	
Y1	6.00	6.82	6.87	7.03	6.37	6.6
Y2	5.90	6.72	6.77	6.93	6.27	6.5

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

Table 4.139: Effect of oat and linseed supplementation on overall acceptability of hind leg nuggets during storage

Storage	Treatment					Storage Mean
	T0	T1	T2	T3	T4	
0	6.5gh	7.1b	7.2b	7.4a	6.8e	7.0A
10	6.1i	6.9d	7.0cd	7.0c	6.5fg	6.7B
20	5.7l	6.5fg	6.6f	6.7e	6.0j	6.3C
30	5.4m	6.4h	6.4h	6.7e	5.8k	6.1D

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05)

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

Table 4.140: Effect of oat and linseed supplementation on overall acceptability of hind leg nuggets during storage

Years/ Storage	Treatment					Years x S Mean
	T0	**T1**	**T2**	**T3**	**T4**	
Y1 0	6.5	7.2	7.2	7.4	6.8	7.0
10	6.2	6.9	7.0	7.1	6.6	6.8
20	5.7	6.6	6.6	6.7	6.1	6.3
30	5.4	6.4	6.5	6.7	5.9	6.2
Y2 0	6.4	7.1	7.1	7.3	6.7	6.9
10	6.1	6.8	6.9	7.0	6.5	6.7
20	5.6	6.5	6.5	6.6	6.0	6.2
30	5.3	6.3	6.4	6.6	5.8	6.1
Mean	5.9E	6.7C	6.8B	6.9A	6.3D	

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

T0 = Control feed

T1 = Feed containing (4%) oat

T2 = Feed containing (2%) oat

T3 = Feed containing (7%) linseed

T4 = Feed containing (3.5%) linseed

The data explicated in Table 4.141 indicates that total serum cholesterol of human subjects was significantly affected by supplementation of meat. The interactive effect of year x days, year x treatment and year x days x treatment showed non-significant while days x treatment showed significant effect on serum cholesterol of human subjects.

The data regarding mean values for total serum cholesterol of human subjects are expressed in Tables 4.142, 4.143 and 4.144. It is evident from the data presented in Table 4.142 that variation in total serum cholesterol of human subjects during the experimental years was non-significant; the average concentration of serum cholesterol during 2012 was 151.33 mg/dl while during 2013 serum cholesterol was observed to be 155.63 mg/dl.The results regarding impact of oat and linseed supplementation in feed on serum cholesterol is expressed in Table 4.143. The serum cholesterol as a function of different treatments varied significantly from 144.47 mg/dl to 166.91 mg/dl. The highest serum cholesterol reduction (177.27-156.55 mg/dl) was observed in a group treated with 7% linseed fed rabbit meat (G4) while lowest serum cholesterol reduction (150.57-144.67 mg/dl) was observed in a group treated with rabbit's meat fed on control feed (G1) as depicted in Figure 4.2. A significant increase in serum cholesterol (148.80-168.47 mg/dl) was seen in a group treated with chicken meat (G6). The total serum cholesterol concentration during different days varied significantly as shown in Table 4.144. The blood serum cholesterol during different days of supplementation varied significantly from 150.63 to 158.37 mg/dl during different days. The highest serum cholesterol (158.37 mg/dl) was observed at 30^{th} day (D2) of meat supplementation while lowest serum cholesterol (150.63 mg/dl) was noted at 0day (D1) in human subjects. The interactive effect of year x days, year x treatment and year x days x treatment showed non-significant while days x treatment showed significant effect on serum cholesterol of human subjects.

It is evident from results that linseed and oat supplementation in feed significantly affect the serum cholesterol of human subjects which is in agreement with finding of Descalzo *et al.* (2007) who establish a positive correlation of linseed activity in cholesterol lowering in human study trial. Results are in agreement with Bierenbaum *et al.* (1993) who did flaxseed supplementation in the form of bread for three months resulted in significant reductions in serum total cholesterol. Shidfar *et al.* (2008) studied the effects of omega-3 fatty acid supplements on serum lipids of human subjects and reported significant reduction in total serum cholesterol.

4.6.2 Total serum triglycerides

The statistical results regarding analysis of variance for total serum triglycerides of human subjects are given in Table 4.145. It is evident from the results that experimental years have non-significant effect on serum triglycerides of human subjects. Total serum triglycerides of human subjects varied significantly during different time period. The data explicated in Table 4.145 indicates that total serum triglycerides of human subjects were significantly affected by supplementation of meat. The interactive effect of year x days, year x treatment and year x days x treatment showed non-significant while days x treatment showed significant effect on serum triglycerides of human subjects.

The data regarding mean values for total serum triglycerides of human subjects are expressed in Tables 4.146, 4.147 and 4.148. It is evident from the data presented in Table 4.146 that variation in total serum triglycerides of human subjects during the experimental years was non-significant; the average concentration of serum triglycerides during 2012 was 109.09 mg/dl while during 2013 serum triglycerides was observed to be 113.08 mg/dl. The results regarding impact of oat and linseed supplementation in feed on serum triglycerides is expressed in Table 4.147. The serum triglycerides as a function of different treatments varied significantly from 80.72 mg/dl to 135.25 mg/dl. The highest serum triglycerides reduction (96.33-65.10 mg/dl) was observed in a group treated with 7% linseed fed rabbit meat (G4) while lowest serum triglycerides reduction (139.00-131.50 mg/dl) was observed in a group treated with rabbit's meat fed on control feed (G1) as depicted in Figure 4.3. A significant increase in serum triglycerides (117.77-148.03 mg/dl) was seen in a group treated with chicken meat (G6). The total serum triglycerides concentration during different days varied significantly as shown in Table 4.148. The blood serum triglycerides during different days of supplementation varied significantly from 105.42 to 116.77 during different days. The highest serum triglycerides (116.77 mg/dl) were observed at 0day (D1) of meat supplementation while lowest serum triglycerides (105.42 mg/dl) were noted at 30^{th} day (D2) in human subjects. The interactive effect of year x days, year x treatment and year x days x treatment showed non-significant while days x treatment showed significant effect on serum triglycerides of human subjects.

Table 4.141: Analysis of variance for total serum cholesterol of human subjects

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	41.69	41.69	3.88^{NS}
Error-I	4	170.6	42.65	
Day	1	2527.6	2527.6	95.19**
Treat	5	12653.2	2530.6	95.30**
Year*Day	1	0.1	0.1	0.00^{NS}
Year*Treat	5	0.6	0.1	0.00^{NS}
Day*Treat	5	11537.2	2307.4	86.90**
Year*Day*Treat	5	0.8	0.2	0.01^{NS}
Error_II	44	1168.4	26.6	
Total	71	28622.4		

NS = Non-significant (P>0.05), ** = Highly significant (P<0.01)

Table 4.142: Effect of oat and linseed supplemented rabbit meat on total serum cholesterol (mg/dl) of human subjects during different years

Years	Days		Years Mean
	D1	D2	
Y1	155.23	147.49	151.33
Y2	159.48	151.78	155.63

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

Table 4.143: Effect of oat and linseed supplemented rabbit meat on total serum cholesterol (mg/dl) of human subjects during different days

Treatments	Days		Treatment Mean
	D1	D2	
G1	150.57d	144.67f	147.62C
G2	168.37b	154.16cd	161.27B
G3	147.57e	141.38fgh	144.47D
G4	177.27a	156.55c	166.91A
G5	157.57c	138.60h	148.09C
G6	148.80f	168.47b	158.64B

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

G1= Control

G2= 4% oat fed rabbit meat

G3= 2% oat fed rabbit meat

G4= 7% linseed fed rabbit meat

G5= 3.5% linseed fed rabbit meat

G6= Chicken meat

Table 4.144: Effect of oat and linseed supplemented rabbit meat on total serum cholesterol (mg/dl) of human subjects

Years/ Treatments	Days		Years x Treatment Mean
	D1	D2	
Y1 G1	147.47	141.57	144.52
G2	165.27	151.00	158.13
G3	144.47	138.33	141.40
G4	174.00	152.67	163.33
G5	154.47	136.00	145.23
G6	145.70	165.37	155.53
Y2 G1	153.67	147.77	150.72
G2	171.47	157.32	164.40
G3	150.67	144.43	147.55
G4	180.53	160.42	170.48
G5	160.67	141.20	150.94
G6	151.90	171.57	161.74
Mean	158.37A	150.63B	

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

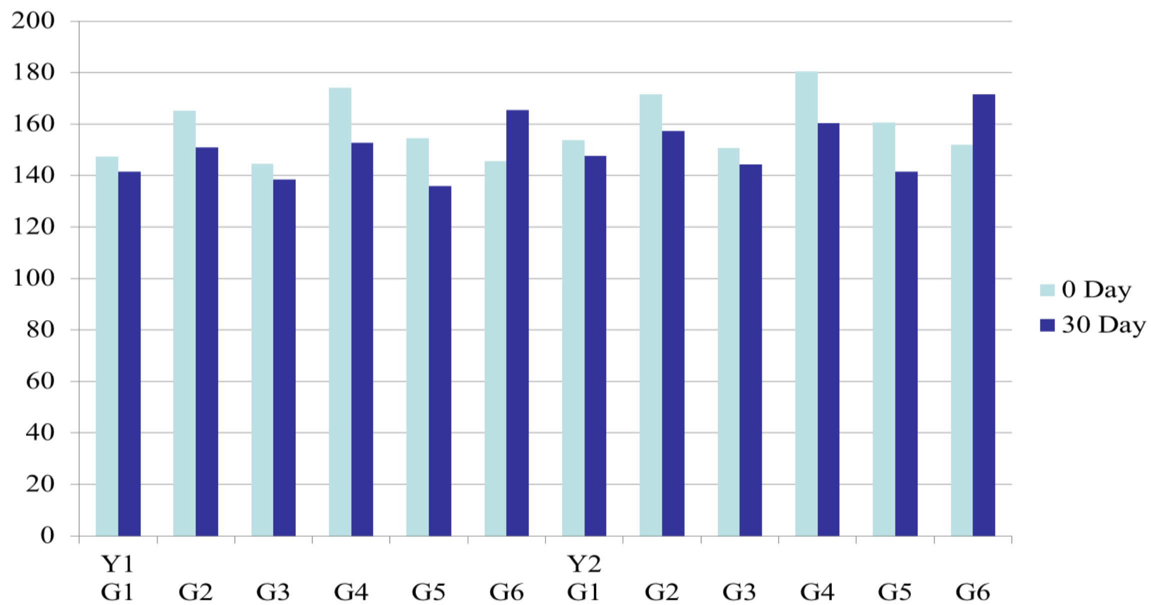

Fig 4.2: Effect of oat and linseed supplemented rabbit meat on total serum cholesterol of human subjects

It is evident from results that linseed and oat supplementation in feed significantly affect the serum triglycerides of human subjects. Tai *et a*l. (2005) reported that the high intake of dietary polyunsaturated fatty acids can reduce serum TG level by modulating genes involved in lipid metabolism (peroxisome proliferator activated receptor α). Shidfar *et al.* (2008) and Movahedian *et al.* (2013) studied the effects of omega-3 fatty acid supplements on serum lipids of human subjects and reported significant reduction in total serum triglycerides.

4.6.3 Serum high density lipoprotein

The statistical results regarding analysis of variance for total serum HDL of human subjects are given in Table 4.149. It is evident from the results that experimental years have non-significant effect on serum HDL of human subjects. Total serum HDL of human subjects varied significantly during different time period. The data explicated in Table 4.149 indicates that total serum HDL of human subjects was significantly affected by supplementation of meat. The interactive effect of year x days, year x treatment and year x days x treatment showed non-significant while days x treatment showed significant effect on serum HDL of human subjects.

The data regarding mean values for total serum HDL of human subjects are expressed in Tables 4.150, 4.151 and 4.152. It is evident from the data presented in Table 4.150 that variation in serum HDL of human subjects during the experimental years was non-significant; the average concentration of serum HDL during 2012 was 48.86 mg/dl while during 2013 serum HDL was observed to be 51.44 mg/dl. The results regarding impact of oat and linseed supplementation in feed on serum HDL is expressed in Table 4.151. The serum HDL as a function of different treatments varied significantly from 37.07 mg/dl to 61.38 mg/dl. The highest serum HDL increase (42.62-80.13 mg/dl) was observed in a group treated with 7% linseed fed rabbit meat (G4) while lowest serum HDL increase (30.25-56.80 mg/dl) was observed in a group treated with rabbit’s meat fed on control feed (G1) as depicted in Figure 4.4. A significant decrease in serum HDL (41.42-35.08 mg/dl) was seen in a group treated with chicken meat (G6). The total serum HDL concentration during different days varied significantly as shown in Table 4.152. The blood serum HDL during different days of supplementation varied significantly from 41.94 to 61.36 during different days. The highest serum HDL (61.36 mg/dl) was observed at 30^{th} day (D2) of meat supplementation while lowest serum HDL (41.94 mg/dl) was noted at 0day

Table 4.145: Analysis of variance for total serum triglycerides of human subjects

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	28.80	28.80	3.34^{NS}
Error-I	4	158.3	39.6	
Day	1	164.4	164.4	21.88**
Treat	5	46952.7	9390.5	1249.95**
Year*Day	1	0.0	0.0	0.00^{NS}
Year*Treat	5	0.0	0.0	0.00^{NS}
Day*Treat	5	25842.0	5168.4	687.95**
Year*Day*Treat	5	0.0	0.0	0.00^{NS}
Error_II	44	330.6	7.5	
Total	71	73735.9		

NS = Non-significant (P>0.05), ** = Highly significant (P<0.01)

Table 4.146: Effect of oat and linseed supplemented rabbit meat on total serum triglycerides (mg/dl) of human subjects during different years

Years	**Days**		**Years Mean**
	D1	**D2**	
Y1	114.77	103.42	109.09A
Y2	118.77	107.43	113.08A

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

Table 4.147: Effect of oat and linseed supplemented rabbit meat on total serum triglycerides (mg/dl) of human subjects during different days

Treatments	**Days**		**Treatment Mean**
	D1	**D2**	
G1	139.00b	131.50c	135.25A
G2	122.27d	104.10f	113.18B
G3	104.33f	82.33h	93.33C
G4	96.33g	65.10i	80.72D
G5	120.93de	101.43f	111.18B
G6	117.77e	148.03a	133.90A

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

G1= Control

G2= 4% oat fed rabbit meat

G3= 2% oat fed rabbit meat

G4= 7% linseed fed rabbit meat

G5= 3.5% linseed fed rabbit meat

G6= Chicken meat

Table 4.148: Effect of oat and linseed supplemented rabbit meat on total serum triglycerides (mg/dl) of human subjects

Years/ Treatments	Days		Years x Treatment Mean
	D1	D2	
Y1 G1	137.00	129.50	133.25
G2	120.27	102.10	111.18
G3	102.33	80.33	91.33
G4	94.33	63.10	78.72
G5	118.93	99.43	109.18
G6	115.77	146.03	130.90
Y2 G1	141.00	133.50	137.25
G2	124.27	106.10	115.18
G3	106.33	84.33	95.33
G4	98.33	67.10	82.72
G5	122.93	103.43	113.18
G6	119.77	150.03	135.90
Mean	116.77A	105.42B	

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

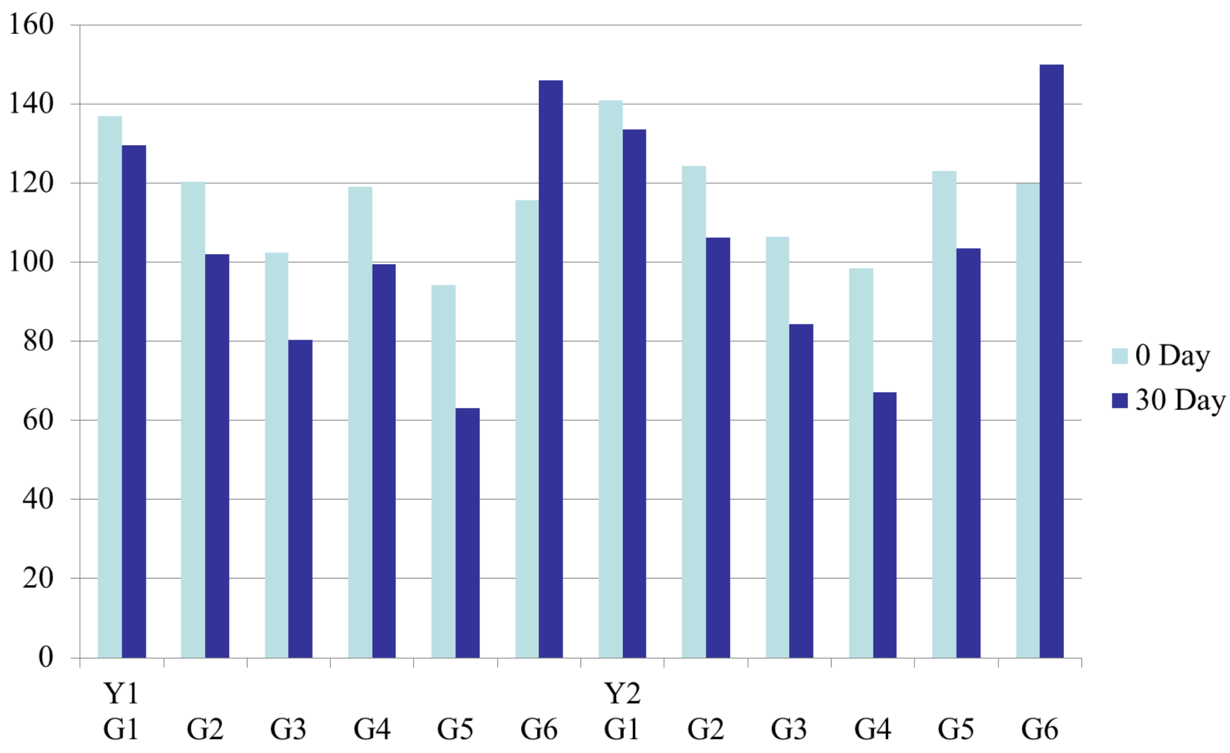

Fig 4.3: Effect of oat and linseed supplemented rabbit meat on total serum triglycerides of human subjects

(D1) in human subjects. The interactive effect of year x days, year x treatment and year x days x treatment showed non-significant while days x treatment showed significant effect on serum HDL of human subjects. It is evident from results that linseed and oat supplementation in feed significantly affect the serum HDL of human subjects. My Svensson *et al.* (2008) investigated the effect of n-3 fatty acids on lipids and lipoproteins in patients and stated that n-3 fatty acids significantly increase the HDL concentration (1.18-1.26 mmol/l) in fasting patients after 3 months of supplementation. The significant increase in HDL due to linseed supplementation may be explained by stimulation of lipid oxidation during activity. Alterations in the transport of blood lipids, with a higher ratio of HDL to LDL increased lipoprotein lipase activity, which increases the use of circulating triglycerides as fuel and increases their clearance. Activation of this enzyme also speeds up the conversion of the very low density lipoproteins (VLDL) to HDL (Press *et al.*, 2003; Lee and Prasad, 2003).

4.6.4 Serum low density lipoprotein

The statistical results regarding analysis of variance for total serum LDL of human subjects are given in Table 4.153. It is evident from the results that experimental years have non-significant effect on serum LDL of human subjects. Total serum LDL of human subjects varied significantly during different time period. The data explicated in Table 4.153 indicates that total serum LDL of human subjects was significantly affected by supplementation of meat. The interactive effect of year x days, year x treatment and year x days x treatment showed non-significant while days x treatment showed significant effect on serum LDL of human subjects.

The data regarding mean values for total serum LDL of human subjects are expressed in Tables 4.154, 4.155 and 4.156. It is evident from the data presented in Table 4.154 that variation in serum LDL of human subjects during the experimental years was non-significant; the average concentration of serum LDL during 2012 was 77.39 mg/dl while during 2013 serum LDL was observed to be 81.39 mg/dl.

The results regarding impact of oat and linseed supplementation in feed on serum LDL is expressed in Table 4.155. The serum LDL as a function of different treatments varied significantly from 61.73 mg/dl to 96.17 mg/dl. The highest serum LDL decrease (90.33-47.23 mg/dl) was observed in the group treated with 7% linseed fed rabbit meat (G4) while the lowest serum LDL decrease (66.87-56.60 mg/dl) was observed in the group treated with

Table 4.149: Analysis of variance for serum HDL of human subjects

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	11.969	11.969	1.97^{NS}
Error-I	4	43.58	10.89	
Day	1	5153.66	5153.66	246.52**
Treat	5	4027.97	805.59	38.53**
Year*Day	1	53.62	53.62	2.35 ^{NS}
Year*Treat	5	205.02	41.00	1.96^{NS}
Day*Treat	5	2318.91	463.78	22.18**
Year*Day*Treat	5	205.02	41.00	1.96^{NS}
Error_II	44	919.85	20.91	
Total	71	13147.32		

NS = Non-significant (P>0.05), ** = Highly significant (P<0.01)

Table 4.150: Effect of oat and linseed supplemented rabbit meat on serum HDL (mg/dl) of human subjects during different years

Years	**Days**		**Years Mean**
	D1	**D2**	
Y1	38.94	58.78	48.86
Y2	42.44	62.44	51.44

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

Table 4.151: Effect of oat and linseed supplemented rabbit meat on serum HDL (mg/dl) of human subjects during different days

Treatments	**Days**		**Treatment Mean**
	D1	**D2**	
G1	30.25f	56.80c	43.53C
G2	46.45cd	70.72a	58.59A
G3	46.55c	59.83b	53.19B
G4	42.62e	80.13a	61.38A
G5	44.35cd	63.63a	53.99B
G6	41.42de	35.08e	37.07D

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

G1= Control

G2= 4% oat fed rabbit meat

G3= 2% oat fed rabbit meat

G4= 7% linseed fed rabbit meat

G5= 3.5% linseed fed rabbit meat

G6= Chicken meat

Table 4.152: Effect of oat and linseed supplemented rabbit meat on serum HDL (mg/dl) of human subjects

Years/ Treatments	Days		Years x Treatment Mean
	D1	D2	
Y1 G1	28.00	54.83	41.42
G2	44.20	68.57	56.38
G3	44.80	58.00	51.40
G4	35.37	74.00	54.68
G5	42.10	62.20	52.15
G6	39.17	35.09	37.13
Y2 G1	32.50	58.77	45.63
G2	48.70	72.87	60.78
G3	48.30	61.67	54.98
G4	49.87	86.27	68.07
G5	46.60	65.07	55.84
G6	43.67	39.06	41.37
Mean	41.94B	61.36A	

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

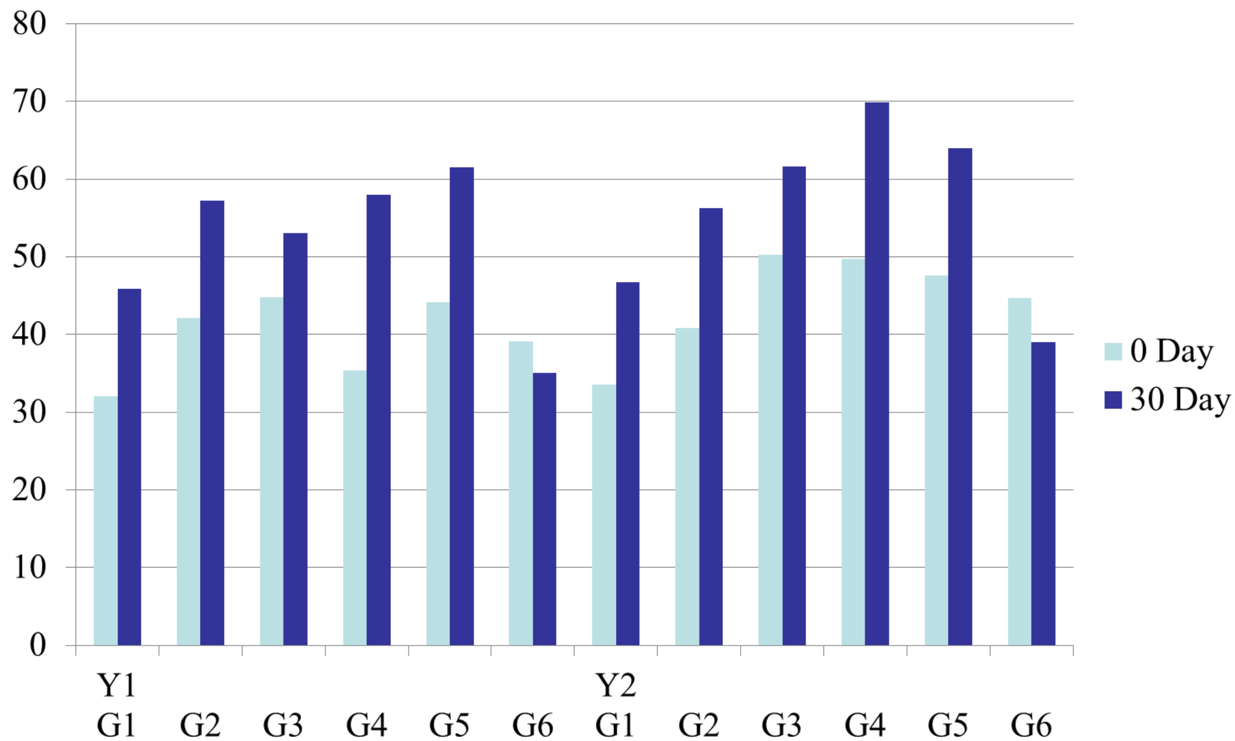

Fig 4.4: Effect of oat and linseed supplemented rabbit meat on serum HDL of human subjects

rabbit's meat fed on control feed (G1) as depicted in Figure 4.5. A significant increase in serum LDL (74.47-89.93 mg/dl) was seen in a group treated with chicken meat (G6). It is evident from results that linseed and oat supplementation in feed significantly affect the serum LDL of human subjects. The total serum LDL concentration during different days varied significantly as shown in Table 4.156. The blood serum LDL during different days of supplementation varied significantly from 68.61 to 90.18 mg/dl during different days.

The highest serum LDL (90.18 mg/dl) was observed at 0day (D1) of meat supplementation while lowest serum LDL (68.61 mg/dl) was noted at 30th day (D2) in human subjects. The interactive effect of year x days, year x treatment and year x days x treatment showed non-significant while days x treatment showed significant effect on serum LDL of human subjects. The results of present study are in context to Nelson and Cox (2005) who stated that linseed show variable effects on plasma lipids. Serum triglycerides (TG), total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) have been reported lowered with linseed consumption, linseed lowers serum TC and LDL-C; however, it has no effect on serum high-density lipoprotein-cholesterol (HDL-C) and TG. In humans the possible mechanism is that n-3 PUFA reduce triglycerides so by decrease hepatic synthesis and the secretion of triglyceride-rich lipoproteins by inhibiting various enzymes (Chan and Cho, 2009). The results of present study indicated a significant decrease in LDL contents of human subjects supplemented with rabbit meat. There are reports that the hypocholesterolaemic effects of linseed may be attributed to the functional components present in its composition like lignans, soluble fibres and linolenic acid (Klag *et al.*, 1993).

4.6.5 Total serum protein

The statistical results regarding analysis of variance for total serum protein of human subjects are given in Table 4.157. It is evident from the results that experimental years have non-significant effect on serum protein of human subjects. Total serum protein of human subjects varied significantly during different time period. The data explicated in Table 4.157 indicates that total serum protein of human subjects was significantly affected by supplementation of meat. The interactive effect of year x days, year x treatment, days x treatment and year x days x treatment showed non-significant effect on serum protein of human subjects.

Table 4.153: Analysis of variance for serum LDL of human subjects

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	28.800	28.800	2.94^{NS}
Error-I	4	42.91	10.73	
Day	1	8380.81	8380.81	842.15**
Treat	5	12105.03	2421.01	243.28**
Year*Day	1	0.00	0.00	0.00^{NS}
Year*Treat	5	0.00	0.00	0.00^{NS}
Day*Treat	5	2134.09	426.82	42.89**
Year*Day*Treat	5	0.00	0.00	0.00^{NS}
Error_II	44	437.87	9.95	
Total	71	23388.72		

NS = Non-significant (P>0.05), ** = Highly significant (P<0.01)

Table 4.154: Effect of oat and linseed supplemented rabbit meat on serum LDL(mg/dl) of human subjects during different years

Years	**Days**		**Years Mean**
	D1	**D2**	
Y1	88.18	66.61	77.39
Y2	92.18	70.61	81.39

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

Table 4.155: Effect of oat and linseed supplemented rabbit meat on serum LDL (mg/dl) of human subjects during different days

Treatments	**Days**		**Treatment Mean**
	D1	**D2**	
G1	66.87g	56.60h	61.73E
G2	104.50b	85.67d	95.08A
G3	79.80e	65.00g	72.40C
G4	90.33c	47.23i	68.78D
G5	109.67a	82.67de	96.17A
G6	74.47f	89.93c	82.20B

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

G1= Control

G2= 4% oat fed rabbit meat

G3= 2% oat fed rabbit meat

G4= 7% linseed fed rabbit meat

G5= 3.5% linseed fed rabbit meat

G6= Chicken meat

Table 4.156: Effect of oat and linseed supplemented rabbit meat on serum LDL (mg/dl) of human subjects

Years/ Treatments	Days		Years x Treatment Mean
	D1	D2	
Y1 G1	64.87	54.60	59.73
G2	102.50	83.67	93.08
G3	77.80	63.00	70.40
G4	88.33	45.23	66.78
G5	107.67	80.67	94.17
G6	87.93	72.47	80.20
Y2 G1	68.87	58.60	63.73
G2	106.50	87.67	97.08
G3	81.80	67.00	74.40
G4	92.33	49.23	70.78
G5	111.67	84.67	98.17
G6	91.93	76.47	84.20
Mean	90.18A	68.61B	

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

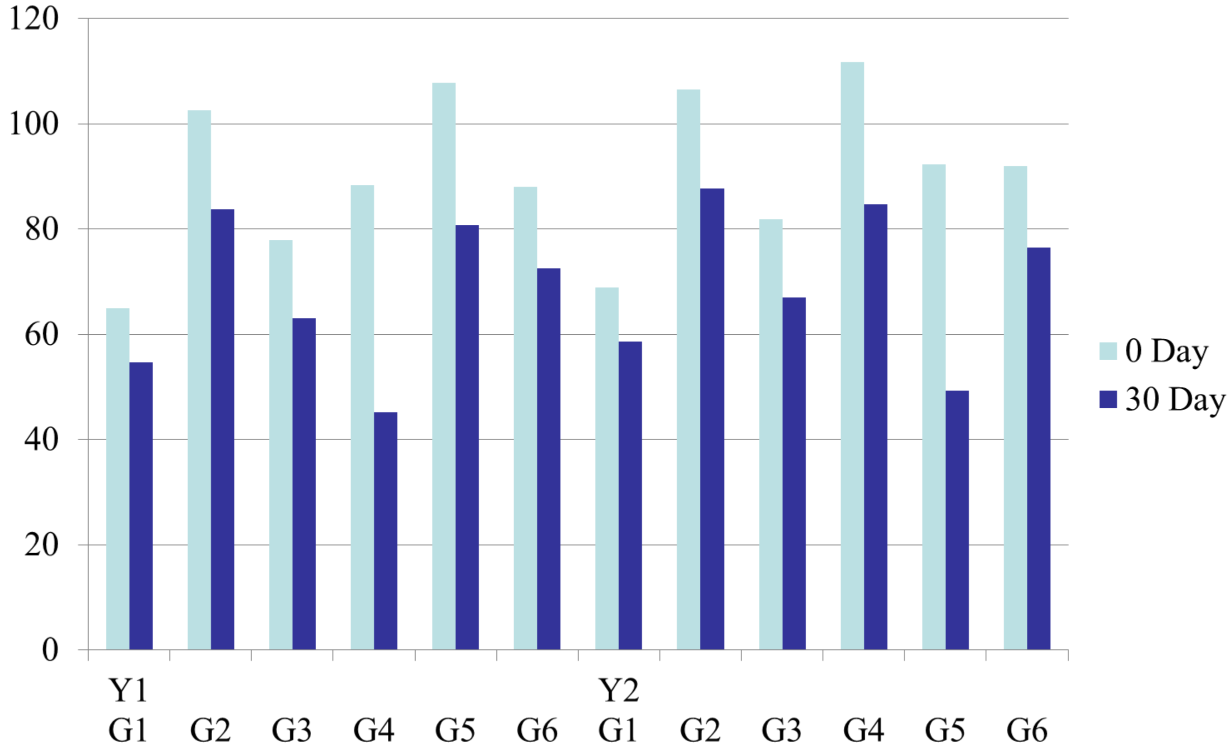

Fig 4.5: Effect of oat and linseed supplemented rabbit meat on serum LDL of human subjects

The data regarding mean values for total serum protein of human subjects are expressed in Tables 4.158, 4.159 and 4.160. It is evident from the data presented in Table 4.158 that variation in serum protein of human subjects during the experimental years was non-significant; the average concentration of serum protein during 2012 was 6.02 g/dl while during 2013 serum protein was observed to be 6.06 g/dl. The results regarding impact of oat and linseed supplementation in feed on serum protein is expressed in Table 4.159. The serum protein as a function of different treatments varied significantly from 5.34 g/dl to 6.30 g/dl. The highest serum protein increase (5.79-6.80 g/dl) was observed in a group treated with chicken meat (G6) while lowest serum protein increase (5.69-6.49 g/dl) was observed in a group treated with rabbit's meat fed on 3.5% linseed feed (G5) as depicted in Figure 4.6. It is evident from results that linseed and oat supplementation in feed significantly increase the serum protein of human subjects.

The total serum protein concentration during different days varied significantly as shown in Table 4.160. The blood serum protein during different days of supplementation varied significantly from 5.60 to 6.48 g/dl during different days. The highest serum protein (6.48 g/dl) was observed at 30th day (D2) of meat supplementation while lowest serum protein (5.60 g/dl) was noted at 0day (D1) in human subjects. The interactive effect of year x days, year x treatment, days x treatment and year x days x treatment showed non-significant effect on serum protein of human subjects.

Table 4.157: Analysis of variance for total serum protein of human subjects

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Year	1	0.1250	0.1250	1.19^{NS}
Error-I	4	2.1111	0.5278	
Day	1	14.5800	14.5800	183.88**
Treat	5	11.0428	2.2086	27.85**
Year*Day	1	0.0450	0.0450	0.57^{NS}
Year*Treat	5	0.0000	0.0000	0.00^{NS}
Day*Treat	5	0.3450	0.0690	0.87^{NS}
Year*Day*Treat	5	0.0000	0.0000	0.00^{NS}
Error_II	44	3.4889	0.0793	
Total	71	32.7378		

NS = Non-significant (P>0.05), ** = Highly significant (P<0.01)

Table 4.158: Effect of oat and linseed supplemented rabbit meat on total serum protein (g/dl) of human subjects during different years

Years	**Days**		**Years Mean**
	D1	**D2**	
Y1	5.59	6.45	6.02A
Y2	5.61	6.51	6.06A

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

Table 4.159: Effect of oat and linseed supplemented rabbit meat on total serum protein (g/dl) of human subjects during different days

Treatments	**Days**		**Treatment Mean**
	D1	**D2**	
G1	4.89	5.79	5.34E
G2	5.45	6.28	5.86D
G3	6.19	7.00	6.59A
G4	5.62	6.53	6.07C
G5	5.69	6.49	6.09C
G6	5.79	6.80	6.30B

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

G1= Control

G2= 4% oat fed rabbit meat

G3= 2% oat fed rabbit meat

G4= 7% linseed fed rabbit meat

G5= 3.5% linseed fed rabbit meat

G6= Chicken meat

Table 4.160: Effect of oat and linseed supplemented rabbit meat on total serum protein (g/dl) of human subjects

Years/ Treatments	Days D1	Days D2	Years x Treatment Mean
Y1 G1	4.87	5.77	5.32
G2	5.43	6.23	5.83
G3	5.80	6.90	6.35
G4	5.60	6.50	6.05
G5	5.67	6.37	6.02
G6	6.20	6.90	6.55
Y2 G1	4.91	5.81	5.36
G2	5.46	6.33	5.90
G3	5.78	6.70	6.24
G4	5.64	6.55	6.10
G5	5.70	6.61	6.16
G6	6.18	7.09	6.64
Mean	5.60A	6.48B	

Means sharing similar letter in a row or in a column is statistically non-significant (P>0.05)

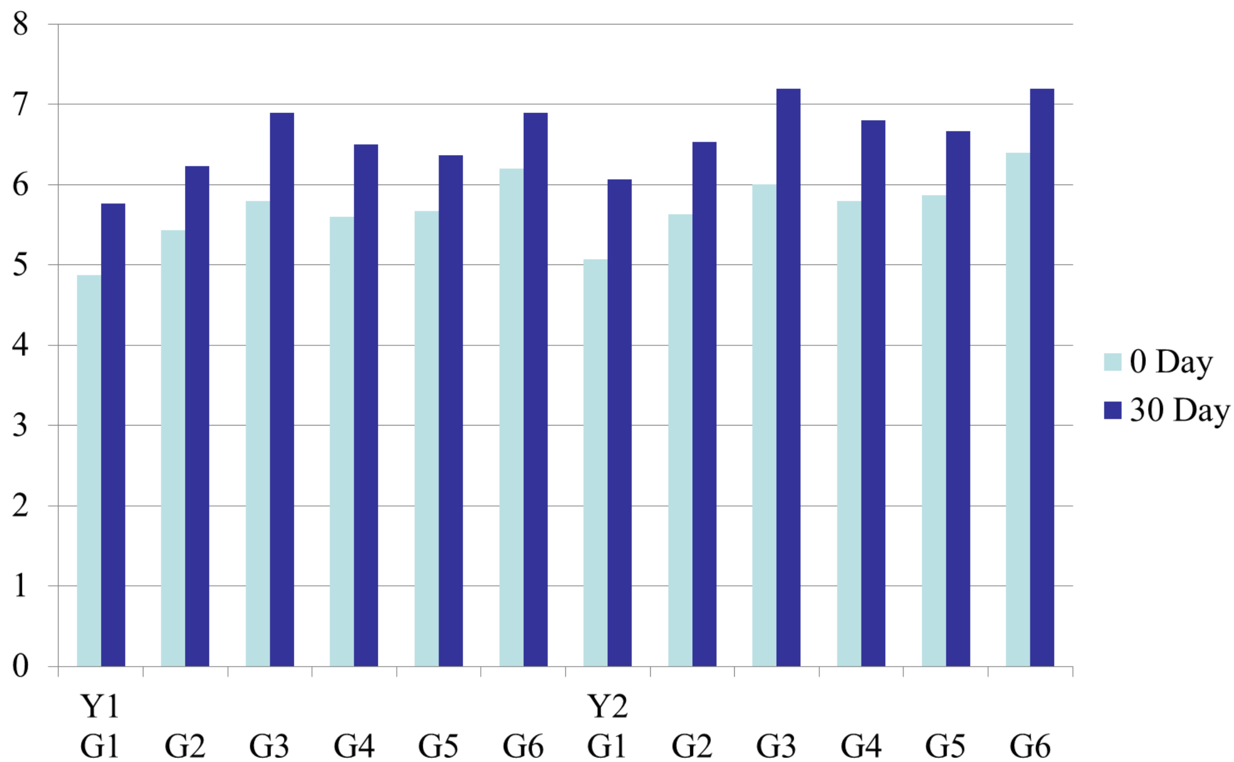

Fig 4.6: Effect of oat and linseed supplemented rabbit meat on serum total protein of human subjects

CHAPTER 5

SUMMARY

Food products that provide some specific health benefits beyond the traditional nutrients they contain are known as functional foods. The main objective of the present research was to explore the potential of rabbit meat as a functional food. Low fat and PUFA enriched rabbit meat was made for hypercholesterolemic persons by rearing the rabbits on different level of oat and linseed. For this purpose two different levels of oats and linseed were used. Two trials were conducted in two different years. First year trial was conducted in 2012 and the second year trial was conducted in 2013. In connection to this twenty five to thirty days old weaned rabbits were subjected to feed supplemented with different level of oat and linseed. The rabbits were reared for eight weeks on experimental feeds. Serum lipid profile of rabbits was measured to check the efficacy of oat and linseed on lipid profile. Nuggets were prepared from experimental rabbit meat and evaluated for their stability and acceptability during storage. Bio-evaluation of low fat and n-3 fatty acids enriched meat was conducted through human subject study trial. Blood serum lipid profile of human subjects was measured. The data obtained for various parameters were subjected to statistical analysis by using different experimental design and the results are summarized below.

Feed treatment showed significant effect on body weight gain and FCR. The feed intake did not differ significantly among different feed treatments. The rabbits fed on 7% linseed gained maximum weight in both experimental years 2012 and 2013. The lowest body weight gain was found in rabbits fed on control feed (T0) in both experimental years (2012 & 2013). The FCR was found significantly higher in rabbits fed on control (T0) and lowest FCR was found in rabbits fed on 7% linseed (T3). pH, Aw, Protein, Fat and Textural values differed significantly between breast and leg of rabbit meat as a function of oat and linseed supplementation. Protein, pH and Textural values were found significantly higher in loin as compared to hind leg meat during the experimental years 2012 and 2013. The highest pH values 5.99 was observed in loin and 5.93 in hind leg of rabbit's meat fed on 3.5% linseed (T4) while lowest pH values 5.64 in loin and 5.56 in hind leg were observed in rabbit's meat fed on control feed (T0). Oat and linseed supplementation in feed did not affect the Aw of loin and hind leg of rabbit meat. The highest protein contents 24.06% in loin and 23.93% in hind leg were observed in rabbit meat fed on 7% linseed (T3) while lowest protein contents

21.06% in loin and 20.88% in hind leg were observed in rabbit meat fed on control feed (T0). The highest fat contents 2.31% in loin and 4.56% in hind leg were observed in rabbit's meat fed on 7% linseed (T3) while lowest fat contents 1.63% in loin and 3.40% were observed in rabbit's meat fed on 4% oat (T1). The highest texture value 2.87 in loin and 2.63 in hind leg was observed in rabbit's meat fed on 4% oat while lowest texture value 2.19 in loin and 1.78 in hind leg was observed in rabbit's meat fed on 7% linseed (T3).

The saturated fatty acid and unsaturated fatty acid in loin and hind leg of rabbits were influenced by different feed treatments during the experimental year 2012 and 2013. Rabbits reared on control feed (T0) had a significantly higher percentage of saturated fatty acids in loin and leg meat of rabbits. Lowest saturated fatty acids were observed in the loin and hind leg meat of rabbits receiving 4% supplementation of oat in feed. Rabbits reared on feed supplemented with 7% linseed had a significantly higher amount of unsaturated fatty acids in the loin and hind leg meat of rabbits. Lowest unsaturated fatty acids were observed in loin and hind leg meat of rabbits receiving 4% supplementation of oat in feed. The highest ratio of SFA/UFA was seen in rabbit's loin and hind leg meat fed on 4% oat supplemented feed while lowest ratio of SFA/UFA was observed in loin meat of rabbits receiving 7% supplementation of linseed in feed. Highest PUFA/SFA was observed in loin meat of rabbits fed on 7% linseed supplementation in feed (T3) while lowest PUFA/SFA was observed in loin meat of rabbits fed on 4% oat supplementation in feed (T1) during the experimental years 2012 and 2013.

The bio-chemical profile of the rabbit serum showed that the feed treatments exerted significant effect on blood chemical profile. The highest serum cholesterol (141.21 mg/dl) and triglycerides (85.93 mg/dl) were observed in rabbits fed on control feed (T0) while lowest serum cholesterol (105.27 mg/dl) and triglycerides (66.23 mg/dl) were noted in rabbits fed on 4% oat (T1). The highest serum HDL concentration (48.00 mg/dl) was observed in rabbits fed on 7% linseed (T3) while lowest serum HDL concentration was observed in rabbits fed on 2% oat (T2). The highest serum LDL (35.33 mg/dl) was observed in rabbits fed on control feed (T0) while lowest serum LDL concentration was observed in rabbits fed on 7% linseed (T3). The highest serum total protein concentration (8.37 g/dl) was observed in rabbits fed on 7% linseed (T3) while lowest serum total protein concentration (8.18 g/dl) was observed in rabbits fed on 4% oat (T1).

The physico-chemical analysis of rabbit nuggets indicates that feed treatment exert significant effect on the pH, color, texture and water activity tested after different storage interval in both the experimental years 2012 and 2013. The highest water activity values were observed in loin and hind leg nuggets of rabbit's meat fed on 7% linseed (T3) while lowest water activity values were noted in loin and hind leg nuggets of rabbit's meat fed on control feed (T0). The water activity of nuggets decreased as a function of storage and product became harder with storage interval. The highest texture values were observed in loin and hind leg nuggets of rabbit's meat fed on 7% linseed (T3) while lowest texture values were noted in loin and hind leg nuggets of rabbit's meat fed on control feed (T0). The loin and hind leg nuggets made from meat of rabbit group fed on 7% linseed (T3) showed higher pH and color with storage intervals. The color of the nuggets was lighter at the start of the storage period and became darker with the passage of storage period. The lipid peroxidation is measure of malondialdehyde (MDA) formed during auto-oxidation of lipids present in meat tissues .and higher malondialdehyde compound deteriorate the meat tissues. The production of MDA and POV in loin and hind leg meat nuggets of rabbits was noted lower in a in a group fed on 4% oat (T1) while the highest MDA and POV were recorded in the loin and hind leg meat of rabbits fed on 7% linseed (T3).

The feed treatments showed a significant effect on the score assigned to color, appearance, taste, texture and overall acceptability of the loin and hind leg rabbit meat nuggets. The nuggets made from rabbit's meat fed on 7% linseed (T3) were assigned significantly highest score to color, appearance, taste, texture and overall acceptability of loin and hind leg nuggets when tested at the end of experiment (30^{th} day). The lowest score of color and appearance was noted in loin and hind leg nuggets of rabbit's meat fed on 2% oat (T2) while the lowest score of taste, texture and overall acceptability was given to the loin and hind leg nuggets of rabbit's meat fed on control feed (T0) during the experimental year 2012 and 2013. The overall acceptability of the loin and hind leg nuggets of rabbit meat decreased significantly when the storage intervals increased. This is due to the fact that lipid peroxidation of the nuggets increased which retarded the overall acceptability of the product.

Human bio-evaluation study trial of functional rabbit meat revealed that serum lipid profile was found to be significant in response to the effect of treatment. The bio chemical profile of human blood serum showed that feed treatment exerted significant effect on blood chemical profile. The cholesterol, low density lipoprotein and triglycerides were found to be lower in group of human subjects blood serum treated with 7% linseed meat (G4) while the highest values were observed in G6 fed on chicken meat during the both experimental years 2012 and 2013.

CONCLUSIONS AND RECOMMENDATIONS

- Linseed and oats are 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 affected by dietary supplementation of oat and linseed in feed of rabbits. Hence weight of the rabbits can be increased by oat and linseed supplementation.
- Poly unsaturated fatty acid ratio is higher over unsaturated fatty acid as compared to oat supplemented group of rabbits. Maximum concentration of poly unsaturated fatty acid was present in the meat of rabbits fed on 7% linseed (T3) and lowest concentration was found in the meat of rabbits fed on 4% oat (T1). Plant materials are cheaper and good sources for modification in meat tissues and improvement of FA profile. Incorporation of oat and linseed in low economic country like Pakistan in the feed of rabbits would be a good feed strategy in order to develop healthier meat and meat products.
- Total cholesterol concentration in rabbit blood serum was found lowest in group of rabbits fed on 4% oat (T1) and highest cholesterol concentration in rabbit blood serum was found in rabbits fed on control feed (T0).
- The production of MDA and POV in loin and hind leg meat nuggets of rabbits was noted lower in a in a group fed on 4% oat (T1) while the highest MDA and POV were recorded in the loin and hind leg meat of rabbits fed on 7% linseed (T3). Oat can be incorporated in the feed of rabbits to increase the antioxidant level in the meat of rabbits that will ultimately increase the storage time of rabbit meat products.
- Sensory evaluation results showed that nuggets made from T3 (7% linseed) were best liked by panel of judges in all parameters and T0 were least liked but in acceptable limit. Meat industry should be encouraged to produce various rabbit meat products for health conscious persons.
- The cholesterol, low density lipoprotein and triglycerides were found to be lower in group of human subjects blood serum treated with 7% linseed meat (G4) while the highest values were observed in G6 (Group fed on chicken meat). Awareness should be created among the public regarding the healthy aspects of rabbit meat.

FUTURE RESEARCH DIRECTIONS

The development of any livestock industry depends heavily on research to uncover information on nutrition and feeding, the cause and prevention of diseases, optimal breeding and genetics programs, and the solution of a myriad of problems that confront the producer. Compared to the situation with other livestock species, research on rabbits has been very limited. It is useful to review the history of rabbit research and the contemporary situation with the inevitable risk of omission. Research relevant to commercial rabbit production has been conducted mainly in several European countries and in the United States. There is little doubt that rabbits could become important meat animals in many countries, particularly in developing nations like Pakistan with high human population density and a shortage of high quality grains and plant protein sources. The purpose of raising livestock is to convert low quality fibrous vegetation to a higher quality human food (meat). Rabbits offer a number of advantages over other livestock in this conversion process. Whether the potential of rabbit production is realized depends on several factors, including research to bring actual productivity closer to the potential limits and increased consumer acceptance of rabbit meat. It is virtually a worldwide phenomenon that rabbits are viewed as cute creatures and many people who readily accept the slaughter of chickens, cattle and other livestock find the idea of slaughtering and eating rabbits difficult to accept. Consideration of recent trends in rabbit production suggests that Europe will continue to be the stronghold of rabbit raising, with a viable industry based on strong consumer demand for rabbit meat. Although the increasing popularity of rabbit production in Asia could likely surpass present trends in Europe. Growth of the North American industry, where rabbits are mostly found in small numbers in back yards or on small farms will likely be modest. Rabbit meat in the United States is in competition with abundant other food resources particularly the highly sophisticated and automated poultry industry. Functional foods should be encouraged in Pakistan for their significance in the improvement of nutrition and curing diseases. Farming system for rabbits should be introduced in Pakistan in order to encourage the production of rabbits for meat. Incorporation of oat and linseed in low economic country like Pakistan in the feed of rabbits would be a good feed strategy in order to develop healthier meat and meat products. Although rabbit meat offers excellent nutritional and dietetic properties in itself, it can be further fortified with bioactive compounds to develop functional meat. Feeding rabbits on

PUFA enriched diet in combination with alfalfa will not increase too much cost of production because it depresses mortality rate and increases growth in rabbits. There is also no commercial feed available in local market that may increase cost of production so consumer will not pay more for meat of rabbits. Future research should be carried out in order to explore functional attributes of rabbit meat by using alternative combinations of feed resources e.g. chia seed, spirulena etc. Human trial should be carried out on hypercholesterolemic patients to check its significance of functional meat. Researchers can consider oat and linseed combination to develop functional rabbit meat. Artificial antioxidents can be added with natural feed to enhance shelf stability of PUFA enriched rabbit meat.

LIMITATIONS OF THE PRESENT STUDY

Various problems were originated during the course of research study. During procurement of rabbits of the same age I have to wait for six months. The numbers of animals were not enough to carry out human trial on large number of subjects. During analysis, energy crises and low voltage electricity caused damage to equipment and ultimately disturbed results and data. There must be availability of large nitrogen tanks to store meat samples for longer period of time.

REFERENCES

Abdel-Khalek, A. 2010. Antioxidants in rabbit nutrition: a review. In Proc. 6th Int. Conf. Rabbit Prod. In Hot Clim. Assuit. Egypt. 117-138.

Ajuyah, A.O., T.W. Fenton, R.T. Hardin and J.S. Sim. 1993. Effect of dietary full flaxseed with and without antioxidant on the fatty acid composition of major lipid classes of chicken meats. Poult. Sci. 72: 125-136.

Alasnier, C., H. Rémignon and G. Gandemer. 1996. Lipid characteristics associated with oxidative and glycolytic fibres in rabbit muscles. Meat Sci. 43: 213-224.

Aly, N.H. 2012. Effect of dietary oat and wheat bran on biochemical changes in rats fed high fat-high cholesterol diets. J. Appl. Sci. Res. 8: 598-604.

American Heart Association. 2006. Heart disease and stroke statistics: 2006 update. Circulation. 113: 85-151.

Ander, B.P., A.L. Edel, R. McCullough, D.R. Rodriguez-Leyva, P. Rampersad and J.S.C. Gilchrist. 2010. Distribution of omega-3 fatty acids in tissues of rabbits fed a flaxseed supplemented diet. Metab. Clin. Exp. 59: 620-627.

Andersen, H.A., N. Oksbjerg, J.F., Young and M. Therkildsen. 2005. Feeding and meat quality–a future approach. Meat Sci. 70: 543–554.

Anjum, F.M., M.F. Haider, M.I. Khan, M. Sohaib and M.S. Arshad. 2013. Impact of extruded flaxseed meal supplemented diet on growth performance, oxidative stability and quality of broiler meat and meat products. Lipids Health Dis. 12:13.

Annoni, G., B.M. Botasso, D. Ciaci, M.F. Donato and A. Tripodi. 1982. Liquid triglycerides (GPO-PAP). Lab. J. Res. Lab. Med. 9: 115.

AOAC. 2000. Official method of analysis (17th Ed.) Volume I. Association of Official Analytical Chemists, Inc., Maryland, USA.

AOCS. 1998. Official methods and recommended practices of AOCS (5th Ed.). American Oil Chemists Society. Champaign, Illinions, USA.

Aquaron, R. and G. Serratrice. 1972. Phosphorylase, Aldolase, Lactico-deshydroge´nase et ses isoenzymes, Cre´atinekinase et taux du glycoge`ne dans les muscles rouges et blancs chez le lapin normal. CRS Biol. 166: 653-661.

Arihara, K. 2006. Strategies for desgning novel functional meat products. Meat Sci. 74: 219-229.

Assmann, G. 1979. HDL cholesterol precipitant. Randox Labs. Ltd. Crumlin Co. Antrim, N. Ireland. Internist. 20: 559.

Bailey, A.J. 1985. The role of collagen in the development of muscle and its relationship to eating quality. J. Animal Sci. 60: 1580-1587.

Bailey, A.J. and N.D. Light. 1989. The role of connective tissue in determining the textural quality of meat. p.170-194. In Connective tissue in meat and meat products. London, UK: Elsevier Appl. Sci.

Bandman, E. 1992. Changes in myofibrillar and cytoskeletal proteins in post-mortem muscle. Recip. Meat Conf. Proc. 45: 47–50.

Becker, C.C. and D.J. Kyle. 1998. Developing functional foods containing Algal docosahexaenoic acid. Food Tech. 52: 68.

Behall, K.M., D.J. Scholfield and J. Hallfrisch. 1997. Effect of beta-glucan level in oat fiber extracts on blood lipids in men and women. J. Am. Coll. Nutr. 6: 46-51.

Beitz, J.A. and J.S. Wall. 1972. Wheat gluten molecular weight determination by sodiuom dodecyl sulfate polyacrylamide gel electrophoresis. Cereal chem. J. 49: 416-430.

Benjamin, S. and F. Spener. 2009. Conjugated linoleic acids as functional food: An insight into their health benefits. Nutr. Metab. 6: 36.

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

Bernardini, M., C. Castellini and A. Dal Bosco. 1995. Qualita` della carcassa di coniglio in funzione del tipo genetico e dell'eta` di macellazione. p. 127-128. In: Proc. XI Cong. Nazionale. A.S.P.A., Grado (GO), Italy,

Betti, M., T.I. Perez, M.J. Zuidhof and R.A. Renema. 2009. Omega-3-enriched broiler meat: 3. Fatty acid distribution between triacylglycerol and phospholipid classes. Poult. Sci. 88: 1740-1754.

Beynen, A.C., D.G. Van Manen and M.W.A. Verstegen. 1990. Dietary fat level and carcass quality of rabbits. J. Appl. Rabbit Res. 12: 266-267.

Bianchi, M., M. Petracci and C. Cavani. 2006. Effects of dietary inclusion of dehydrated Lucerne and whole linseed on rabbit meat quality. World Rabbit Sci. 14: 247-258.

Bianchi, M., M. Petracci and C. Cavani. 2009. The influence of linseed on rabbit meat quality. World Rabbit Sci. 17: 97-107.

Bierenbaum, M.L., R. Reichstein and T.R. Watkins. 1993. Reducing atherogenic risk in hyperlipemic humans with flaxseed supplementation: a preliminary report. J. Am. Coll. Nutr. 12: 501–504.

Biswas, S., A. Chakraborty and S. Sarkar. 2006. Comparision among the qualities of patties prepared from chicken broiler, spent hen and duck meats. J. Poult. Sci. 43: 180–186.

Blasco, A., M. Piles and L. Varona. 2003. A Bayesian analysis of the effect of selection for growth rate on growth curves in rabbits. Genet. Sel. Evol. 35: 21-41.

Botsoglou, N.A., E. Christaki, D.J. Fletouris, P. Florou-Paneri and A.B. Spais. 2002. The effect of dietary oregano essential oil on lipid oxidation in raw and cooked chicken during refrigerated storage. Meat Sci. 62: 259-265.

Botsoglou, N.A., P. Florou-Paneri, E. Christaki, I. Giannenas and A.B. Spais. 2004. Performance of rabbits and oxidative stability of muscle tissues as affected by dietary supplementation with oregano essential oil. Archi. Anim. Nutr. 58: 209-218.

Botsoglou, N.A., S.H. Grigoropoulou, E. Botsoglou, A. Govaris and G. Papageorgiou. 2003. The effects of dietary oregano essential oil and α-tocopheryl acetate on lipid oxidation in raw and cooked turkey during refrigerated storage. Meat Sci. 65: 1193-1200.

Brand, T.S. and J.P. Vandermerwe. 1996. Naked oats (Arena nuda) as a substitute for maize in diets for weanling and grower-finisher pigs. Anim. Feed Sci. Tech. 57: 139-147.

Brannan, R.G. 2008. Effect of grape seed extract on physicochemical properties of ground, salted, chicken thigh meat during refrigerated storage at different relative humidity levels. J. Food Sci. 73: 36–40.

Bremer, J.M., R.S. Scott and C.J. Lintott. 1991. Oat bran and cholesterol reduction: evidence against specific effect. Aust. N.Z.J. Med. 21: 422-426.

Brettonnet, A., A. Hewavitarana, S. Dejong and M.C. Lanari. 2010. Phenolic acids composition and antioxidant activity of canola extracts in cooked beef, chicken and pork. Food Chem. 121: 927-933.

Burdge, G.C. and P.C. Calder. 2006. Dietary α-linolenic acid and health related outcomes: a metabolic perspective. Nutr. Res. Rev. 19: 26-52.

C.I.E. 1978. International commission on illumination, recommendations on uniform color spaces, color difference equations, psycometric color terms. Supplement No. 15 C.I.E. Publication No. 15 (E-1.3.1). Central Bureau of the C.I.E., Paris, France.

Ca´ceres, E., M.L. Garcia and M.D. Selgas. 2008. Effect of pre-emulsified fish oil as source of PUFA n-3 on microstructure and sensory properties of mortadella, a Spanish bologna-type sausage. Meat Sci. 80: 183–193.

Cabanes, A., J. Ouhayoun and S. Gilbert. 1996. Conge´lation de la viande de lapin. Influence de la dure´e de conservation sur les proprie´te´s physico-chimiques et sensorielles (3, 6, 9, 12, 18 mois). Viandes Prod. Carne´s 17: 166-171.

Cagdas, E. and S. Kumcuoglu. 2014. Effect of grape seed powder on oxidative stability of precooked chicken nuggets during frozen storage. J. Food Sci. Technol. DOI 10.1007/s13197-014-1333-7.

Canada Poultry Annual. 2010. Global Agricultural Information Network Report No. CA 0031.

Carlos, M.L., R.C. Mendes and L.N. Maria. 2009. Instrumental texture and sensory characteristics of cod frankfurter sausages. Int. J. Food Proper. 12: 625-643.

Castellini C., A. Dal Bosco and M. Bernardini. 1999. Effect of dietary vitamin E supplementation on the characteristics of refrigerated and frozen rabbit meat. Ital. J. Food Sci. 11: 151-160.

Castellini, C., A. Dal Bosco and M. Bernardini Battaglini. 1999. Effetto dell’integrazione alimentare di acidi grassi polinsaturi della serie (n23) sulla composizione lipidica e sulla stabilita` ossidativa della carne di coniglio. Zootec. Nutr. Anim. 25. 63-70.

Cavani, C. and M. Petracci. 2004. Rabbit meat processing and traceability. p. 1318-1336. In Proc. 8th World Rabbit Congress. Puebla, Mexico.

Cavani, C., M. Bianchi, M. Petracci, .T.G. Toschi, G.P. Parpinello and Kuzminsky. 2004. Influence of open-air rearing on fatty acid composition and sensory properties of rabbit meat. World Rabbit Sci. 12, 247-258.

Cave, N.A. and V.D. Burrows. 1993. Evaluation of naked oat (Arena nuda) in broiler chicken diet. Can. J. Anim. Sci. 73: 393-399.

CDC National Center for Chronic Disease Prevention. 2005. Number of Americans with Diabetes Continues to Increase. In O. o. Communication (Ed.), (Vol. CDC).

Chan, E.J. and L. Cho. 2009. What can we expect from omega-3 fatty acids? Cleve. Clin.J. Med. 76(4).

Charlton, K.E., L.C. Tapsell and M.J. Batterham. 2011. Effect of 6 weeks' consumption of β-glucan-rich oat products on cholesterol levels in mildly hypercholesterolaemic overweight adults. British J. Nutr. 1: 1-11.

Chen, J., J. He, R.P. Wildman, K. Reynolds, R.H. Streiffer and P.K. Whelton. 2006. A randomized controlled trial of dietary fiber intake on serum lipids. Eur. J. Clin. Nutr. 60: 62-68.

Chizzolini, R., E. Zanardi, V. Dorigoni and S. Ghidini. 1999. Calorific value and cholesterol content of normal and low-fat meat and meat products. Trends Food Sci. Tech. 10: 119-128.

Christ, B., K. Lange and H. Jeroch. 1996. Effect of rapeseed oil on fattening performance, carcass yield, nutrient and sensoric parameters of meat of growing rabbits. p. 153-156. In: Proc. 6th World Rabbit Congress, Toulouse, France.

Claeys, E., L. Uytterhaegen, B. Buts and D. Demeyer. 1995. Quantification of beef myofibrillar proteins by SDS-PAGE. Meat Sci. 39: 177–193.

Clydesdale, F.M. 1997. A proposal for the establishment of scientific criteria for health claims for health claims for functional foods. Nutr. Rev. 55: 413-422.

Cobos, A., M.I. Cambero, J.A. Ordon˜ez and L. De La Hoz. 1993. Effect of fat-enriched diets on rabbit meat fatty acid composition. J. Sci. Food Agri. 62: 83-88.

Codex. 1999. Codex standard for edible fats and oils codex“ stan 19 - 1981, Rev. 1999.

Colin, M., N. Raguenes, G. Le Berre, S. Charrier, A.Y. Prigent and G. Perrin. 2005. Influence d'un enrichissement de l'aliment en acides gras oméga 3 provenant de graines de lin extrudées (Tradi-Lin) sur les lipides et les caractéristiques de la viande de lapin. p. 163-166 In Proc. 11èmes Journées Recherche Cunicole, 2005 November, Paris, France.

Colin, M., N. Raguenes, G. Le Berre, S. Charrier, A.Y. Prigent and G. Perrin. 2005. Influence d'un enrichissement de l'aliment en acides gras oméga 3 provenant de graines de lin extrudées (Tradi-Lin®) sur les lipides et les caractéristiques de la viande de lapin. p. 163-166. In Proc: 11èmes Journées de la Recherche Cunicole, Paris.

Collins, F.W. 1986. Oat phenolics: structure, occurrence and function. p. 227-295. In: Webster, F.H. (ed.) Oats: Chemistry and Technology. Am. Association of Cereal Chemists, St. Paul, MN.

Combes, S. 2004. Valeur nutritionnelle de la viande de lapin. INRA Productions Animales. 17: 373-383.

Combes, S. and A. Dalle Zotte. 2005. La viande de lapin: valeur nutritionnelle et particularités technologiques. Proc. 11èmes Journées de la Recherche Cunicole, 29–30 November 2005, Paris, France(pp. 167-180).

Conchillo, A., D. Ansorena and I. Astiasaran. 2005 Intensity of lipid oxidation and formation of cholesterol oxidation products during frozen storage of raw and cooked chicken. J. Sci. Food Agri. 85: 141-146.

Corino, C., F. Filetti, M. Gambacorta, A. Manchisi, S. Magni and G. Pastorelli. 2003. Influence of dietary conjugated linoleic acids (CLA) and age at slaughtering on meat quality and intramuscular collagen in rabbits. Meat Sci. 66: 97-103.

Corino, C., G. Pastorelli, L. Pantaleo, G. Oriani and G. Salvatori. 1999. Improvement of color and lipid stability of rabbit meat by dietary supplementation with vitamin E. Meat Sci. 52: 285-289.

Corino, C., J. Mourot, S. Magni, G. Pastorelli and F. Rosi. 2002. Influence of dietary conjugated linoleic acid on growth, meat quality, lipogenesis, plasma leptin and physiological variables of lipid metabolism in rabbits. J. Anim. Sci. 80: 1020-1028.

Coronado, S.A., G.T. Trout, F.R. Dunshea and N.P. Shah. 2002. Antioxidant effects of rosemary extract and whey powder on the oxidative stability of wiener sausages during 10 months frozen storage. Meat Sci.62: 217-224.

Cosenza, G.H., S.K. Williams, D.D. Johnson, C. Sims and C.H. McGowan. 2003. Development and evaluation of a fermented cabrito snack stick product. Meat Sci. 64: 51-57.

Cross, H.R. and K.E. Belk. 1992. Objective measurements of carcass and meat quality. p. 127-134. In: Proc. 38th ICoMST, Cler-mont-Ferrand, France.

Cunanne, S.C., M.J. Hamadeh and A.C. Liede. 1995. Nutritional attributes of traditional flaxseed in healthy young adults. Am. J. Clin. Nutr. 61: 62-68.

Dal Bosco A., C. Castellini and M. Bernardini. 2001. Nutritional quality of rabbit meat as affected by cooking procedure and dietary vitamin. Eur. J. Food Sci. 66: 1047-1051.

Dal Bosco, A., C. Castellini and D. Mugnai. 2002. Rearing rabbits on a wire net floor or straw litter: Behaviour, growth and meat quality traits. Livest. Prod. Sci. 75: 149-156.

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

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

Dal Bosco, A., C. Mugnai, E. Mourvaki, C. Castellini. 2007. Effet d'un accés au paturage sur le profil des acides gras et le niveau de TBARs de la viande de lapin. In Proc. 12émes Journ. Rech. Cunicole, Le Mans, France (195−198).

Dal Bosco, A., C. Mugnai, V. Roscini, S. Mattioli, S. Ruggeri and C. Castellini. 2014. Effect of dietary alfalfa on the fatty acid composition and indexes of lipid metabolism of rabbit meat. Meat Sci. 96: 606-609.

Dalle Zotte, A. 2002. Perception of rabbit meat quality and major factors influencing the rabbit carcass and meat quality. Livest. Prod. Sci. 75: 11-32.

Dalle Zotte, A. 2004. Avantage diététiques. Le lapin doit apprivoiser le consommateur. Viandes Produits Carnés, 23: 1-7.

Dalle Zotte, A. and G. Paci. 2006. Effetto del tipo genetico paterno, della stagione di macellazione, dell'ordine di parto e del sesso sulle caratteristiche qualitative delle carni di conigli ottenuti secondo il sistema di produzione biologico. p. 55-58. Proc. V Convegno Nazionale dell'Associazione Italiana di Zootecnia Biologica e Biodinamica. Arezzo, Italy.

Dalle Zotte, A. and J. Ouhayoun. 1998. Effect of genetic origin, diet and weaning weight on carcass composition, muscle physico-traits in the rabbit. Meat Sci. 50: 471-478.

Dalle Zotte, A. and M.E. Cossu. 2009. Dietary inclusion of tannin extract from red quebracho trees (Schinopsis spp.) in the rabbit meat production. Ital. J. Anim. Sci. 8: 784-786.

Dalle Zotte, A. and Z. Szendrő. 2011. The role of rabbit meat as functional food. Meat Sci. 88: 31-331.

Dalle Zotte, A., M.E. Cossu and R. Parigi Bini. 2000. Effect of the dietary enrichment with animal fat and vitamin E on rabbit meat shelf-life and sensory properties. In Proc. 46th ICoMST, 2000 August, Buenos Aires, Argentina, 4.II-P8.

Dalle Zotte, A., P. Berzaghi, L. Serva and R. Verdiglione. 2006. Comparison of oven drying with permeable film in substitution to freeze-drying in rabbit meat submitted to chemical analysis. Acta Agraria Kaposvàriensis, 10: 245-249.

Dalle Zotte, A., Z. Princz, A. Metzger, S. Szabó, I. Radnai and E. Biró-Németh. 2009. Response of fattening rabbits reared under different housing conditions. 2. Carcass and meat quality. Livest. Sci. 122. 39-47.

Dam, H. 1957. Influence of antioxidants and redox substances on signs of vitamin E deficiency. Pharmacol. Rev. 9: l-9.

Daniells, S. 2008. European omega-3 market to grow by 24 per cent: analyst. "The European Omega 3 & 6: Beyond High Tides!" http://www.nutraingredients.com/Industry/European-omega-3-market-to-grow-by-24-per-cent-analyst.

Daniels, D.G.H. and H.F. Martin. 1967. Antioxidants in oats: monoesters of caffeic and ferulic acids. J. Sci. Food Agric. 18: 589-595.

Daniels, D.G.H. and H.F. Martin. 1968. Antioxidants in oats: glyceryl esters of caffeic and ferulic acids. J. Sci. Food Agric. 19: 710-712.

Dawkins, N.L., O. Phelps, K.W. McMillin, I.T. Forrester. 1999. Composition and physicochemical properties of chevon patties containing oat bran. J. Food Sci. 64: 597-600.

Dawson, P.L. 2010. Packaging. p. 101-123. In: Sams A.R. (ed.) Poultry Meat Processing.CRC Press, Boca Raton, Florida, USA.

De Carlo, N. 1998. Indagine sulla valorizzazione della qualita` nel settore cunicolo Veneto. p. 1-13 In: Proc. Workshop Il coniglio nell'alimentazione: aspettative dei consumatori eopportunita` per gli operatori. Padova, Italy.

De Smet, S., M. Van Paemel and N. Dierick. 2010. Altering the content of essential nutrients in meats? p. 25-33. Proc. 56th ICoMST, August 15-20, Jeju, Republic of Korea. http://www.icomst.helsinki.fi/ ISBN: 978-89-480-0730-5 93520.

Decker, E.A. and Y. Park. 2010. Healthier meat products as functional foods. Meat Sci. 86: 49-55.

Descalzo, A.M., L. Rossetti, G. Grigioni, M. Irurueta, A.M. Sancho, J. Carrete and N.A. Pensel. 2007. Antioxidant status and odour profile in fresh beef from pasture or grain-fed cattle. Meat Sci. 75: 299–307.

Devendra, K. and V.K. Tanwar. 2011. Utilization of clove powder as phytopreservative for chicken nuggets preparation. J. Stored Prod. Postharvest Res. 2: 11–14.

Diplock, A.T., P.J. Aggett, M. Ashwell, F. Bornet, E.B. Fern and M.B. Roberfroid. 1999. Scientific concepts of functional foods in Europe: consensus document. Brit. J. Nutr. 81: 1-27.

Drozen, M. and T. Harrison. 1998. Structure/function claims for functional foods and nutraceutjcals. Nutraceuticals World. 1: 18.

Dupasquier, C.M.C., A.M. Weber, B.P. Ander, P.P. Rampersad, S. Steigerwald, J.T. Wigle, R.W. Mitchell, E.A. Kroeger, J.S.C. Gilchrist, M.M. Moghadasian, A. Lukas and G.N. Pierce 2006. The effects of dietary flaxseed on vascular contractile function and atherosclerosis in rabbits during prolonged hypercholesterolemia. Am. J. Physiol. Heart Circ. Physiol. 291: 2987-2996.

Dupasquier, C.M.C., E. Dibrov, A.L. Kneesh, P.K.M. Cheung, K.G.Y. Lee, H.K. Alexander, B.K. Yeganeh, M.H. Moghadasian and G.N. Pierce. 2007. Dietary flaxseed inhibits atherosclerosis in the LDL receptor deficient mouse in part through antiproliferative and anti-inflammatory actions. Am. J. Physiol. Heart Circ. Physiol. 293: 2394-2402.

Eiben, C.S., B. Végi, G.Y. Virág, K. Gódor-Surmann, A. Maró, M. Odermatt, E. Zsédely, T. Tóth and J. Schmidt. 2010. Effect of different dietary ratios of sunflower and linseed oils on growth and carcass traits of rabbits. Livest. Sci. 131: 15-22.

El Rabey, H.A., M.N. Al-Seeni and H.M. Amer. (2013). Efficiency of Barley Bran and Oat Bran in Ameliorating Blood Lipid Profile and the Adverse Histological Changes in Hypercholesterolemic Male Rats. BioMed Res. Int. Article ID 263594, 10 pages.

Enser, M., K. Hallett, B. Hewitt, G.A.J. Fursey and J.D. Wood. 1996. Fatty acid content and composition of English beef, lamb and pork at retail. Meat Sci. 42: 443-456.

ES. 2005. Egyptian standard products of meat poultry treated with heat. No. 3493.

FAOSTAT. 2010. http://faostat.fao.org/site/291/default.aspx.

Fasseas, M.K., K.C. Mountzouris, P.A. Tarantilis, M. Polissiou and G. Zervas. 2007. Antioxidant activity in meat treated with oregano and sage essential oils. Food Chem. 106: 1188-1194.

Ferna´ndez-Espla, M.D. and E. O'Neill. 1993. Lipid oxidation in rabbit meat under different storage conditions. J. Food Sci. 58: 1262-1264.

Fernandez, C. and M.J. Fraga. 1996. The effect of dietary fat inclusion on growth, carcass characteristics and chemical composition of rabbits. J. Anim. Sci. 74: 2088-2094.

Fernández-Ginés, J.M., J. Fernández-López, E. Sayas-Barberá and J.A. Pérez-Alvarez. 2005. Meat products as functional foods: A review. J. Food. Sci. 70: 37-43.

Fletcher, D.L. 2004. Further processing of poultry. In: Mead G.C. (ed.) Poultry Meat Processing and Quality. CRC Press, Boca Raton, Florida, USA, 108-134.

Forrester-Anderson, I.T., J. Mcnitt, R. Way and M. Way. 2006. Fatty acid content of pasture-reared fryer rabbit meat. J. Food Compos. Anal. 19: 715-719.

Foti, M., M. Piatelli and M.T. Baratta. 1996 Flavonoids, coumatism, nd cianamic acids as antioxidants in micellar system: structure activity relationship. J. Agri. Food Chem. 44: 497-501.

Gai, F., L. Gasco, H.W. Liu, C. Lussiana, A. Brugiapaglia and G. Masoero. 2009. Effect of diet chestnut tannin supplementation on meat quality, fatty acid profile and lipid stability in broiler rabbits. Ital. J. of Anim. Sci. 8: 787-789.

Gandemer, G., 1998. Lipids and meat quality, lipolysis, oxidation and flavor. p. 106-119. In: Proc. 44th ICoMST, Barcelona, Spain.

Gigaud, V. and S. Combes. 2008. The effect of decreasing the omega 6/omega 3 ratio in feed on fatty acid content of rabbit meat to meet human dietary recommendations. p. 1353-1357. Proc. 9th World Rabbit Congress, Verona, Italy.

Gil, M., J.A. Ramı´rez, M. Pla, B. Arin˜o, P. Herna´ndez and M. Pascual. 2006. Effect of selection for growth rate on the ageing of myofibrils, meat texture properties and the muscle proteolytic potential of m. longissimus in rabbits. Meat Sci. 72: 121-129.

Givens, D. 2005. The role of animal nutrition in improving the nutritive value of animal-derived foods in relation to chronic disease. Proc. Nutr. Soc. 64: 395-402.

Gliger, J., 1983. Natural antioxidants. p. 89-107. In: Allen, J.C. and R.J. Hamilton, (eds.) Rancidity in Foods. Appl. Sci. Publishers.

Glore, S.R., D. Van Treeck, A.W. Knehans and M. Guild. 1994.Soluble fiber and serum lipids: a literature review. J. Am. Diet. Assoc. 94: 425-436.

Gogus, U. and C. Smith. 2010. n-3 Omega fatty acids: A review of current knowledge. Int. J. Food Sci. Tech. 45: 417-436.

Goldberg, I. 1994. Functional foods: Designer Foods, Pharma Foods, Nutraceuticals. Chapman and Hall, NY. USA.

Goldin, B.R. 1990. Intestinal microflora: metabolism of drugs and carcinogens. Ann. Med. 22: 43-48.

Gómez-Conde, M.S., D. Menoyo, S. Chamorro, C.J. López-Bote, P. García-Rebollar and J.C. De Blas. 2006. Conjugated linoleic acid content in cecotrophes, suprarenal and intramuscular fat in rabbits fed commercial diets. World Rabbit Sci. 14: 95-99.

Gondret, F. and M. Bonneau. 1998. Mise en place des caracte´ris-tiques du muscle chez le lapin et incidence sur la qualite´ de la viande. INRA. Prod. Anim. 11: 335-347.

Gondret, F., S. Combes, C. Larzul and H. Rochambeau. 2002. Effects of divergent selection for body weight at a fixed age on histological, chemical and rheological characteristics of rabbits muscles. Livest. Prod. Sci. 76: 81-89.

Harris, W.S. 2007. International recommendations for consumption of long-chain omega- 3 fatty acids. J. Cardiovasc. Med. 8: 50-52.

Hasler, C., S. Kundrat and D. Wool. 2000. Functional Foods in Cardiovascular Disease. Current Atherosclerosis Reports. 2: 467-475.

Heasman, M. 1997. The regulation of functional foods and beverages in Japan. In Proc. 1st Vitafoods Int. Conf. D.E. Blenford, (Ed.) Food Tech. Copenhagen, Europe.

Heller, L. 2009. http://www.nutraingredients-usa.com/Consumer-Trends/Omega-3-foods-will-favor-EPA-DHA-over-ALA-predicts-report.

Herna´ndez, P., L. Guerrero, J. Ramı´rez, W. Mekkawy, M. Pla and B. Arin˜o. 2005. A Bayesian approach to the effect of selection for growth rate on sensory meat quality of rabbit. Meat Sci. 69: 123-127.

Herna´ndez, P., M. Pla and A. Blasco. 1998. Carcass characteristics and meat quality of rabbit lines selected for different objectives: II. Relationships between meat characteristics. Livest. Prod. Sci. 54, 125-131.

Hernàndez, P. 2007. Carne de conejo, ideal para dietas bajas en ácido úrico. Revista Científica de Nutrición. N° 8 Septiembre.Boletín de Cunicultura, 154: 33-36.

Hernàndez, P. and A. Dalle Zotte. 2010. Influence of diet on rabbit meat quality. p. 163-178. In: Nutrition of the rabbit. Edited by C. de Blas, Univesidad Poletenica, Madrid, J. Wiseman, University of Nottingham, UK, (2nd Ed.). ISBN-13:978 1 84593 669 3.

Hernández, P. and F. Gondret. 2006. Rabbit Meat Quality. p. 269-290. In: Maertens, L and P. Coudert (eds.) Recent Advances in Rabbit Sciences. ILVO, Merelbeke, Belgium.

Hernandez, P., M. Pla, M.A. Oliver and A. Blanco. 2000. Relationships between meat quality measurements in rabbits fed with three diets of different fat type and content. Meat Sci. 55: 379-384.

Hernández, P., V. Cesari and A. Blasco. 2008. Effect of genetic rabbit lines on lipid content, lipolytic activities and fatty acid composition of hind leg meat and perirenal fat. Meat Sci. 78: 485-491.

Hernández, P., V. Cesari and M. Pla. 2007. Effect of the dietary fat on fatty acid composition and oxidative stability of rabbit meat. p. 367-370. In Proc. 53rd International Congress of Meat Science and Technology, August, Beijing, China.

Hilliam, M. 1995. The market for healthy and functional confectionery. The World of Ingredients. 8.

Hoz, L., M. D'Arrigo, I. Cambero and J.A. Ordonez. 2004. Development of an n-3 fatty acid and a-tocopherol enriched dry fermented sausage. Meat Sci. 67: 485–495.

Hulot, F. and J. Ouhayoun. 1999. Muscular pH and related traits in rabbits: a review. World Rabbit Sci. 7: 15-36.

Jaturasitha, S., R. Khiaosaard, A. Pongpaew, A. Leowtharakul, S. Saitong, T. Apichatsarangkul, T. Leaungwunta and V. Langani. 2004. The effects of strain, sex, weight and muscle on fat quality of Thai native and crossbred chickens (Kai Baan Thai). p: 137-146. In: Proc. 42nd Annual Conference. Kasetsart University, Bangkok, Thailand.

Jehl, N. and H. Juin. 1999. Effet de l'ˆage d'abattage sur les qualite´s sensorielles de la viande de lapin. Cuniculture 148: 171-174.

Jeun-Hornga, L., L.Yuan-Huib and K. Chun-Chinc. 2002. Effect of dietary fish oil on fatty acid composition, lipid oxidation and sensory property of chicken frankfurters during storage. Meat Sci. 60: 161–167.

Jiménez-Colmenero, F., J. Carballo and S. Cofrades. 2001. Healthier meat and meat products: Their role as functional foods. Meat Sci. 59: 5-13.

Joo, S.T., J.I. Lee, Y.L. Ha and G.B. Park. 2002. Effects of dietary conjugated linoleic acid on fatty acid composition, lipid oxidation, color, and water-holding capacity of pork loin. J. Anim. Sci. 80: 108-112'

Josephson, B. and A. Gyllensward. 1975. Gesamt protein (Biuret methode) Scand. J. Clin. Lab. 9: 29.

Judd, P.A. and A.S. Trusswell. 1981. The effect of rolled oats on blood lipids and fecal steroid excretion in man. Am. J. Clin. Nutr. 34: 2061-2067.

Kawahara, S., S. Takenoyama, K. Takuma, M. Muguruma and K. Yamauchi. 2009. Effects of dietary supplementation with conjugated linoleic acid on fatty acid composition and lipid oxidation in chicken breast meat. Anim. Sci. J. 80: 468-474.

Kerckhoffs, D.A.J.M., G. Hornstra and R.P. Mensink,. 2003. Cholesterol-lowering effect of β-glucan from at bran in mildly hypercholesterolemic subjects may decrease when β-glucan is incorporated into bread and cookies. Am. J. Clin. Nutr. 78: 221-227.

Kerckhoffs, D.A.J.M., G. Hornstra and R.P. Mensink. 2003. Cholesterol-lowering effect of β-glucan from oat bran in mildly hypercholesterolemic subjects may decrease when β-glucan is incorporated into bread and cookies. Am. J. Clin. Nutr. 78: 221-227.

Kitts, D.D., Y.V. Yuan and A.N. Wijewickreme. 1999. Antioxidant activity of the flaxseed lignan secoisolariciresinol diglycoside and its mammalian lignans metabolites enterodiol and enterolactone. Mol. Cell. Biochem. 202: 91-100.

Klag, M.J., D.E. Ford and L.A. Mead. 1993. Serum cholesterol in young men and subsequent cardiovascular disease. N. Engl .J. Med 328: 313-318.

Klag, M.J., D.E. Ford, L.A. Mead, J. He, P.K. Whelton, K.Y. Liang and D.M. Levine. 1993. Serum cholesterol in young men and subsequent cardiovascular disease. N. Engl. J. Med. 328: 313–318.

Kouba, M, F. Benatmane, J.E. Blochet and J. Mourot. 2008. Effect of linseed diet on lipid oxidation, fatty acid composition of muscle, perirenal fat, and raw and cooked rabbit meat. Meat Sci. 80: 829-834.

Kowalska, D. and P. Bielanski. 2009. Meat quality of rabbit fed a diet supplemented with fish oil and antioxidant. Anim. Sci. 27: 139-148.

Kris-Etherton, P.M., W.S. Harris and L.J. Appel. 2003. Omega-3 fatty acids and cardiovascular disease: new recommendations from the American Heart Association. Arterioscler Thromb. Vasc. Biol. 23: 151-152.

Krishnamurthy, S. and J.G. Bieri. 1962. Dietary antioxidants as related to vitamin E function. J. Nutr. 77: 245-252.

Kritchevsky, D., S.A. Tepper, S. Wright, P. Tso and S.K. Czarnecki. 2000. Influence of conjugated linoleic acid (CLA) on establishment and progressions of atherosclerosis in rabbits. J. Am. Coll. Nutr. 19: 472−477.

Kumar, M. and B.D. Sharma. 2003. Soy protein as fat replacer. Fleischwirtsch. Intern. 18: 54-58.

Kwak, N.S. and D.J. Jukes. 2001a. Functional foods. Part 1: The development of a regulatory concept. Food Control. 12: 99-107.

Laemmli, U.K. 1970. Cleavage of structural proteins during the assembly of the head of bacteriophage T4. Nature. 15: 680-685.

Lambertini, L., G. Bergoglio, G. Masoero and A. Gramenzi. 1996. Comparison between Provisal and Hyla rabbit strains. I. Slaughtering performances and muscle composition. p. 195-199. In: Proc. 6th World Rabbit Congress, Toulouse, France.

Larzul, C., F. Gondret, S. Combes and H. Rochambeau. 2005. Divergent selection on 63-day body weight in the rabbit: Response on growth, carcass and muscle traits. Genet. Sel. Evol. 37: 105-122.

Lazzaroni, C., D. Biagini and C. Lussiana. 2009. Fatty acid composition of meat and perirenal fat in rabbits from two different rearing systems. Meat Sci. 83:135-139.

Lebas, F., J. Ouhayoun and D. Delmas. 1988. Effects of hempseed oil cake introduction in rabbit feeding on growth performance and carcass quality. p. 254-259. In: Proc. 4th World Rabbit Congress, Budapest, Hungary.

Lee, J. C., F. Bhora, J. Sun, G. Cheng, E. Arguiri, C.C. Solomides, S. Chatterjee and M. Christofidou-solomidou. 2008. Dietary flaxseed enhances antioxidant defenses and is protective in a mouse model of lung ischemia-reperfusion injury. Am. J. Physiol. Lung Cell. Mol. Physiol. 294: L255–L265.

Lee, P. and K. Prasad. 2003. Effects of flaxseed oil on serum lipids and atherosclerosis in hypercholesterolemic rabbits. J. Cardiovasc. Pharmacol. Ther. 8: 227-235.

Lee, Y.C. and H.S. Ahn. 1977. Studies on lipids and proteins of rabbit meat. I. Emphasis on lipid components of rabbit meat. Korean J. Nutr. 10: 78-86.

Liu, H.W., F. Gai, L. Gasco, A. Brugiapaglia, C. Lussiana and K.J. Guo. 2009. Effects of chestnut tannins on carcass characteristics, meat quality, lipid oxidation and fatty acid composition of rabbits. Meat Sci. 83: 678-683.

Lo Fiego, D.P., P. Maccioni, P. Santoro, R. Rossi, G. Pastorelli and C. Corino. 2005. Influence of conjugated linoleic acid (CLA) on intramuscular fatty acid composition in the rabbit. Ital. J. Anim. Sci. 4: 553-555.

Lo Fiego, D.P., P. Santero, P. Macchioni, D. Mazzoni, F. Piattoni, F. Tassone and E. De Leonibusb. 2004.The effect of dietary supplementation of vitamins C and E on the α-tocopherol content of muscles, liver and kidney, on the stability of lipids, and on certain meat quality parameters of the Longissimus dorsiof rabbits. Meat Sci. 67: 319-327.

Lombardi-Boccia, G., S. Lanzi and A. Aguzzi. 2005. Aspects of meat quality: trace elements and B vitamins in raw and cooked meats. J. Food Comp. Anal. 18: 39-46.

Lopez-Bote, C., A. Rey, J. Ruiz, B. Isabel and R. Sanz Arias. 1997. Effect of feeding diets high in monounsaturated fatty acids and a-tocopheryl acetate to rabbits on resulting carcass fatty acid profile and lipid oxidation. Anim. Sci. 64: 177-186.

Lopez-Bote, C.J., M. Sanz, A. Rey, A. Castaiio and J. Thos. 1998. Lower lipid oxidation in the muscle diets containing oats of rabbits fed. Anim. Feed Sci. Tech. 70: l-9.

Lukefahr, S. D., C.V. Nwosu and D.R. Rao. 1989. Cholesterol level of rabbit meat and trait relationships among growth, carcass and lean yield performances. J. Anim. Sci. 67: 2009-2017.

Maclean, J., A.B. Webster and D.M. Anderson. 1994. Naked oats in grower and finisher diets for male chicken roasters and female turkey broilers. Can. J. Anim. Sci. 74: 135-140.

Maertens L., G. Huyghebaert and E. Delezie. 2008. Fatty acid composition of rabbit meat when fed a linseed based diet during different periods after weaning. p. 1381-1386. In Proc. 9th World Rabbit Congress, 10-13 June, 2008. Verona, Italy.

Marín-Martinez, R., R Veloz-García,., R., Veloz-Rodríguez, S. H., Guzmán-Maldonado, G., Loarca-Pina, A., Cardador-Martinez, L. Guevara-Olvera, R. Miranda-López, I. Torres-Pacheco, C.P. Pérez, G. Herrera-Hernández, F. Villaseñor-Ortega, M. González-Chavira, R.G. Guevara-Gonzalez. 2009. Antimutagenic and antioxidant activities of quebracho phenolics (Schinopsis balansae) recovered from tannery wastewaters. Bioresour. Technol. 100: 434−439.

Marlett, J.A., K.B. Josig, N.W. Vollendorf, F.L. Shinnick, V.S. Haack and J.A. Story. 1994. Mechanism of serum cholesterol reduction by oat bran. Hepatology. 20: 1450-1457.

Marounek, M., V. Skrivanova, A. Dokoupilova, M. Czauderna and A. Berladyn. 2007. Meat quality and tissue fatty acid profiles in rabbits fed diets supplemented with conjugated linoleic acid. Vet. Med. 52: 552−561.

Martin, J.C. and K. Valeille. 2002. Conjugated linoleic acid: All the same or to everyone it own function? Reprod. Nutr. Dev. 42: 525-536.

McNamara, J.R., J. Cohn, P.W. Wilson and E.J. Schaefer. 1990. Calculated values for low-density lipoprotein cholesterol in the assessment of lipid abnormalities and coronary disease risk. Clin. Chem. 36: 36-42.

McNitt, J.I., Z. Negatu and K. McMillin. 2003. Influence of rabbit age, deboner drum aperture, and hind/fore carcass half on mince components of mechanically separated rabbit. J. Muscle Foods. 14: 25-32.

Meilgaard, M.M., G.V. Civille and T. Carr. 2007. Overall difference tests: Does a sensory difference exist between samples? p. 63-104. In: Sensory Evaluation Techniques. (4th Ed.). CRC Press,New York, USA.

Meineri, G., P. Cornale, S. Tassone and P.G. Peiretti. 2010. Effect of Chia (Salvia hispanica L.) seed supplementation on rabbit meat quality, oxidative stability and sensory traits. Ital. J. Anim. Sci. 9: 45-49.

Modi, V.K., N.S. Mahendrakar, N.D. Rao and N.M. Schindra. 2003. Quality of buffalo meat burger containing legume flours as binders. Meat Sci. 66: 144-149.

Møller, A.J. 1980. Analysis of Warner Bratzler shear force pattern with regard to myofibrilar and connective tissue components of tenderness. Meat Sci. 5: 247-260.

Movahedian, A., S. Bordbar-Bonab, M. Rahbani-Nobar, M. Mortazavi, S. Fattahi and H. Dolatkhah. 2013. Effect of omega 3 fatty acids on serum lipid profile, malondialdehyde and paraoxonase activity in patients with end stage renal disease under regular hemodialysis. Int. J. Pharm. Chem. Res. 2: 2278-8700.

Muchenje, V., K. Dzama, M. Chimonyo, P.E. Strydom, A. Hugo and J.G. Raats. 2009. Some biochemical aspects pertaining to beef eating quality and consumer health: A review. Food Chem. 112: 279-289.

Mugnai, C., A. Finzi, C. Zamparini, A. Dal Bosco, E. Mourvaki and C. Castellini. 2008. Pasture availability and genotype effect in rabbit: 3. Performance, carcass and meat characteristics. p. 1405-1409. Proc. 9th World Rabbit Congress, Verona, Italy.

My Svensson, E.B. Schmidt, K.A. Jørgensen and J.H. Christensen. 2008. The effect of n-3 fatty acids on lipids and lipoproteins in patients treated with chronic haemodialysis: a randomized placebo-controlled intervention study. Nephrol. Dial. Transplant. 23: 2918–2924.

Narvaez-Rivas, M., I.M. Vicario, E.G. Constante and M. Leon-Camacho. 2008. Changes in the fatty acid and triacylglycerol profiles in the subcutaneous fat of Iberian ham during the dry-curing process. J. Agri. Food Chem. 56: 7131-7137.

Naveena, B.M., A.R. Sen, S. Vaithiyanathan, Y. Babji and N. Kondaiah. 2008. Comparative efficacy of pomegranate juice, pomegranate rind powder and BHT in cooked chicken patties. Meat Sci. 80: 1304–1308.

Negatu, Z., J.I. Mcnitt and K.W. McMillin. 2006. Determination of small bone fragments in mechanically separated rabbit meat. J. Muscle Foods. 17: 185-197.

Nelson, D.L. and M.M. Cox. 2005. Lehninger principles of biochemistry, 4th edition. W.H. Freeman and Company. New York, NY.

Newairy A.A. and H.M. Abdou. 2009. Protective role of flax lignans against lead acetate induced oxidative damage and hyperlipidemia in rats. Food Chem. Toxicol. 47: 813–8.

Nounou, H.A., M.M. Deif and M.A. Shalaby. 2012. Effect of flaxseed supplementation and exercise training on lipid profile, oxidative stress and inflammation in rats with myocardial ischemia. Lipids Health Dis. 11:129.

Ntawubizi, M., E. Colman, S. Janssens, K. Raes, N. Buys and S. De Smet. 2010. Genetic parameters for intramuscular fatty acid composition and metabolism in pigs. J. Anim. Sci. 88: 1286-1294.

Ohr, L.M. 2005. Nutraceuticals and functional foods. Food Tech. 59: 63-65.

Othman, R.A., M.H. Moghadasian and P.J.H. Jones. 2011. Cholesterol- lowering effects of oat β-glucan. Nutr. Rev. 69: 299-309.

Ouhayoun, J. and A. Dalle Zotte. 1993. Muscular energy metabolism della carcassa e and related traits in rabbit. World Rabbit Sci. 1: 96-107.

Ouhayoun, J. and R. Rouvier. 1973. Composition corporelle et degre´ de maturite´ en poids de lapereaux de plusieurs ge´notypes. In: Proceeding of the Journees de Recherches avicoles et cunicoles, Paris.

Ouhayoun, J., D. Delmas and B. Poujardieu. 1989. La viande de lapin. Effet des conditions de re´frige´ration et de conservation des carcasses sur le pH musculaire et les pertes de poids. Viandes Prod. Carne´s. 10: 87-89.

Paci, G., A. Schiavone and M. Marzoni. 2001. Influence d'un extrait végétal naturel (oléuropéine) sur les processus oxydatifs de la viande de lapin: premiers résultats. p. 27-30. Proc. 9èmes Journées de la Recherche Cunicole, Paris, France, 28-29 Novembrer.

Parigi Bini, R., G. Xiccato, A. Dalle Zotte and A. Carazzolo. 1994. Fibre alimentaire sur l'utilisation digestive e la qualite´ bouche`re chez le lapin. p. 347-354. In: Proc. 6e`mes Journe´es de la Recherche Cunicole. La Rochelle, France, 6-7 De´cembre, 2.

Peiretti, P.G. and F. Gai. 2009. Fatty acid and nutritive quality of chia (Salvia hispanica L.) seeds and plant during growth. Anim. Feed Sci. Tech: 148: 267-275.

Peiretti, P.G. and G. Meineri. 2008a. Effects on growth performance, carcass characteristics, and the fat and meat fatty acid profile of rabbits fed diets with chia (Salvia hispanica L.) seed supplements. Meat Sci. 80: 1116-1121.

Peiretti, P.G. and G. Meineri. 2008b. Effects of diets with increasing levels of Spirulina platensis on the performance and apparent digestibility in growing rabbits. Livest. Sci. 118: 173-177.

Peiretti, P.G. and G. Meineri. 2009. Effects of two antioxidants on themorpho-biometrical parameters, apparent digestibility and meat composition in rabbits fed low and high fat diets. J. Anim.Vet. Adv. 8: 2299-2304.

Perlo, F., P.G. Bonato, R. Teira and S. Kueider. 2006. Physicochemical and sensory properties of chicken nuggets with washed mechanically deboned chicken meat: Research note. Meat Sci. 72: 785-788.

Peters, F.N. and S. Musher. 1937. Oat flour as an antioxidant. Ind. Eng. Chem. 29: 146-151.

Petracci, M., M. Bianchi and C. Cavani. 2009. Development of rabbit meat products fortified with n–3 polyunsaturated fatty acids. Nutrients. 1: 111–118.

Pla, M. 2008. A comparison of the carcass traits and meat quality of conventionally and organically produced rabbits. Livest. Sci. 115: 1-12.

Pla, M. and C. Cervera. 1997. Carcass and meat quality of rabbits given diets having a high level of vegetable or animal fat. Anim. Sci. 65: 299-303.

Pla, M., M. Pascual and B. Ariño. 2004. Protein, fat and moisture content of retail cuts of rabbit meat evaluated with the NIRS methodology. World Rabbit Sci. 12: 149-158.

Pla, M., M. Piles and J.J. Valdevira. 1997. Peso adulto y dimorfismo sexual de dos lı´neas sinte´ticas de conejo. Informacio´nTe´cnica Econo´ - mica Agraria. 18: 342-344.

Pokomy, J. 1991. Natural antioxidants for food use. Trends Food Sci. Tech. 2: 223-227.

Poławska1, E. Dariusz Lisiak, Artur Jóźwik, Mariusz Pierzchała, Nina Strzałkowska, Janusz Pomianowski, Anna Wójcik. 2012. The effect of the diet supplementation with linseed and rapeseed on the physico-chemical and sensory characteristics of ostrich meat. Anim. Sci. Pap. Rep. 30: 65-72.

Prasad, K. 1997. Dietary flax seed in prevention of hypercolesterolemic atherosclerosis. Atherosclerosis. 132: 69-76.

Prasad, K. 2005. Hypochelesterolemic and antiatherosclerotic effect of flax lihnan complex isolated from flaxseed. Atherosclerosis. 179: 269-275.

Press, V., I. Freestone and C.F. George. 2003. Physical activity: the evidence of benefit in the prevention of coronary heart disease. Q. J. Med. 96: 245-251.

Preziuso, G., A. Dalle Zotte, M. D'agata, C. Russo and G. Paci. 2008. Effect of outdoor rearing system, in floor cage, on meat quality of slow growing rabbits. p. 1431-1435. Proc. 9th World Rabbit Congress, Verona, Italy.

Raimondi, R., M.T. Auxilia, G. Masoero and C. De Maria. 1974. Effetto dellla grassatura dei mangimi sulla produzione di carne di coniglio. 1 — Accrescimento, consumo alimentare, resa alla macellazione. Ann. Ist. Sperim. Zootec. 7: 217–235.

Ramadan, M.F., M.M.S. Asker and Z.K. Ibrahim. 2008. Functional bioactive compounds and biological activities of Spirulina platensis lipids. Czech J. Food Sci. 26: 211-222.

Ramı´rez, J.A., M.A. Oliver, M. Pla, L. Guerrero, B. Arin˜o and A. Blasco. 2004. Effect of selection for growth rate on biochemical, quality and texture characteristics of meat from rabbits. Meat Sci. 67: 617-624.

Ramírez, J.A., I. Díaz, M. Pla, M. Gil, A. Blasco and M.A. Oliver. 2005. Fatty acid composition of leg meat and perirenal fat of rabbits selected for growth rate. Food Chem. 90: 251-256.

Reuter, H.D., H.P. Koch and L.D. Lawson. 1996. Therapeutic effects and applications of garlic and its preparations. p. 162-172. In: Koch H.P. and L.D. Lawson (eds.) Garlic: the science and therapeutic application of *Allium sativum L.* and related species. Baltimore.Williams and Wilkins.

Reyes-Caudillo, E., A. Tecante and M.A. Valdivia-López. 2008. Dietary fibre content and antioxidant activity of phenolic compounds present in Mexican chia (Salvia hispanica L.) seeds. Food Chem. 107: 656-663.

Rhee, Y. and A. Brunt. 2009. Flaxseed lignan increased glucose uptake by human red blood cells. The Open Nutraceuticals J. 2: 81-85.

Roa, V and Tapia, M.S. 1998. Estimating water activity in systems containing multiple solutes based on solute properties. J. Food Sci. 63: 559 -564.

Rochambeau de, H. 1997. Genetics of the rabbit for meat production: what's new since the world rabbit congress held in Budapest in 1988? A review. World Rabbit Sci. 5: 77-82.

Romans, J.R., I.S. Palmer, D.R. Wenger, W.J. Costello, H.J. Tuma and R.C. Wahlstrom. 1974. Pre slaughter treatment affecting intramuscular and plasma lipid. 1— Effect of ACTH in rabbits. J. Anim. Sci. 38: 32-42.

Rossanderhulthen, L., A. Gleerup and L. Hallberg. 1990. Inhibitory effect of oat products on non-heme iron-absorption in man. Eur. J. Clin. Nutr. 44: 783-791.

Ruberfroid, M. 1993. Dietary fiber, inulin and oligofrutose: A review. Comparing their physiological effects. Crit. Rev. Food Sci. Nutr. 33: 1303-1348.

Rudolph, W. and W. Fischer. 1979. Carcass quality of broiler rabbits 86 and 100 days of age. Arch. Tierzucht. 22: 201-207.

Ruiz, J.A., A.M.P. Vendrell and E.E. Garcia. 1999. Effect of beta-carotene and vitamin E on oxidative stability in leg meat of broilers fed different supplemental fats. J. Agric. Food Chem. 47: 448–454.

Rymer, C. and D.I. Givens. 2005. N-3 fatty acid enrichment of edible tissue of poultry. A review. Lipids. 40: 121-30.

Sallama, Kh., I., M. Ishioroshib and K. Samejima. 2004. Antioxidant and antimicrobial effects of garlic in chicken sausage. Lebensm. Wiss. U. Tech. 37: 849-855.

Salma, U., A.G. Miah, T.M. Maki Nishimura and H. Tsujii. 2007. Effect of dietary Rhodobacter capsulatus on cholesterol concentration and fatty acid composition in broiler meat. Poult. Sci. 86: 20−1926.

Sawashita, N, A. Naemura and M. Shimizu. 2006. Effect of dietary vegetable and animal proteins on atherothrombosis in mice. Nutrition. 661-667.

Schmedes, A. and G. Holmer. 1989. A new thiobarbituric acid (TBA) method for determination of free malonaldehyde (MDA) and hydroperoxides selectivity as a measure of lipid peroxidation. J. Am. Oil Chem. Soc. 66: 813-817.

Shakir, K.A.F. and B. Madhusudhan. 2007. Hypocholesterolemic and hepatoprotective effects of flaxseed chutney: evidence from animal studies. Ind. J. Clin. Biochem. 22: 117-121.

Shidfar, F., A. Keshavarz, S. Hosseyni, A. Ameri and S. Yarahmadi. 2008. Effects of omega-3 fatty acid supplements on serum lipids, apolipoproteins and malondialdehyde in type 2 diabetes patients. East. Mediterr. Health J. 14: 305-313.

Simopoulos, A. P. 2002. The importance of the ratio of omega-6/omega-3 essential fatty acids. Biomed. Pharmacother. 56: 365−379.

Simopoulos, A.P. 2000. Human requirement for n-3 polyunsaturated fatty acids. Poult. Sci. 79: 961-970.

Smith, D.P. and J.C. Acton. 2010. Marination, cooking, and curing of poultry products. p. 311-336. In: Sams A.R. (ed.) Poultry Meat Processing. CRC Press, Boca Raton, Florida, USA.

Sohaib, M. F.M. Anjum, M.I. Khan, M.S. Arshad and M. Shahid. 2012. Enhancement of lipid stability of broiler breast meat and meat products fed on alpha lipoic acid and alpha tocopherol acetate supplemented feed. Lipids Health Dis. 11:5.

Soultos, N., Z. Tzikas, E. Christaki, K. Papageorgiou and V. Steris. 2009. The effect of dietary oregano essential oil on microbial growth of rabbit carcasses during refrigerated storage. Meat Sci. 81: 474-478

St. Angelo, A.J. 1996. Lipid oxidation in foods. Crit. Rev. Food Sci. Nutr. 36:175-224.

Stanley, J.C., R.L. Elsom, P.C. Calder, B.A. Griffin, W.S. Harris, S.A. Jebb, J.A. Lovegrove, C.S. Moore, R.A. Riemersma and T.A.B. Sanders. 2007. The effects of the dietary n-6/n-3 fatty acid ratio on cardiovascular health. UK Food Standards Agency Workshop Report: Brit. J. Nutr. 98: 1305-1310.

Steel, R.G.D., J.H. Torrie and D.A. Dicky. 1997. Principles and procedures of statistics. A biometrical approach. (3rd Ed.). McGraw Hill Book Co. Inc., New York.

Stevenson, D.G., G.E. Inglett, D. Chen, A. Biswas, F.J. Eller and R.L. Evangelista. 2008 Phenolic content and antioxidant capacity of supercritical carbon dioxide-treated and air-classified oat bran concentrate microwave-irradiated in water or ethanol at varying temperatures. Food Chem. 108: 23-30.

Stockbridge, H., R.I. Hardy and C.J. Glueck. 1989. Photometric determination of cholesterol (CHOD-PAP method). J. Lab. Clin. Med. 114:142-151.

Sunki, G.R., R. Annapureddy and D.R. Rao. 1978. Microbial, biochemical and organoleptic changes in ground rabbit meat stored at 5 to 78 ^{o}C. J. Anim. Sci. 46: 584-588.

Szabó, A., H. Fébel, A, Dalle Zotte, M. Mézes, Z. Szendrő and R. Romvári. 2004a. Reversibility of the changes of rabbit muscle fatty acid profile. Ital. J. Food Sci. 16: 69-77.

Szabó, A., R. Romvári, H. Fébel, P. Bogner and Z. Szendrő. 2002. Training-induced alterations of fatty acid profile of rabbit muscle. Acta Veterinaria Hungarica, 50: 357-364.

Szendro, Z., I. Radnai, E. Biro´-Ne´meth, R. Romva´ri and G. Milisits. 1996a. The effect of live weight on the carcass traits of rabbits between 2.2–3.5 kg. p. 263-267 In: Proc. 6th World Rabbit Congress, Toulouse, France.

Taga, M.S., E.E. Miller and D.E. Pratt. 1984. Chia seeds as a source of natural lipid antioxidants. J. Am. Oil. Chem. Soc. 61: 928-931.

Tai, E.S., D. Corella, S. Demissie, L.A. Cupples, O. Coltell, E.J. Schaefer, K.L. Tucker, J.M. Ordovas. 2005. Polyunsaturated fatty acids interact with the PPARA-L162V polymorphism to affect plasma triglyceride and apolipoprotein C-III concentrations in the Framingham Heart Study. J. Nutr. 135: 397−403.

Talukder, S. and D.P. Sharma. 2010. Development of dietary fiber rich chicken meat patties using wheat and oat bran. J. Food Sci. Technol. 47: 224-229.

Tarasewicz, Z., M. Piech, D. Szczerbi´nska, A. Da´nczak, K. Romaniszyn. 2001. Wpływ owsa nieoplewionego na uz˙ytkowos´c´ rzez´na˛ młodych przepiórek japon´skich [Effect of naked Atos on slaughter efficiency of young Japanese quails]. Zesz. Nauk. PTZ 57: 195–205.

Taylor, C.S. 1985. Use of genetic size-scaling in evaluation of animal growth. J. Anim. Sci. 61: 118-143.

Theodoratou, E., G. McNeill, R. Cetnarskyj, S.M. Farrington, A. Tenesa, R. Barnetson, M. Porteous, M. Dunlop and H. Campbell. 2007. Dietary fattyacids and colorectal cancer: a case-control study. Am. J. Epidemiol. 166: 181– 195.

Tres, A., R. Bou, R. Codony and F. Guardiola. 2008. Influence of dietary doses of n-3- or n-6 rich vegetable fats and α-tocopheryl acetate supplementation on raw and cooked rabbit meat composition and oxidative stability. J. Agri. Food Chem. 56: 7243-7253.

Troller, J.A. and J.H.B. Christian. 1978. Water Activity and Food, Academic Press, New York.

Truswell, A.S. 1995. Dietary fibre and plasma lipids. Eur. J. Clin. Nutr. 49: 105-109.

Turnbull, A.S. and A.R. Reeds. 1989. The effect of rolled oats and a reduced fat modified diet on Apo lipoprotein AI and B.J. Clin. Nutr. Gastroenterol. 1: 15-19.

Ubhayasekera, S.J.K.A., A. Tres, R. Codony and P.C. Dutta. 2010. Effect of different levels of transfatty acids and oxidised lipids in diet on cholesterol and cholesterol oxidation products formation in rabbit. Food Chem. 121: 1198-1202.

Valencia, I., M. O'Grady, D. Ansorena, I. Astiasarán and J. Kerry. 2008. Enhancement of the nutritional status and quality of fresh pork sausages following the addition of linseed oil, fish oil and natural antioxidants. Meat Sci. 80: 1046-1054.

Valsta, L.M., H. Tapanainen and S. Männistö. 2005. Meat fats in nutrition. Meat Sci. 70: 525-530.

Vekiari, S.A., V. Oreopoulou, C. Tzia and C.D. Thomopoulos. 1993. Oregano flavonoide as lipid antioxidants. J. Am. Oil Chem. Soc. 70: 483-487.

Verbeke, W., F.J.A. Pérez-Cueto, M.D. de Barcellos, A. Krystallis and K.G. Grunert. 2010. European citizen and consumer attitudes and preferences regarding beef and pork. Meat Sci. 84: 284−292.

Verdelhan, S., A. Bourdillon, B. Renouf and E. Audoin. 2005. Effet de l'incorporation de 2% d'hulie de lin dans l'aliment sur les performances zootechniques et sanitaries de lapins en croissance. In Proc.: 11èmes Journées de la Recherche Cunicole, Paris. 209-211.

Von, S.C., P. Angerer, W. Kothny, K. Theisen and H. Mudra. 1997. Study on Prevention of Coronary Atherosclerosis with Marine Omega-3 fatty acids (SCIMO)—first results of a randomized double blind study. Can. J. Cardiol., 13(suppl):42B (abstr).

Warris, P.D. 2000. Meat Science. An Introductory Text. (2nd Ed.). CABI Publishing, Wallinford, Oxon, UK.

Weiss, J., M. Gibis, V. Schuh and H. Salminen. 2010. Advances in ingredient and processing systems for meat and meat products. Meat Sci. 86: 196-213.

White, P.J. and L.S. Armstrong. 1986. Effect of selected oat sterols on the deterioration of heated soybean oil. J. Am. Oil Chem. Soc. 63: 525-529.

Whitney, E. N. and S.R. Rolfes. 2002. Understanding nutrition (9th Ed.). Belmont, CA: Wadsworth/Thomson Learning.

Williams, D.S., M. Verghese, L.T. Walker, J. Boateng, L.A. Shackelford, M. Guyton, J. Jones, J. Khatiwada and C.B. Chawan. 2008. Chemopreventive effects of flaxseed oil and flax seed meal on azoxymethane-induced colon tumors in fisher 344 male rats. Int. J. Cancer Res. 2: 28–40.

Williams, P. 2007. Nutritional composition of red meat (http://ro.uow.edu.au/hbspaprers/48)

Wood, J.D., M. Enser, A.V. Fisher, G.R. Nute, P.R. Sheard and R.I. Richardson. 2008. Fat deposition, fatty acid composition and meat quality: A review. Meat Sci. 78: 343-358.

Wood, J.D., M. Enser, A.V., Fisher, G.R. Nute, P.R. Sheard, R.I. Richardson, S.I. Hughes, F.M. Whittington. 2008. Fat deposition, fatty acid composition and meat quality: A review. Meat Sci. 78: 343−358.

Wood, J.D., R.I. Richardson, G.R. Nute, A.V. Fisher, M.M. Campo, E. Kasapidou, P.R. Sheard and M. Enser. 2004. Effects of fatty acids on meat quality: a review. Meat Sci. 66: 21-32.

Woods, V.B. and E.A. Fearon. 2009. Dietary sources of unsaturated fatty acids for animals and their transfer into meat, milk and eggs, a review. Livest. Sci. 126: 1–20.

Xiccato, G. and A. Trocino. 2003. Role of dietary lipid on digestive physiology immune system and growth in rabbits. Cost 848, Agriculture and Biotechnology, Praga, Czech Republic. 48-57.

Yadav, P.L. and M.K. Sanyal. 1996. Development of livestock products bycombination preservation technique. In Proc. National seminar on food preservation by hurdle technology and related areas. Mysore, India: DFRL. 104–109.

Youssef, M.K. and S. Barbut 2009. Effects of protein level and fat/oil onemulsion stability, texture, microstructure and color of meat batters. Meat Sci. 82: 228−233.

Zhang, W., S. Xiao, H. Samaraweera, E.J. Lee and D.U. Ahn. 2010. Improving functional value of meat products. A review. Meat Sci. 86: 15-31.

Zsédely, E., T. Tóth, C. Eiben, G. Tóbiás, K. Gódor-Surmann, B. Végi, G. Virág and J. Schmidt. 2006. Influence of sunflower and linseed oil addition in rabbit feed. 2. Composition and fatty acids profile of the meat and liver p. 59-65. 18th Hungarian Conf. on Rabbit Production, Kaposvár (Hungary).

Zsédely, E., T. Tòth, C. Eiben, G. Viràg, J. Fàbià and J. Schmidt. 2008. Effect of dietary vegetable oil (sunflower, linseed) and vitamin E supplementation on the fatty acid composition, oxidative stability and quality of rabbit meat. p. 1473-1477. In Proc. 9th World Rabbit Congress, June 10-13, Verona, Italy.

Zuidhof, M.J., M. Betti, D.R Korver, F.I.L. Hernandez, B.L. Schneider, V.L. Carney and R.A. Renema. 2009. Omega-3-enriched broiler meat: 1. Optimization of production system. Poult. Sci. 88: 1108–1120.