ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

**PhD THESIS**

**Mustafa mohammad MONAZEL ALSHDAIFAT**

# EFFECT OF FISH OIL SUPPLEMENTATION DURING GESTATION ON MATERNAL AND OFFSPRING PERFORMANCE IN AWASSI SHEEP

**DEPARTMENT OF ANIMAL SCIENCE**

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**ÇUKUROVA UNIVERSITY**
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We certify that the thesis titled above was reviewed and approved for the award of degree of the Doctorate of Science by the board of jury on 10/11/2010.

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## ABSTRACT

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A study was conducted to evaluate the effects of feeding Omega-3 during pregnancy on maternal performance, lamb birth weight, colostrums production and quality, milk production and composition, postpartum lambs performance and milk fatty acid profile of Awassi ewes. Fat sources used in this study were palm oil (PO) and fish oil (FO). One hundred Awassi ewes (BW=57±1.5 kg, age=3.5±1.2 years), were randomly assigned to four dietary treatments. Treatments were 1) diet containing PO from 0-150 days of pregnancy (PO; n = 25), 2) diet containing PO from 0-65 days of pregnancy, then diet containing FO 66-150 days of pregnancy (POFO; n = 25), 3) diet containing FO from 0-65 days of pregnancy, then diet containing PO from 66-150 days of pregnancy (FOPO; n = 25) and 4) diet containing FO from 0-150 days of pregnancy (FO; n = 25). Animals were housed with three replicates per treatment.

The including FO into diet during pregnancy especially in the late gestation period increased birth weight, gestation length and colostrums IgG content, but decreased colostrums production, and lowered percentage of milk fat and milk protein. Also, it decreased saturated fatty acids and increased polyunsaturated fatty acids especially omega-3 polyunsaturated fatty acids, of docosahexaenoic acid, eicosapentaenoic acid and conjugated linoleic acid.

**Keywords:** Ewes, Maternal feeding, Fish oil, Colostrum, Omega 3, Performance.

# ÖZ

## DOKTORA TEZİ

**İVESİ KOYUNLARINDA GEBELİK DÖNEMİNDE RASYONA BALIK YAĞI İLAVESİNİN MATERNAL VE KUZU PERFORMANSLARI ÜZERİNE ETKİSİ**

**Mustafa mohammad MONAZEL ALSHDAIFAT**

**ÇUKUROVA ÜNİVERSİTESİ**
**FEN BİLİMLERİ ENSTİTÜSÜ**
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Mevcut çalışmaİvesi koyunlarında gebelik döneminde Omega-3 ile beslemenin performans, kuzu doğum ağırlığı, kolostrum üretimi ve kalitesi , süt üretimi ve kompozisyonu, doğum sonrası kuzu performansı ve süt yağ asidi profile üzerine etkisini belirlemek için yürütülmüştür. Omega-3 yağ kaynağı olarak balık yağı (FO), kontrol olarak ise hurma yağı kullanılmıştır. Gebelik dönemi 0-65. gün ile 66-150. gün şeklinde 2 periyota ayrılmıştır. Yağ kaynakları gebeliğin ilk yarısında toplam karışım rasyonda %2.4, ikinci yarısında ise %2.1 oranında kullanılmıştır. Çalışmada oluşturulan muameleler gebelik boyunca (0-150 gün) hurma yağı verilen koyunlar (PO; n = 25), 2) gebeliğin 0-65 günü hurma yağı alan ve 66-150 günü balık yağı alan koyunlar (POFO; n = 25), 3) gebeliğin 0-65 günü balık yağı, 66-150 gün hurma yağı alan koyunlar, (FOPO; n = 25), 4) gebelik boyunca (0-150) balık yağı alan koyunlar (FO; n = 25) şeklinde olmuştur. Hayvanlar her bir muamele grubu için 3 tekerrürlü olacak şekilde barındırılmış ve böylece her bir muamele 3 alt gruba bölünmüştür.

Özellikle gebeliğin ikinci yarısındarasyona FO'nun dahil edilmesi doğum ağırlığını, gebelik süresini ve kolostrum IgG içeriğini arttırmıştır. Ayrıca, kuzuların ölüm oranı sayısal olarak azalmıştır. Gebelik döneminde rasyonda balık yağı kullanılması süt doymamış yağ asit oranını arttırmış ve özellikle omega 3 çoklu doymamış yağ asitleri, dokosaheksaenoik asit, eikosapentaenoik asit ve konjüge linoleik asit gibi çoklu doymamış yağ asit düzeylerinin arttığı saptanmıştır.

**Anahtar Kelimeler:** Koyunlar, Gebelik beslemesi, Balık yağı, Kolostrum, Omega 3, Performans.

## EXTENDED ABSTRACT

A study was conducted to evaluate the effects of feeding Omega-3 during gestation on maternal performance, lamb birth weight, colostrums production and quality, milk production and composition, postpartum lambs performance and milk fatty acid profile of Awassi ewes. Fat sources used in this study were palm oil (PO) and fish oil (FO) and they were used in 2.4% DM during early stage of gestation and in 2.1% DM during late stage of gestation.

One hundred mature Awassi ewes at 2-4 years of age, parity ranging from 1 to 3 and body weight 57±1.5 kg were randomly assigned to four dietary treatments. Treatments were 1) diet containing PO from 0-150 days of pregnancy (PO; *n* = 25), 2) diet containing PO from 0-65 days of pregnancy, then diet containing FO 66-150 days of pregnancy (POFO; *n* = 25), 3) diet containing FO from 0-65 days of pregnancy, then diet containing PO from 66-150 days of pregnancy (FOPO; *n* = 25) and 4) diet containing FO from 0-150 days of pregnancy (FO; *n* = 25). Animals were housed with three replicates per treatment, each treatment was divided to three subgroups (first two groups contained 8 ewes, third groups contained 9 ewes).

After birth ewes with their lambs were housed with three replicates per treatment, every treatment divided to three subgroups in shaded pens (12 m ×6 m) and all pens have an area for creep feeding. At the end of nursing period, lambs were separated from their dams, and continue with the same ewes groups to milking period and fattening for ram lambs, thirty two (average age = 70±0.99 d) Awassi ram lambs (average BW = 19 ±1.7 kg) were assigned to the same diet. All lambs were separated to four groups (8 lamb/group) as the ewes group. After lambing diets were formulate without FO and/or PO and to be isonitrogenous and the same for all ewes and lambs. Diets were mixed every day, were sampled for laboratory analysis to ensure consistency in their chemical composition (triplicate).

Ewes with their lambs were housed as groups. Experimental diets are adequate for nursing ewes (NRC, 2007).

The study lasted 11 months in total; 5 months of pregnancy, 4 months of nursing and milking period and 2 months of fattening period. During pregnancy period ewes were weighed monthly before morning feeding. Pregnancy, lambing, abortion and mortality were recorded. During nursing and milking period ewes and lamb intake was measured and weight were recorded, average daily gain before weaning calculated using the biweekly body weights for each lamb. Colostrum and milk yield was measured, colostrum was analyzed for solids not fat, fat, crude protein and immunoglobulin G. Milk was analyzed for solids not fat, fat, crude protein and fatty acids composition. During fattening period the daily dry matter intake, average daily gain and mortality were measured.

The including FO into diet during pregnancy especially in the late gestation period increased birth weight, gestation length and colostrums IgG content, but decreased colostrums production, and lowered percentage of milk fat and milk protein. Also, it decreased mortality of their lambs numerically. However, the reduction in milk production and composition were over short timescale.

About the milk fat content of ewes the including FO in Awassi ewes during pregnancy especially in late gestation period decreased saturated fatty acids and increased polyunsaturated fatty acids especially omega-3 polyunsaturated fatty acids, of docosahexaenoic acid, eicosapentaenoic acid and conjugated linoleic acid.In milk FA profile, the maternal dietary composition affected the FAs profile of milk in dietary ewes, our results show that it is possible to enhance ewes milk in n-3 PUFAs, CLA, EPA and DHA, by inclusion of FO in ewes diet during late gestation, which is considered beneficial to human health. Also, these findings support ideas that high transfer efficiencies into ewes milk for EPA and DHA than other species and/ or than other n-3 PUFA sources.

In conclusion, the addition of FO at 2.1% DM, in late pregnancy period, could be used as sheep feed additive for improve birth weight, colostrums IgG

concentration and milk poly unsaturated fatty acids content, with decreased the abortion and mortality rates numerically. Without any adversely affect on animal health or nutrient intakes during pregnancy period.
Keywords: Ewes, maternal feeding, fish oil, colostrum, omega 3, performance.

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**CONTENTS** PAGE

**LIST OF TABLES** **PAGE**

**LIST OF FIGURE** **PAGE**

## LIST OF ABBREVIATIONS

| | |
|---|---|
| AA | : Arachidonic acid |
| ADF | : Acid detergent fiber |
| ADG | : Average daily gain |
| ADGW | : Average daily gain before weaning |
| ALA | : α-linolenic acid |
| BWC | : Body weight change |
| BW | : Body weight |
| $CH_4$ | : Methane |
| CHD | : Coronary heart disease |
| CLA | : Conjugated linoleic acid |
| CL | : Corpus luteum |
| CSFAs | :Calcium salts of fatty acids |
| DHA | : Docosahexaenoic acid |
| DM | : Dry matter |
| DMI | : Dry matter intake |
| DPA | : Docosapentaenoic acid |
| $E_2$ | : Oestradiol |
| EFA | : Essential fatty acids |
| EPA | : Eicosapentaenoic acid |
| FA | : Fatty acid |
| F:C | : Forage to concentrate ratio |
| FM | : Fishmeal |
| FO | : Fish oil |
| GLA | : γ-linolenic acid |
| GR | : Growth rate |
| IFNT | : Trophoblast interferon |

| | |
|---|---|
| Ig | : Immunoglobulin |
| IGF | : Insulin-like growth factor |
| LA | : linoleic acid |
| LCFA | : Long chain fatty acids |
| MCFA | : Medium chain fatty acids |
| MFD | : Milk fat depression |
| MR | : Milk replacer |
| MUFA | : Monounsaturated fatty acids |
| n-3 | : Family of ω-3 fatty acids |
| n-6 | : Family of ω-6 fatty acids |
| NDF | : Neutral detergent fiber |
| NEFA | : Non esterified fatty acids |
| NFC | : Non-fibrous carbohydrates |
| NRC | : The National Research Council |
| OA | : Oleic acid |
| $P_4$ | : Progesterone |
| PA | : Palmitic acid |
| $PGF_{2\alpha}$ | : Prostaglandin $F_{2\alpha}$ |
| PUFA | : Polyunsaturated fatty acids |
| P:S | : Ratio of polyunsaturated fatty acids to saturated fatty acids |
| RA | : Rumenic acid |
| SAO | : Safflower oil |
| SCC | : Somatic cell content |
| SCFA | : Short chain fatty acids |
| SFA | : Saturated fatty acids |
| SNF | : Solids-not-fat |
| SO | : Soybean oil |
| StAR | : Steroid-genic acute regulatory protein |

| | |
|---|---|
| TG | : Triglycerides |
| TMR | : Total mixed ration |
| TS | : Total solids |
| USFA | : Unsaturated fatty acids |

XIX

# 1. INTRODUCTION

The Awassi sheep is the native local breed in Jordan and in the semi-arid areas of the Near East countries including Turkey. This breed is raised for its meat, milk, and wool. It has been introduced to more than 30 countries (Galal et al. 2008). Awassi breed is preferable in this area because they tolerant to harsh environmental conditions, and has other favourable traits including diseases and parasites resistance, the ability to walk for long distances while grazing, inherent strong flock instinct, and being adapted to fluctuations in management, especially those related to scarcity of feed and high temperatures (Gürsoy 2005). Awassi rams reach puberty at around 8 months, and ewes reach by the age of 9 months. The breeding season of Awassi ewes starts in April and lasts through September. The gestation length varies from 149 to 155days (average 152days). Under natural conditions, undergo a postpartum anoestrus which results in only one offspring per year (Abu Zanat et al. 2005). Abortions, neonatal disease, mortality and low of fertility are the main problems facing livestock industry in Jordan and Middle East region. These problems have a significant impact on the profitability of livestock breeders. Milk and meat produced by Awassi sheep are important products that are preferred by many consumers in the Middle East region over products of any other breed and species (MOA, 2012). Therefore must concentrate the researches during pregnancy and the factors effect in this period to improve the profitability from sheep industry and productivity of offspring in Middle East countries.

Maternal nutrition in the gestation period plays important function in the fetal growth regulation and affects the offspring lifespan health and productivity (Belkacemi et al. 2010). Maternal nutritional status is an important factor associated with nutrient dividing and eventually the evolution and development of major fetuses organ systems (Caton et al. 2009, Caton and Hess, 2010). Some metabolic problems in the fetal period, the fetus and the offspring of lifelong development may affect the health and performance (Wu et al. 2006). During gestation period the challenge pregnant ewes has to overcome is providing adequate amounts of nutrients in order to support fetus organs growth, provide maintenance for physiological needs, mammary gland development, colostrum and milk production (Amanlou et al. 2010). Undernutrition or the lacking nutrients in maternal diet may has pose unfavourable effect in birth weight, with significant effect on newborn morbidity and mortality. There is an extensive increase demand for nutrients for ewes in pregnancy period in comparison to its demand during other stages.

Many studies were conducted to recognize significant periods of development and the period with high nutrients demand during which, in practice, nutritional insufficiency is potentiality to happen, for instance, the periods of late gestation and in the early lactation. During early pregnancy characterized by minimal fetal development, undernutrition might be relatively safe as the demand of the nutrients for the fetus development during that stage of gestation is low comparatively with other gestation periods. This is particularly true as suggested by the fact that about 75% of the growth of bovine fetuses happening in the last 40 days of pregnancy (Stewart et al. 2001). So, during early gestation nutrient requirements for fetus growth are minimal. These requirements are covered without additional requirements for the placental delivery system. Actually, some research involving sheep fetuses from the sixth to ninth week of pregnancy period have shown that the undernutrition of the maternal in this weeks of gestation lead to lateness in the growth of reproductive system of the fetuses ( Rae et al. 2000).

Maternal nutrition affects offspring reproductive development and performance (Rae et al. 2000; Rhind et al. 2001; Rhind, 2004; and Bell, 2006). In both male and female fetuses there are critical development windows such as germ cell migration, gonadal development, steroidogenesis, folliculogenesis, and sertoli cell replication occurring in distinct periods of development (Rhind et al. 2001; Rhind, 2004). Nutritional status of the dam can affect on development of fetus organs at many stages of development. Nevertheless, the critical stage of this effect is not well known until now. Rhind (2004) reported that as several effects on the fetal development were exerted at a specific period of fetal growth, they were not expressed in some cases until a later stage. This author further suggested that there was a lack in knowledge regarding maternal nutritional effects and mediation to foetal reproductive functions and performance including the underlaying processes. The reason that disruptions in fetal development during pregnancy (intrauterine growth retardation) occurring in farm animals that may affect the development and performance of a lifetime has recently attracted intense interest. Disruptions occurring fetal development, reduces the strength to live after birth, offspring of the coarse / may affect the concentrate feed use capability, may adversely affect carcass composition and meat quality in the long term can increase their health problems (Wu et al. 2006).

Fat supplementation to ruminant has been extensively studied in regard to effects on many reproductive aspects such as sperm production and seminal characteristics (Castellano et al. 2010), maternal recognition of pregnancy (Filley et al. 2000, Lopes et al. 2009) through suppression of luteolytic signals from the endometruim (Mattos et al. 2000), follicle development, oocyte quality (Staples and Thatcher, 2005; Bilby et al. 2006a), embryo quality and viability (Cerri et al. 2009), and on milk production and quality (Rego et al. 2004; Bernal et al. 2010) and/or meat characteristics and quality (Wood et al. 2003).Fatty acids (FA) are very important for ruminants into consideration as well as considering the important role FAs play in the reproductive processes such as steroidogensis, the effects of fat in ruminants nutrition and reproduction aspects not affected by the total fat intake or consumed by animal, but affected by the type of fat consumed This is especially important because the ruminant animals hydrogenated polyunsaturated fatty acids (PUFAs) by the rumen population, and subsequently, decreasing the amount of PUFAs available for absorption in small intestine (Thatcher and Staples, 2007, Santos et al. 2008, Doreau et al. 2011). However, it is possible that some specific PUFAs may escape biohydrogenation in the reticulorumen, and absorbed in the small intestine, allowing for better reproductive activity by immediately affecting the purpose tissue of the reproductive system in the ewe (autocrine or paracrine) or indirectly by mediation of the endocrine system (Staples and Thatcher, 2005).

Structural changes in FA structures including chain length, level of unsaturation and double bonds position in the acil chain of FAs may have a major effect on reproductive functions and may also play a role in reproduction (Mattos et al. 2000). Several studies have concluded that ω-3 PUFAs (n-3) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) undergo no or little biohydrogenation in the rumen (Thatcher and Staples, 2007). Feedstuff sources containing such FAs are mainly derived from fish and/or other marine products, such as the fish oil and the fishmeal, which are considered non-essential since they can be synthesized from linolenic acid (n-3). In addition, they appear to play a crucial role in animal reproductive performance (Thatcher and Staples, 2007). In various reproductive tissues, PUFAs play a mediator role as they participate in a series of functions including fluidity of cell membrane, intracellular signaling process, and mitigation of oxidative stress damage (Wathes et al. 2007).

Fat supplementation to dairy ewes leads to improvement in milk production (Gargouri et al. 2006). In beef cows it increase follicular growth from dams supplemented with fat sources (Bottger et al. 2002). Production performance traits like milk production and live and weaning weights have been reported to differently respond to fat supplementation. Delayed regression of corpus luteum, improved embryo survival and subsequently better fertility have been reported in cattle fed diets containing fishmeal (Staples et al, 1998). The possible reason for this is that fishmeal is rich in EPA and DHA which may reduce the synthesis of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) (Staples et al, 1998).

Docosahexaenoic acid has been shown to play a specific functional role in neural development of the fetus and early infant, which may influence the viability of neonates (Cattaneo et al. 2006; Capper et al. 2007). This FA is highly concentrated in tissues of brain and accumulated, selectively, during later stages of infant brain growth and fetal development (Brenna and Lapillonne, 2009; Hsieh and Brenna, 2009). Research findings suggest that intake of DHA during gestation proves advantageous to both mother and developing fetus (Saldanha et al. 2009).

Hypothermia is a major factor that contributes to high lamb mortality rates. This is particularly due to delayed suckling and exhaustion of brown adipose fat (Singer, 1998). PUFA supplementation through inclusion of fishmeal (FM) to diets of sheep during late pregnancy has reduced the latency of suckling in lambs (Capper et al. 2006). On the other hand, the very long chain n-3 PUFAs are considered essential, as they are not adequately synthesized by ruminant tissues or systems to meet their requirements. Therefore, long chain n-3 PUFAs concentration in the animal body depends primarily on feed intake. It is possible, then, that supplementation FM or fish oil (FO) to ewes` diets may improve the essential FA status of ruminant animals during gestation. Dawso and Edgar, (2006) have studied the source and level of FO supplementation effects in ewes during late pregnancy ewes. Their results indicated that supplementing ewe diets in late pregnancy with 20 g FO per day improved lamb survival to weaning. Moreover, Capper et al. (2006) and Pickard et al. (2005) reported improved neonatal lamb vigour through the inclusion of PUFA in the diet of pregnant ewes, an effect that may be mediated through increased gestation length or enhanced neural tissue development within the fetus.

The release of trophoblast interferon-***T*** ($IFN_T$) is involved in successful maternal recognition of pregnancy, and subsequently, embryo survival. $IFN_T$ inhibits endometrial oxytocin receptors expression (Wathes and Lamming, 1995) and secretion of Prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) from the endometrium. This prevents corpus luteum regression and maintains maternal progesterone (P4) levels. Thus, diets rich in n-3, lower $PGF_{2\alpha}$ synthesis and prevent CL regression and, subsequently, allow continued secretion of P4 and improve embryonic survival (Inskeep, 2004). A number of authors have previously inferred a positive effect of n-3 on embryo survival by $PGF_{2\alpha}$ secretion reduction from bovine endometrial cells in vitro (Mattos et al. 2003; Caldari-Torres et al. 2006).

In sheep, FO supplementation during third trimester of gestation was reported to extend the gestation for two days compared to Megalac (Capper et al. 2006). In addition, the pregnancy period was prolonged when ewes were supplemented with DHA rich algal (Pickard et al. 2008).

The adding rumen bypass fat to ruminant diets was reported as beneficial feeding way to improve milk fat percentage. Generally, Ca salts of PO have been reported to increase milk yield and fat percentage (Pulina et al. 2006). Milk fat profile and concentration did not affected by feeding dairy ewes Ca salts of PUFA from oil (Kitessa et al. 2003) or calcium soap from olive oil (Antongiovanni et al. 2002; Dobarganes García et al. 2005). Rotunno et al. (1998) reported the supplementation of dairy ewes with rumen bypass fat at 4% and 8% DM, increased the milk contents of fat and reduced protein concentration in the milk. Rotunno et al. (1998) have reported similar findings on dairy goats. Casals et al. (1999) found that feeding ewes during milking period 200g calcium soap of fatty acid (CSFA) of PO during their complete lactational period has markedly increased milk fat content (+23%) and yield (+16%). However, these authors reported reduced milk protein content (-9%). In addition, the total milk solids were higher during the last periods of lactation with no dietary effects observed in the yield of total milk solids. Martin et al. (1999) found that adding 100g of CSFA of PO to Verata goats diets produced higher milk fat content and total milk solids, with no effect on either milk protein proportion or production. Greater milk fat content and yield was also seen in dairy ewes fed diets containing (45g/day CSFA) of olive oil.

Perez-Alba et al. (1997) demonstrated that supplementation of CSFA of olive FA at 10% of basal diet of dairy ewes tended to produce 11% more milk. Higher daily milk production was reported in ewes fed a basal diet supplemented with about 50 g of CSFA compared to control diet (Hegazy et al. 1999).

Furthermore, Dobarganes-Garcia et al. (2005) observed 4.1% greater milk yields in dairy ewes given 45 g/d CSFA of olive oil.

Between all marine products and other fat sources, marine oil was reported to result in highest conjugated linoleic acid (CLA), vaccenic acid (VA) and ω-3 FA levels in ewe milk. Protected FO supplements of 30 and 45 g/d have been reported to increase CLA concentration in dairy ewes milk (Mozzon et al. 2002). Despite the fact that marine oil is poor in CLA precursors, it proved efficient in improving milk concentration of VA and CLA by inhibiting the ruminal bacterial reduction of VA to stearic acid.

When rumen-protected marine oil was supplemented to ewes, concentration of EPA and DHA in milk fat increased compared to controls (Mozzon et al. 2002; Kitessa et al. 2003; Ferreira et al. 2011), Although the carry-over of nutrients from ration to milk was just about 20% (Mozzon et al. 2002; Kitessa et al. 2003). Probably, the transition of EPA and DHA (PUFA) from dairy ewes diet to milk was more than in dairy goats or cows (Kitessa et al. 2001; Lock and Bauman, 2004).The augmentation of PUFA n-3 long chain polyunsaturated fatty acids (LC-PUFA) such as EPA and DHA from dairy ewes diet to milk is tricky because of the biohydrogenation in the rumen is very high for EPA and DHA. This biohydrogenation maybe reach to about 72% for DHA in dairy ewes (Wachira et al. 2000). An additional reason for this high biohydrogenation is the reality that these PUFA are not transported with the plasma lipid fractions (TG and NEFA), which are the main mammary sources of FA uptake (Lock and Bauman, 2004).

The development of the immunity system in new born of ruminants take a time, then the immunity system needs some time to react and define from pathogens by produce antibodies to protect the new born. So the new born in the beginning of life take the antibodies from mother by colostrum. In another species, the antibodies transferred from mother during pregnancy period, this not occurs in ruminants. Wherefore, the new born should be suckling from mother at birth immediately and take good amount from colostrum. The newborn of ruminants is totally depending of immunoglobulin (Ig) from mother colostrum (Kehoe and Heinrichs, 2007). Establishment of appropriate passive transfer (APT) is very important to improve herd productivity by reduce the newborn mortality and morbidity (Quigley and Drewry, 1998; Donovan et al. 1998).

Few researchers have studied the effect of using FAs in ruminant diets during pregnancy on immune system response of newborns. Enke et al. (2008) studied the fetal programming and reported the supplementation of PUFAs in ruminant diets in late pregnancy period, led to improved immune system development in early life of newborns. Petit and Berthiaume (2006indicated that newborns from cows that supplemented fat during pregnancy period had low mortality rate in the early life of newborn and at the weaning, while at birth the birth weight not different and average daily gain (ADG) during preweaning period were not different. Encinias et al. (2004) reported the added of safflower seed to pregnant ewes ration decreased the mortality rate and increased number of lambs were weaned.

The ruminants very sensitive to show the effect of feeding LCFAs during pregnancy period on newborn behaviour, because the diets of ruminants normally very low in DHA (Givens et al. 2001). Besides the low amount of PUFAs reach small intestine by hydrogenation process that occurs in rumen(Chikunya et al. 2004; Sinclair et al. 2005), whereas tissue elongation and de-saturation of linolenic acid (18:3), the precursors for 22:6, were shown to be limited in sheep (Cooper et al. 2004). Increased tissue incorporation of n-3 PUFA reduces oxidative stability in sheep (Demirel et al. 2004), and strategies to increase tissue n-3 PUFA levels may benefit from a concomitant increase in the supply of antioxidants such as vitamin E.

In last years increase concern in the link between the animal fat intake and the incidence of coronary heart disease (CHD) and cancer. Epidemiologists identified strong relationships between the proportion of the dietary energy which was consumed as saturated fatty acids (SFA) and the incidence of CHD (Hu et al. 2001) and colon, prostate, and breast cancer (Wynder et al. 1997). The Department of Health in United Kingdom recommended for a reduction of SFA in the diet, because CHD is related to the influence of SFA on the development of high levels of cholesterol in the circulating serum lipoproteins, with PUFAs seemingly modulating these rises in risk factor (Department of Health, 2003). This was relatively easy to respond to in non-ruminants where the FA composition of adipose and intramuscular lipids closely reflects those of the dietary components. However, microbial biohydrogenation dictates that ruminant products (e.g., milk and red meats) have much higher SFA.

The increasing awareness of the need for diets to contain higher levels of n-3 PUFA has focused on the importance of meat and milk as a natural supplier of these to the diet. Many researchers reported the addition of marine products such as marine oil high level of PUSFAs (DHA and EPA) to dairy ewes diets, led to transfer these PUFAs to milk and increase milk composition of DHA and EPA(Mozzon et al. 2002; Kitessa et al. 2003; Ferreira et al. 2011).

Fortunately, we can manipulation of animal products lipid composition by incorporation of n-3 PUFA sources in animal diets, and then PUFAs will transfer to the lipid fraction of animal tissues and animal products such as meat and milk (Boyazoglu andMorand-Fehr 2001; Kolanowski et al. 2001). The concentration of PUFAs in milk depends on the amount of PUFA in feed and escapes the rumen biohydrogenation and absorb in small intestine, because the PUFAs cannot be synthesized in rumen (Chilliard et al. 2000). Marine products the most source of the n-3 PUFAs in animal diets such as DHA and EPA. With poor dietary supply of PUFAs (DHA and EPA) and thus low amount availability for absorption in intestine by biohydrogenation in rumen of DHA and EPA (Wachira et al. 2000; Chikunya et al. 2004).

In the last years with increasing attention to the global warming by reducing emissions of greenhouse gases. Methane (CH4) is a potent greenhouse gas that is produced by bacteria in the rumen, every 1 kg DMI by ruminant produce about 20 g CH4 (Hristov et al. 2013). The fat supplementation is a new strategy to reduce the CH4 emission by decrease the methanogenesis, this suppress may be related to the degree of unsaturation of these FA as they undergo biohydrogenation in the rumen (Fievez et al. 2003). In in vitro studies reported a using of FO has a positive effect on reducing CH4 emission (Fievez et al. 2003; Woodward et al. 2006; Patra and Yu, 2013).

Limited data are available on feeding of Awassi ewes diets containing FO. Therefore, the objectives of the study were to evaluate the effects of feeding FO on:

- Maternal performance,
- Embryo survival,
- Morbidity and mortality of the newborn,
- Colostrum and milk production,
- Milk FA profile,
- Newborn performance in preweaning period,
- Lamb performance in fattening period,

In Awassi ewes during pregnancy and the effects on offspring.

# 2. LITERATURE REVIEW

## 2.1. Fatty Acids

Fatty acid is a carboxylic acid with a long aliphatic chain, with two form saturated fatty acid (SFA) or unsaturated fatty acid (USFA) (Table 2.1. and 2.2.), derived from triglycerides or phospholipids. The FA are most important source of energy, because they produce large amount of ATP when metabolized, the cell can use the FAs for energy production (IUPAC, 1997).

Table 2.1. Major unsaturated fatty acids

| Common name | C: D[1] | n−x[2] |
|---|---|---|
| Myristoleic acid | 14:1 | n−5 |
| Palmitoleic acid | 16:1 | n−7 |
| Sapienic acid | 16:1 | n−10 |
| Oleic acid | 18:1 | n−9 |
| Elaidic acid | 18:1 | n−9 |
| Vaccenic acid | 18:1 | n−7 |
| Linoleic acid | 18:2 | n−6 |
| Linoelaidic acid | 18:2 | n−6 |
| α-Linolenic acid | 18:3 | n−3 |
| Arachidonic acid | 20:4 | n−6 |
| Eicosapentaenoic acid | 20:5 | n−3 |
| Erucic acid | 22:1 | n−9 |
| Docosahexaenoic acid | 22:6 | n−3 |

[1]C is the number of carbon atoms in the fatty acid and D is the number of double bonds in the fatty acid.
[2]Family of ω-x fatty acid.

Table 2.2. Major Saturated Fatty Acids

| Common name | C: D |
|---|---|
| Caprylic acid | 8:0 |
| Capric acid | 10:0 |
| Lauric acid | 12:0 |
| Myristic acid | 14:0 |
| Palmitic acid | 16:0 |
| Stearic acid | 18:0 |
| Arachidic acid | 20:0 |
| Behenic acid | 22:0 |
| Lignoceric acid | 24:0 |
| Cerotic acid | 26:0 |

C is the number of carbon atoms in the fatty acid and D is the number of double bonds in the fatty acid

Generally FAs derive from animal and/or vegetable fats and oils. Lipids that come from animal products have a high concentration of SFAs and the lipids come from vegetable products have a high concentration of USFAs. However, this not standard for all lipids, some of lipids are not following this standard. Specific FAs are very important for animal health, reproduction and production aspects and for animal survival (Burr and Burr, 1929, 1930). The main FAs terms include:

- Essential fatty acid: An essential FAs is PUFAs and that is not synthesized in adequate amount in the body and it is therefore a dietary requirement.
- Free fatty acids: it is Byproducts of the metabolism of fat in adipose tissues.
- Omega-3 fatty acids: Omega-3 FAs are a group of fatty acids found in marine sources such as FO, which lower cholesterol levels.
- Trans fatty acid: Trans fatty acids (Trans fats) are made during hydrogenation. They increase the shelf-life of oils and are found in some vegetable and in some margarines, crackers, cookies, and snack foods (La´ıset al. 2014).

### 2.1.1. Nomenclature and Classification of Fat

The amount of carbon double bond and the number of carbon atoms in FA chemical structure, define the physical and chemical properties of dietary lipids. The chain of hydrocarbons (short 2-4 carbon atoms, medium 6-10 carbon atoms or long 12-26 carbon atoms) and a carboxylic acid is the main structural elements of FAs. The short chains FAs have a low melting point and length of chain is directly proportional to melting point. The chemical structure of FA not have carbon-carbon double bonds is classified as saturated fatty acids (SFA), one carbon-carbon double bond is classified as MUFA or more than one carbon-carbon double bond this classified as PUFA. The double bond decreases melting point and is more reactive than a single bond in chemical reactions.

The alpha carbon is the carbon atom closest to the carboxylic group and the omega or n end carbon is the methyl end. To describe FAs used the number of carbons to the first carbon-carbon double bond, such as omega-3 (or n-3) FAs are classified as such since the first double bond occurs three carbons away from the omega carbon.

The essential nutrient cannot be synthesized in the body or synthesize but not in sufficient amount and must it be supplied by the diet to meet cellular demands. The alpha-linolenic acid (ALA;18:3n-3) and linoleic acid (LA;18:2n-6) considered as a essential fatty acids, these two essential fatty acids used to capillary wall integrity, maintain cell membrane structure, prostaglandin production and lubrications of the skin. The alpha-linolenic acid (ALA; 18:3n-3) and linoleic acid (LA; 18:2n-6) must be obtained from the diet because lack the enzymes to introduce double bonds at the omega-3 and/or omega-6 position of a long fatty acid molecule (Umhau and Dauphinals, 2007). The increased of circulating omega-3 fatty acids concentrations in blood result in a healthier mix of metabolites as fatty acids enzymes are redirected towards omega-3 pathways (King, et al. 2008).

### 2.1.2. Omega 3 and Omega 6

Omega-6 and omega-3 fatty acids ratio in diets play important roles in animal production and reproduction processes, and have a positive effects on human and animal health (Abayasekara and Wathes 1999). The omega-3 FAs include EPA and DHA and the omega-6 fatty include arachidonic acid (AA). The first double bond in omega-6 FAs occurs between sixth and seventh carbons from the methyl end, but the first double bond in omega-3 FAs occurs between third and fourth carbons from the methyl end of the fatty acid chain. Because of a lack of the appropriate FA desaturase enzymes these FAs (EPA, DHA and AA) cannot synthesize in body. Therefore must be included in the diets as these PUFAs are essential for numerous processes including growth, reproduction, vision, and brain development (Gurr et al. 2002).

The $PGF_{2\alpha}$ and $PGF_{3\alpha}$ Prostaglandins, have important roles in animal reproduction such as parturition, embryo survival, ovulation and oestrus (Gulliver et al. 2012). The $PGF_{2\alpha}$ are more inflammatory than $PGF_{3\alpha}$ (Lands 1992). The omega-3 PUFAs and omega-6 PUFAs EPA and AA are the precursors for these prostaglandins (PG). The ratio of omega-6 to omega-3 in ruminant diets is particularly important in determining the relative availability of the precursors for PG formation. The omega-3 PUFAs and omega-6 PUFAs metabolism to PGs, the remove of two double bonds from EPA leads to the formation of $PGF_{3\alpha}$ and the remove of two double bonds from AA leaves two double bonds and leads to the formation of $PGF_{2\alpha}$ Therefore, diets high in omega-6 are associated with increased $PGF_{2\alpha}$ synthesis.

Clayton et al. (2010) and Gulliver et al. (2012) reported when pasture supply is limited that high in omega-3 FAs, sheep must supplemented by grain that are low in omega-3 and high in omega-6 FAs, to improve the reproduction. To increase of profitability of the sheep production system must be improve the weight of lambs weaned per ewe by minimizing lambs mortality and maximizing lambs growth rate, especially before weaning period when lamb growth rate is positively correlated with ewe milk yield and composition (Merrell, 1998). The PUFA such as AA or DHA are essential for the development of neural tissue within the neonatal and sucking animal and may influence neonatal viability (Koletzko, 1992). The feeding lamb diets high in EPA and DHA increase the concentrations of these FAs within muscle phosphatidylglycerols and triacylglycerols (Cooper et al. 2004). Improved neonatal lamb vigour from ewes that supplemented PUFAs during gestation period, this effect may be through increased gestation length or enhanced neural tissue development within the fetus (Pickard et al. 2005; Capper et al. 2006). The dairy ewes during lactation supplemented with PO calcium soap of fatty acid decreased in body condition score (BCS) during the first week of lactation period compare with dairy ewes not supplemented palm oil calcium soap of fatty acid and after weaning they recovered body condition score, but the dairy ewes not supplemented palm oil calcium soap of fatty acid (CSFA) lost more weight (Casals et al. 1999). The body condition score (BCS) and live weigh increased in ewes supplemented with CSFA than control group without fat in diet (Hegazy et al. 1999). Casals et al. (1999) reported the fed CSFA of PO to dairy ewes during lactation period increased the weaning weight (WW) of lambs born from this ewes and more efficient conversion of milk into lamb gain at four week of age (Casals et al. 1999). In another study Hegazy et al. (1999) noted that ewes fed hydrogenated vegetable palm oil CSFA at 3% of dry matter (DM) during gestation period and early lactation increased birth weight, WW and growth rate of these ewes lamb compare with lamb from ewes fed control diet (Hegazy et al. 1999).

### 2.1.3. Sources

The major FAs sources from animal and vegetable fat used in ruminant diets in Table2.3. For example protected fats, calcium salts of fatty acid (CSFA), marine oils, rendered fats, oilseeds and purified vegetable oils.

Table 2.3. The main sources of fatty acids in ruminants nutrition

| | Total FA[1] | Myristic acid | Palmitic acid | Stearic acid | Vaccenic acid | Linoleic acid | α-Linolenic acid | AA | EPA |
|---|---|---|---|---|---|---|---|---|---|
| Vegetable oils[2] | | | | | | | | | |
| PO | 88.3 | 1.11 | 43.7 | 4.42 | 39.1 | 10.1 | 0.32 | - | - |
| CCO | 85.1 | 18.4 | 8.6 | 2.71 | 6.01 | 1.52 | 0.12 | - | - |
| SFO | 88.7 | - | 6.11 | 2.33 | 13.3 | 76.0 | 0.34 | 0.52 | 0.54 |
| CAO | 89.0 | 0.12 | 5.12 | 1.72 | 60.2 | 21.4 | 9.94 | - | - |
| LSO | 89.1 | 0.11 | 5.52 | 3.72 | 19.4 | 16.3 | 53.3 | - | - |
| CS | 89.2 | 0.81 | 24.24 | 2.34 | 17.5 | 53.4 | 0.22 | - | - |
| CO | 89.3 | - | 12.35 | 1.97 | 27.6 | 56.3 | 1.01 | - | - |
| SB | 88.8 | 0.13 | 10.82 | 3.92 | 23.8 | 52.2 | 7.85 | - | - |
| SF | 88.7 | 0.12 | 6.44 | 4.54 | 22.3 | 65.8 | 0.53 | - | - |
| Animal fats and blends | | | | | | | | | |
| Tallow[1] | 88.6 | 3.02 | 25.2 | 19.6 | 42.2 | 3.02 | 0.32 | - | - |
| Yellow grease[2] | 88.5 | 1.04 | 21.4 | 6.12 | 41.4 | 21.4 | 1.44 | - | - |
| Fish oil[3] | 90.4 | 8.32 | 16.8 | 3.22 | 10.2 | 1.52 | 2.15 | 0.91 | 13.2 |
| Lard[4] | - | 1.74 | 30.3 | 22.7 | 26.4 | 12.1 | 1.22 | - | - |
| Commercial fats | | | | | | | | | |
| Megalac[5] | 82.3 | 3.14 | 47.5 | 4.64 | 34.4 | 5.54 | 0.21 | - | - |
| Megalac | 82.4 | 1.95 | 32.3 | 5.04 | 23.3 | 30.4 | 3.15 | - | - |
| Energy booster | 98.1 | 2.92 | 29.4 | 55.34 | 6.31 | 0.36 | - | - | - |

PO :palm oil, CCO :coconut oil, SFO : safflower oil, CAO :canola oil, LSO :linseed oil, CS : cottonseed, CO :corn oil, SB :soybean, SF :sunflower.
[1]Onetti et al. 2002. [2]Avila et al. 2000. [3]Ballou et al. 2009. [4]Huuskonen et al. 2005. [5]Theurer et al. 2009.

Fat is a source of energy in pre-weaned ruminants, and in milk replacers for new born calf fat and oil are used. Commonly animal fat and vegetable oils are used. Glycerolipids is the most popular structure of lipid in fats and oils, essentially triglycerides (TG). The FA found in TG is SFA, MUFA, or PUFA (FAO, 2010). In ruminants nutrition mostly used omega-3 and omega-6 USFAs (Eastridge, 2002;

FAO, 2010). The most important sources of LA are sunflowers, safflowers, corn, soybeans and cotton, and the most important sources of ALA are linseed oil and canola. The main source of EPA and DHA in ruminant diets is marine products such as fish oil and fish meal.

**2.1.4. Metabolism**

The dietary fats and oil exposed to special process in the rumen before its absorption in the small intestine and then used in the animal body. After fat digest the products are transported from rumen to small intestine then absorbed to blood through wall gut (Gurr et al. 2002). There are differences being between the ruminants and non-ruminants or new born ruminants in the lipids structure that entering the small intestine, this due to in non-ruminants or new born ruminants have one stomach or non-development stomach and the lipids do not exposed to high digestion process as in ruminants, but in ruminant they have fore-stomach so high lipid metabolism occur before lipids absorption (Bauchart, 1993).

The first step in the formation of free fatty acid (FFA) it is occur by lipase enzyme then involves to an extensive hydrolization, and the second step is hydrogenation in the rumen by rumen microbes, the final products of this process is stearic acid. The formation of isomers of PUFA or CLA and cis and trans isomers of monoenoic free fatty acid, this result from incomplete hydrogenation (Hocquette and Bauchart, 1999). However, the FFA is not like FAs in the diet as a final product of microbial hydrolysis and biohydrogenation. The LCFFA, dietary TG that escape microbial hydrolysis, phospholipids from bile and microbial phospholipids arrive to small intestine (Hocquette and Bauchart, 1999; Drackley and Andersen, 2006).

The adding high amount of fat and oil in ruminant diets has detrimental effects on microbial activity and inhibits the fiber digestion in rumen and decrease animal productivity (Eastridge, 2002). Many ways have been developed to decrease the detrimental effects on microbial activity and escape lipid hydrogenation such as lipid encapsulation and saponification of LCFA (Hocquette and Bauchart, 1999).

In the ruminants the major lipids metabolism occurs in the rumen and responsible for identifying the profile of FAs available for absorption and tissue utilization. Hydrolysis of ester linkages in lipids and the biohydrogenation of USFAs this two major process occur in the rumen in lipid metabolism. The lipid hydrolysis occur by salivary or plant lipases and in the rumen by rumen bacteria, protozoa and fungi. With high extent of hydrolysis (>85%), there are some factors affect the extent and rate of hydrolysis in rumen. When factors such as low rumen pH and ionophores inhibit the growth and activity of bacteria or when increase the dietary fat level, the extent of hydrolysis is reduced (Doreau et al. 1997 and Harfoot and Hazlewood, 1997).

The USFAs have a toxic affect to rumen bacteria, the biohydrogenation is the second major transformation that dietary lipids can undergo in the rumen, it need FFA to proceed, and then the rates are very low of hydrolysis, all factors that affect hydrolysis also impact biohydrogenation. The majority of biohydrogenation occurs in association with the fine food particles, and then associated with the feed or free in suspension (Harfoot and Hazlewood, 1997).

With increased USFAs in the diet, increased the rates of rumen biohydrogenation of FAs. The hydrogenation of diets linoleic acid is 70-95% and for diets linolenic acid is 85-100%, thus the major FA enters the duodenum and the extensive metabolism of unsaturated FA in the rumen is a stearic acid.

Mainly the FAs absorption occurs in the small intestine in jejunum region. Before digesta reaching the jejunum, in the duodenum two secretions bile and pancreatic juice are added to the digesta. The efficiency of FA absorption depends on lipid material absorbed into the feed particles to be solubilized into the aqueous environment; the key of this process is micelle formation (Davis, 1990). Pancreatic juice provides the enzyme to convert lecithin to lysolecithin and the bicarbonate to raise the pH, and bile supplies bile salts and lecithin. The bile salts with lysolecithin desorbed the FAs from feed particles and bacteria allowing the formation of the micelle. The FAs and lysolecithin absorbed, when the micelles are formed and they simplify transfer of water-insoluble lipids across the unstirred water layer of intestinal epithelial cells of the jejunum. Then the FAs transport in lymph to the blood by re-esterifies into triglycerides and then packaged into chylomicrons. No modification or absorption occur in the abomasum and omasum for long and medium chain fatty acids, in the small intestine the lipid absorption is the same to that leaving the rumen (Moore and Christie, 1984). The lipids available to absorption in small intestine consists about 80-90% free fatty acids and the other 20-30% are microbial phospholipids and some amounts of glycolipids and triglycerides from residual feed material, which are hydrolyzed by intestinal and pancreatic lipases (Doreau and Ferlay, 1994). The total FAs that leave the rumen very similar to dietary FAs, this occur with wide range of diets, despite of the changes occur in the rumen. Some time the total amount of FAs that leave the rumen can exceed FA intake and this most often occurs when lipid intake is low, such as with high forage-based diets, this resulted from bacterial lipid synthesis. However, the effect of bacterial or microbial lipid is variable with associative effects of different diets (Noble, 1981).

**2.2. Nutrition During Gestation and Fetal Programming**

The fetal development and then productivity and lifelong health of offspring depend on maternal nutrition during gestation (Belkacemi et al. 2010). In pregnancy period the maternal diet must cover the nutrients requirement for maintenance and for fetal requirement to grow and development. The protein and energy the major nutrients must be covered during this stage to provide the nutrients requirement for maternal maintenance of physiology needs, mammary gland growth, colostrums and milk yield, embryonic and fetal growth(Amanlou et al. 2010). The shortage in maternal nutrition leads to increase in morbidity and mortality of the newborn and low birth weight.

The maternal nutrition state associated with growth and development of major fetal organ systems and then offspring growth and performance (Wallace et al. 1999; Godfrey and Barker, 2000; Wu et al. 2006; Caton et al. 2009, Caton and Hess, 2010). There is a substantial increase in nutrient requirements for the late pregnancy ewe compared with maintenance (Table 2.4).

The maternal nutrient restriction in ewes and human during early gestation period lead to increase in the length and thinness of the neonate with normal birth weight (Barker et al. 1993; Godfrey et al. 1996; Whorwood et al. 2001). After birth the number of muscle fibers not increased, just during fetal period the skeletal muscle developed (Greenwood et al. 2000; Nissen et al. 2003). Greenwood et al. (2004) reported the steers from cows nutrition restricted during gestation period lower in live and carcass weight than steers from adequately nutrition at 30 month of age (Greenwood et al. 2004). No effect of protein supplementation during late gestation period on birth weight, but the heifers from cows supplemented protein in the late gestation period increased in pregnancy rate (Martin et al. 2007).

Table 2.4. Recommended nutrient intakes and dietary nutrient content for a mature 70-kg ewe at various physiological states[1]

| Physiological State | Energy concentration Kcal/kg | Dry matter[2] kg/d | ME[3] Mcal/d | MP[4] g/d |
|---|---|---|---|---|
| Maintenance | 1.91 | 1.68 | 2.25 | 60 |
| Gestation, Early (Single lamb; BW = 3.9 to 7.5 kg) | 1.91 | 2.09 | 2.80 | 81 |
| Gestation, Late(Single lamb; BW =3.9 to 7.5 kg) | 1.91 | 2.58 | 3.45 | 105 |

[1]Adapted from NRC, Nutrient Requirements of Sheep, 2007.
[2]The daily dry matter intake, expressed as kg, of a diet having the indicated energy Concentration (previous column) that is required to meet energy requirements.
[3]Energy requirements expressed as metabolizable energy (ME) as kcal/d.
[4]Protein requirement expressed as metabolizable protein (MP).

Many studies concentrate on the effects of maternal nutrition in the late stage of gestation and early neonatal period because higher demand for maternal and fetal nutrients to grow in these stages, and increase the fetal nutrient requirements in late pregnancy stage than early stage (Gunn et al. 1995; Rhind et al. 1998). The maternal nutrition can effect on the fetal reproductive system on all stages of development and on all physiological systems. This effect may be able to differentiate between hypothalamus or pituitary gland and other reproductive organs (Hyttel et al. 2000). The effect of nutrition during pregnancy and neonatal development can extend to adult offspring and effect on the adult offspring reproductive performance, and may be able to extend to subsequent generations on endocrine status, fertility and fetal growth (Lumey, 1992). These effects of nutrition may be not appear directly on the first stage of offspring life but may be manifested at a later stage of development and/or in adult life. When maternal diet give under requirement during the first gestation period, from mating on day 50 of gestation, the delay in ovarian follicular development was observed at Day 110 (Rae et al. 2001). The ovarian structures in this stage are not present or affected. Rae et al. (2002) reported the prolonged periods of malnutrition reduced ovulation rates in the offspring (Rae et al. 2002). The under-nutrition before conception leads to altered endocrine profiles, specifically the pattern of ovine fetal plasma insulin-like growth factor (IGF-1) and plasma insulin-like growth factor binding protein (IGFBP-3) concentrations during late pregnancy and fetal development, and effect on reproductive organ development (Gallaher et al. 1998).

### 2.2.1. Effect of Maternal Nutrition on Hormonal Status

During fetal development and in early life the nutrition and hormonal state have a major role in control of energy metabolism in offspring life (Silveira et al. 2007; McMillen et al.2008). The epigenetic mechanisms are the link between early life events and health later in life, with epigenetic marker being considered as long-lasting environmental sign (Gabory et al. 2011; Jammes et al. 2011). Gonads and many organs affected by this process, fertility of offspring and the quality and epigenetic markings on his gametes (Sharpe and Franks, 2002; Dunn and Bale, 2011). The pool of oocytes is complete and definitive before birth in females of ruminants, based on the resting reserve of primordial follicles established during fetal life, which represent the lifespan supply for the female’s fertilizable oocytes (Rhind et al. 2001; Magre, and Vigier, 2001). Then folliculogenesis and the accompanying steroid genesis take place during fetal life in humans and sheep, maternal nutrition can affect the synthesis of endogenous maternal hormones, which are essential during fetal development (Sharpe and Franks, 2002). The under nutrition of maternal increased the risk of early onset CVD, hypertension, increased body mass index (BMI), and glucose intolerance in the offspring (Lumey, 1998).

### 2.2.2. The Critical Periods of Fetus Development

From nutritional point the pregnancy in ewes can be divided into three periods. In the first trimester, specific growth rate and the fetal metabolic activity are high, but the energy requirement for the developing embryo is relatively small (Robinson et al. 1999). The second trimester, placental development period, at this period the fetal size and growth being relatively small. The last trimester, in this period the fetal growth very high and increasing in the nutritional demands (Kenyon and Webby, 2007). Regardless of in the first trimester the fetal nutrient requirements are very small and infinitesimal, the development of the fetal reproductive system affected by maternal nutrition at all stages of development, involving many different physiological systems (Figure 1). In ewes the fetal development stage divided to: fetal ovarian differentiation (0–30 days of gestation), ovarian growth (31–50 days of gestation), ovarian growth and germ cell meiosis (31–65 of days gestation), and folliculogenesis (65–110 of days gestation). The over nutrition of ewes during pregnancy increase the multiple births of offspring of these ewes (Gunn et al. 1995). Da Silva et al. (1998) reported the placentally nutritional restriction may be decrease the development of the fetal hypothalamic–pituitary–gonadal axis and delay the onset of puberty and this effect can be expressed at least as late as the onset of puberty.

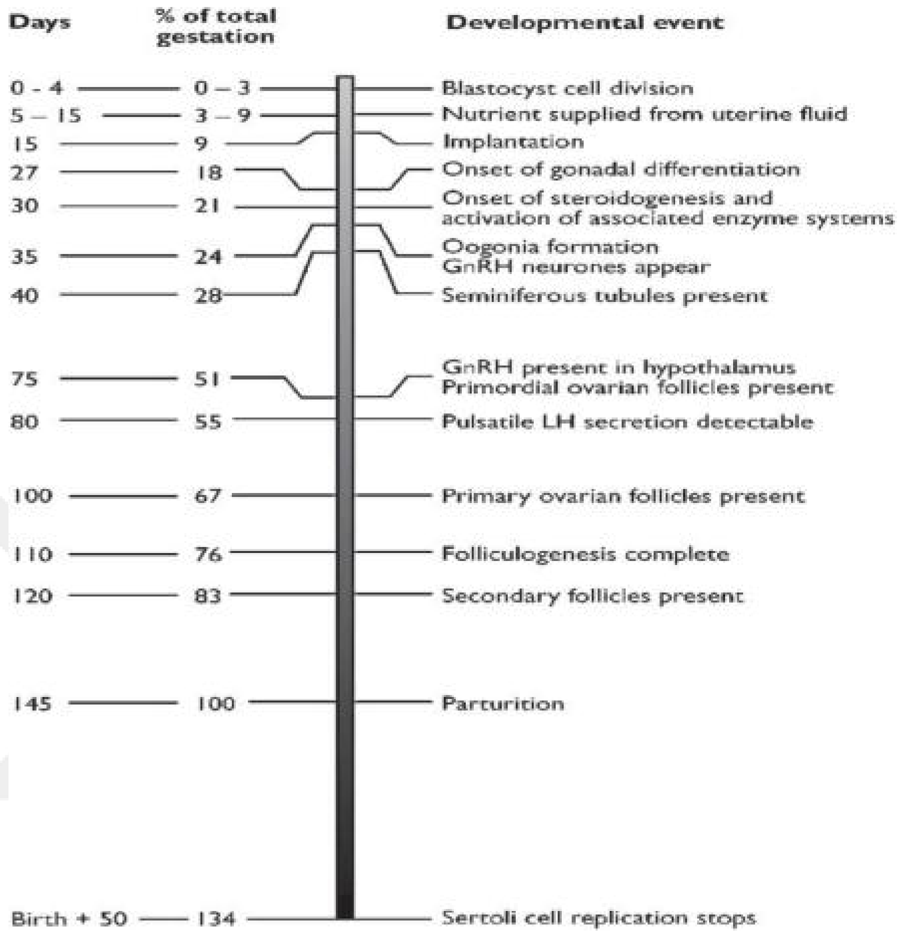

Figure 2.1. The developmental events during pregnancy in ewes

During late pregnancy and early lactation are the critical periods of fetal development and the maximum demand for nutrients. The 75% of the growth of ewes fetuses occur during the last gestation period and in the early stage of pregnancy and fetal development the under nutrition is not very important in maintenance requirement and the demand for nutrient to fetus growth and maintenance in the early period of pregnancy are very low, the maternal demand of nutrients in the first period of pregnancy for body growth are very low and the fetus take it without the requirement for a placental delivery system. Borwick et al. (1997) reported that under nutrition of pregnant ewes during the first pregnancy period between 47 days and 65 days decreased in fetal ovarian structural development (Borwick et al. 1997), and changes in associated patterns of testicular steroid genesis (Rae et al. 2000).

The critical stage of development is the alteration of subsequent function on gonad formation, process of tissue differentiation and process of tissue differentiation by the effect of nutrition. The transient period of steroid synthesis in ewes occurs in the fetal ovary between approximately day 35 and day 55 of pregnancy (Mauleon. 1973). The precise function of this transient phenomenon is unknown but it broadly synchronizes with the onset of meiosis in the germ cells (Mauleon and Mariana, 1977). Another critical window in the female fetus development occurs at the end of folliculogenesis beyond which time the number of ovarian follicles cannot be modified (Mauleon, 1973). The critical windows in male fetuses in 35 day and 70 day when seminiferous cords are present and in these days the network of blood vessels (rete testis) is organized in the centre of the testis and stains intensively for androgen receptor (Sweeney et al. 1997). During the fetal life and after birth by about6–8 weeks the sertoli cell replication continues and may be susceptible to the effects of environmental or nutrition factors throughout this period (Sharpe, 1994).

In the male and female fetuses the nutrition affect in the development of the hypothalamic–pituitary axis and the associated synthesis of gonadotrophins. Between 35 day and 85 day of gestation GnRH neuronal systems develop in sheep fetuses (Caldani et al. 1995).

The under nutrition of fetal can adversely affect on the maturation of neurocircuitry and axonal growth (Sima and Sourander, 1978; Sharma et al. 1987; Morgane et al. 1993). The effects of fetal programming on reproductive performance may be extending to the next generation (Cavalli and Paro, 1998).

Rae et al. (2000) reported the restriction of diet from the time of mating or from the time of ovarian development reduced the ovarian mass at day 50 of gestation. The nutritionally restricted ewes fed 50% of live weight maintenance requirements give more oocytes compare with fetuses from adequately fed ewes fed 150% of live weight maintenance requirements (Borwick et al. 1997). The restriction in diet leads to decrease in phagocytosis of oocytes.

The maternal under nutrition before conception to late pregnancy can reduce the lamb birth weight (Mellor, 1983), and the under nutrition in the late gestation may reduce the lamb growth rate to weaning (Harding, 2001), while under nutrition in early gestation is less likely to affect weaning weight (Robinson et al. 1999). Thus, the under nutrition in early gestation not affect on birth weight, but in later stage of gestation can reduce the birth weight and then increase the risk of lamb death and newborn survival (Symonds et al. 2007)

Rhind et al. (2001) reviewed the effects of maternal nutrition on the reproductive development and performance of offspring, in different stages of male and female fetus development there are critical windows of development occur with gonad development, germ cell migration, folliculogenesis, sertoli cell replication, and steroidogenesis. Therefore, the maternal nutrition during gestation period can affect the fetal reproductive system at differing stages of development; effects on the fetus are exerted at one particular stage of development, in some cases these effects are not expressed until a later stage (Rhind, 2004). Under nutrition of maternal lead to decrease the ovulation rates in offspring (Rae et al. 2002). The ewes born from dam afford low nutrition during gestation period in mid to late pregnancy and lactation gave birth to less multiple born lambs, and decreases the embryo loss (Gunn et al. 1995).

## 2.3. Effect of Fatty Acid Supplementation on Reproduction and Pregnancy

### 2.3.1. Fatty Acid and Reproduction

The fats from animal or plant sources have been used to improve reproductive function in ruminant animals. The linseed, rapeseed, soybean and sunflower (plant sources), have a major affects on reproductive functions. The animal fats such as tallow and the CSSFAs have a major impact on production and composition of milk and meat. However, degree of the effect varies regarding to composition of specific FAs.

Many researches were aimed to evaluating the effect of supplementation fat on reproductive performance and function, such as, the embryo development (Cerri et al. 2009), hormones synthesis and secretion that have extensive effects on reproduction aspects in ruminants(Staples et al. 1998), establishment of puberty (Smith et al. 1989), the gestation period (Abayasekara and Wathes, 1999, Filley et al. 2000, Lopes et al. 2009), restart of ovarian activity after parturition (de Fries et al. 1998), the offspring semen produce(Castellano et al. 2010), and follicle growth and evolution, the oocytes size and quality(Staples and Thatcher, 2005; Bilby et al. 2006a).Also, there are researches about effects of fat supplementation on production aspects such as milk and meat quality (Wood et al. 2003; Rego et al. 2004; Bernal et al. 2010). The effect of fat in reproduction is not from total lipid intake but by the type of lipid consumed, because in ruminants in rumen hydrogenate the PUFAs and thus limiting the amount of PUFAs that are absorbed from the small intestine (Thatcher and Staples, 2007, Santos et al. 2008, Doreau et al. 2011). However, some PUFAs such as DHA and EPA may escape rumen biohydrogenation and then reach to small intestine, in this process allow to the specific PUFAs effect to the endocrine system or by reach directly to the aim tissue of the reproductive system of the fetus (Staples and Thatcher, 2005). The PUFAs of the n-3 family such as EPA and DHA suffer insignificant biohydrogenation in the rumen and pass intact the rumen (Thatcher and Staples, 2007). These FAs play an important role in animal performance which is can be not essential because they synthesized from linolenic acid, usually found in marine products such as meal and oil (Thatcher and Staples, 2007). Calcium salts of long chain fatty acids is another source of PUFAs can resistant biohydrogenation in the rumen and thus increase the amount of PUFAs which can be reached small intestine by limit biohydrogenation in rumen (Mattos et al. 2000). PUFAs can help in reproductive tissues growth and development such as intracellular signaling, susceptibility to oxidative damage and fluidity of cell membrane (Wathes et al. 2007). The degree of unsaturation, position of the double bonds in the chain of FAs and changes in chain length play large role in ruminant reproduction and may have a major impact on reproductive processes (Mattos et al. 2000).

The success of pregnancy and ovulation depend on size and number of follicles and the effects PUFAs of omega-3 family on follicle growth till now is undefined (Ambrose et al. 2006). The feeding dairy cow's diet with high in n-3 increased the diameter of the follicle and CL compare with feeding diet high in n-6, and the follicle size was reduced when cows were fed diets high in n-6 (Homa and Brown, 1992; Petit et al. 2002; Ambrose et al. 2006). In contrast, some results from other researches indicate that the follicle numbers and diameters, or CL volume not affected by n-3 compared with n-6 (Burke et al. 1996; Petit et al. 2004; Bilby et al. 2006a; Heravi Moussavi et al. 2008).

We not have many researches on the effect of feeding fat to sheep and goat. The supplementation of CSFA in ewes during out of the breeding season lead to increased the number and size of ovarian pre-ovulatory follicles, increased conception rate, increased levels of lipid profiles, glucose, and progesterone hormone, so maintain reproductive performance (Hayat et al. 2012). The postpartum supplementation fat to Awassi ewes lead to earlier return to oestrus and thus possibility of lambing every six months (Oqla et al. 2004). The supplementation of calcium soaps of fatty acids (CSFA) to ewes increased the circulating progesterone concentration and increases the number and size of ovarian follicles in oestrous cycle (Liel et al. 2010). Another reported, increased plasma concentrations of progesterone, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, cholesterol and triglycerides (Ghoreishi et al. 2007; Ghattas and Nasra, 2010). In goat, the added of fat in diets improved pregnancy rate and increase the number and size of corpora lutea, increase the number of ovarian follicles and stimulation of postpartum ovarian activity (Abd El-Rahman et al. 2008).

### 2.3.2. Effect of Fat Supplementation in Ruminant Diets on Pregnancy Rate

The addition of fats in ruminant diets usually increased the energy content of diet and thus improves the reproductive and lactation aspects (Funston, 2004).But in early lactation, supplementation lipid lead to decrease in feed intake due to decreased the digestibility and increase the energy, so in this period with higher energy density ration consumed normally negative energy may be occur (Santos et al. 2008).

The addition of fat to ruminant diets not just for improve the energy status, the reproductive system affected from the type of FAs in the diet not from the improve the energy of the diet (Staples et al. 1998, Williams and Amstalden, 2010). In dairy cow, the supplementation fat improves the reproductive process (Staples et al. 1998). In beef cattle increased pregnancy rate when Brahman cows consumed 5.2% fat in the diet than other group which consumed 3.7% fat in the diet (de Fries et al. 1998). In another study, Ferguson et al. (1990) reported the cows during lactation period which consumes about 500 g of fats every day increase the pregnancy possibility. Bader et al. (2000) observed a pregnancy rate of grazing cows supplemented with fat at first service was 16% higher than in cows which did not receive fat. The supplementation CSFAs of PO or with linoleic and trans-octadecenoic acids before and after parturition, increased pregnancy rate than those supplemented with PO (Juchem et al. 2010). In dairy ewes Hegazy et al. (1999) reported that ewes supplemented 3% CSFA or hydrogenated vegetable PO during flushing period higher than control group in pregnancy rate, and in fertility rate the group supplemented CSFA higher than another two groups.

In agreement with the previous study Staples and Thatcher, (2005), who observed that the effect of addition fat in ruminant diets come from FAs in the fat source, and the low amounts of USFAs that reach to small intestine to absorption by effect of biohydrogenation(Lopes et al. 2009).

**2.3.3. Effect of Fatty Acid Supplementation on Hormonal Secretion**

In dairy heifers fed fat supplementation increased circulating concentrations of progesterone in blood (Talavera et al. 1985), and in early postpartum in cows enhanced lifespan of induced corpus luteum (Williams, 1989; Ryan et al. 1995). Harrison et al. (1995) reported an improved energy balance which directly influences hypophysis-gonadal activity postpartum when fat is added to diet of cows. Other studies suggest that increased fat consumption in cow increased the number of follicles of medium and this improvement of follicles accompanied with increase the insulin, growth hormone and intra-ovarian insulin-like growth factor concentration in blood (IGF-1) (Wehrman et al. 1991; Ryan et al. 1992; Thomas et al. 1997). The cholesterol is the main precursor for progesterone and steroid hormones (Childs et al. 2008c). Thus, the supplementation of protected fat increased progesterone in blood in dairy cows (Lopes et al. 2009), and lead to improve pregnancy rate in cows (Santos et al. 2008). In ewes the supplementation diet with PUFA n-3 increased the progesterone level in the follicular fluid than ewe's supplementation diet with PUFA n-6 (Wonnacott et al. 2010).

Oestradiol is a hormone stimulates secretion of $PGF_{2\alpha}$ on uterine and derived from cholesterol and may be able to increase sensibility of the corpus luteum (Knickerbocker et al. 1986; Howard et al. 1990). The infusion of fat in abomasums reduces the oestradiol during oestrus cycle (Stocco et al. 2005).

### 2.3.4. Effect of Fatty Acid Supplementation on Ovarian Activity

The incorporation of fat in ruminant diets improves reproductive performance by increasing follicular growth and ovulation. In study by Lucy et al. (1993) reported, an increasing in the number of medium and large size of follicles in the first 25 days after birth, and the size of follicle was superior with dairy cows that have CSFAs in the diet from PO at calving. The animal fat, FO and calcium salts of saturated fatty acids have a less effects on follicular growth than plant oil, resulted from effects of high levels of linoleic acid in the rumen with plant oil. When plant oil fed at 4-6% of diet dry matter maximum follicular growth occurred (Ryan et al. 1994). Beef cows supplemented PUFAs and dairy cows consumed diet with 5% FO, the number of medium size follicles was higher compared with other groups (Thomas et al. 1997; Heravi-Moussavi et al. 2007). The increase lipids and PUFAs in the ruminant's diet lead to increased in the size of the dominant follicle, the size of the dominant follicle increase approximately 23% (Staples and Thatcher, 2005; Bilby et al. 2006d). El-Shahat and Abo-El maaty, (2010) and Herrera-Camacho et al. (2008) reported the effect of using Ca-LCFA from PO or from corn oil in sheep ration increased the number and size of the pre-ovulatory follicles, and improved the rate of ovulation. The supplementation of ewes with 40 g/day of protected fat, improved the number ovarian follicles larger than 7 mm in diameter (Zamiri et al. 2002). Sklan et al. (2002) reported, with contains 4% of FO in ewes diet increase the number of follicles than other groups without FO.

The adding PUFAs to ruminant diets can modulate prostaglandin metabolism, prostaglandin synthesized from C20 FAs (Mattos et al. 2000). The two series of prostaglandins are derived from arachidonic acid. These prostaglandins are the most active two series, and the three series prostaglandins are less active and derived from EPA by the action of the same enzymes (Robinson et al. 2002). In the re-establishing oestruscycles the prostaglandins play a major role, immediately after parturition and thereafter until conception. The process of uterine involution after parturition, prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) play an important role in this process. If the animal is not pregnant and to initiate a new oestruscycle, the uterus releases $PGF_{2\alpha}$ during each oestrus to regress each new corpus luteum. To maintain pregnancy, release of $PGF_{2\alpha}$ from the uterus is prevented in order to preserve the corpus luteum (Funston and Filley, 2002). Linoleic acid inhibits prostaglandin synthesis by inhibition of $PGF_{2\alpha}$ synthesis. Regulatory enzymes for this conversion include delta 6 desaturase and cyclooxygenase. The EPA and DHA inhibit cyclooxygenase activity, thus inhibit prostaglandin synthesis (Mattos et al. 2000).

The EPA and DHAFAs reduce synthesis of prostaglandins series 2 in tissues and cells (Mattos et al. 2003). The ratio n- 6: n-3 and the concentration of linolenic acid may inhibit synthesis of $PGF_{2\alpha}$ (Harris et al. 2001). From this results are interesting because in cow the most embryonic losses occur during the first 16 days after artificial insemination (Sreenan et al. 2001), this losses in embryonic may be to that some embryos not reach the appropriate size in first 16 days to inhibit synthesis of $PGF_{2\alpha}$ for luteolysis to occur (Thatcher et al. 1994), showing the inability to inhibit luteolytic action by $PGF_{2\alpha}$ during the critical period of maternal recognition of pregnancy (Childs et al. 2008a).Theinhibition of the synthesis of $PGF_{2\alpha}$ in this stage increases the rates of embryo survival and pregnancy (Binelli et al. 2001). The FO and meal have a high and concentrations of EPA and DHA, when adding in ruminant diets reduce the synthesis of $PGF_{2\alpha}$ and delay regression of the corpus luteum, improving embryo survival and herd fertility (Staples et al. 1998).

Oldick et al. (1997) reported, the infusion into lactating dairy cows abomasum fat source rich in linoleic acid reduced the release of PGFM, indicate that high concentrations of PUFAs in the ration decrease endometrial secretion of prostaglandins. In ruminants, the fed fish meal or FO high n-3 FAs, reduce the secretion of arachidonic acid, and increase secretion of EPA and total n-3 FAs (Burns et al. 2003; Bilby et al. 2006ab).

During the pre-partum period the lipids supplementation with high linoleic acid increase secretion of $PGF_{2\alpha}$ from uterine (Cullens, 2005). Childs et al. (2008b) showed that the fed heifers diet with FO rich in n-3 FA or whole soybean rich in n-6 FA, the heifers fed a diet rich in n-6 FAs was higher metabolite of serum concentration of PGFM on day 15 of the oestrus cycle than heifers fed a diet rich in n-3 FAs (Mattos et al. 2004). When cows before calving supplemented with calcium salts rich in n-6 FAs, reduced metritis and mastitis, and improved reproductive efficiency (Cullens, 2005). Therefore, the n-3 FAs reduce synthesis of 2 prostaglandin by competes with arachidonic acid, but the linoleic acid increase the synthesis of series 2 prostaglandin. Caldari-Torres et al. (2006), carried out in vitro study and investigated the addition of EPA to the culture media of endometrial cells of cows, reported this addition reduce production of endometrial $PGF_{2\alpha}$ to 40%, the inhibition may depend on the amount of n-6 FAs that reach the secretory tissue (Achard et al. 1997; Caldari-Torres et al. 2006).

**2.3.5. Effect of Fatty Acid on Embryo Development**

In ruminants the pregnancy requires the ovulation of a competent oocyte, during follicular and luteal phase of oestrus the insemination must in the appropriate time and a correct pattern of secretion of progesterone and oestradiol. In embryo development period, avoid luteolysis producing enough interferon t which stimulates the expression of genes in the endometrium to inhibit the synthesis of oxytocin receptors and consequently final production of $PGF_{2\alpha}$, allowing the establishment of a corpus luteum (Bott et al. 2010). In this period in dairy cows the embryos loss about 60% and only about 40% of pregnant cows at the first30 days of pregnancy period is remain pregnant (Santos et al. 2008). This event may be affected by supplementation of PUFAs in the ruminant diets (Wathes et al. 2007). The cell proliferation and fluidity can modify by the added FAs to ruminant rations (Bilby et al. 2006a).

The major economic loss in sheep industry high fetal and embryonic mortality. This can reach to about 43% from the total ewes, in the first 25 days of pregnancy about 28% embryonic loss occur, and during late embryonic and fetal periods accounted for 15% (Dixon et al. 2007). This embryonic loss increased by increasing the ovulation rate (Knights et al. 2003; Kleemann and Walker, 2005). However, there are many factor can affect on the embryonic loss but this factors are not well established, the involvement of luteal inadequacy may the major factor effect on the embryonic loss in sheep, resulting from nutrition or heat stress or from other environmental factors (Binelli et al. 2001). In ruminants oocyte lipids composition, about 58% triglycerides, 20% cholesterol, 20% phospholipids and 10% free fatty acids (McEvoy et al. 2000). Oleic and Palmitic acids the main fatty acids of the membrane of ooocyte. The linoleic acid is the most PUFAs, about 20% (Santos et al. 2008).

The better quality oocytes and better integrity membrane when supplement ewes with CSFAs from FO, compare with ewes not have CSFAs in ration (Zeron et al. 2002). Thangavelu et al. (2007) reported the embryo development increase in cows consumed USFAs compared to the cows which consumed saturated fatty acids, the number of transferable embryos and rate of fertilization not different. The high qualities of embryos were observed when dairy cow supplemented with Ca-LCFA from PO (Cerri et al. 2009). Increased registering number of corpus luteum increased super ovulatory response when incorporate PUFAs in ewe diets (Herrera-Camacho et al. 2008). Santos et al. (2008), showed in vivo and in vitro researches, the supplemented fats in ruminant diets resulted the better embryo development and the major benefit of supplemented with FAs for embryo survival. In the fetus and early infant neural development, the role of DHA influences neonatal viability (Cattaneo et al. 2006; Capper et al. 2007). In the later stages of fetal development and infant brain growth, the DHA concentration in brain tissues very high (Brenna and Lapillonne, 2009; Hsieh and Brenna, 2009). In pregnancy stage, the DHA intake provides advantages to both the developing fetus and mother (Saldanha et al. 2009).

The embryo survival and continuance of pregnancy depend on release of trophoblast interferon ($IFN_T$) from the embryo, thus inhibit the expression of endometrial oxytocin receptors and the secretion of $PGF_{2α}$, thus preventing regression of the P4 secreting CL (Wathes and Lamming, 1995). The supplementation with n-3 PUFAs reduced $PGF_{2α}$ synthesis and prevents regression of the CL, lead to continued secretion of P4 that may improve embryo survival and may be reduced $PGF_{2α}$ secretion (Inskeep, 2004; Caldari-Torres et al. 2006). Petit and Twagiramungu (2006) reported, diets high in n-3 from linseed may reduce embryo mortality in dairy cows (Petit and Twagiramungu, 2006). When dairy cows fed a ruminally protected n-3 PUFAs from FO, the number of death embryos reduced by dietary inclusion of n-3 (Childs et al. 2008b).

### 2.3.6. Effect of Fatty Acid on Gestation Length and Parturition

Feeding a diets with n-3 PUFA also effects gestation length and timing of parturition, by alter the quantity and type of PG synthesis, as PG are essential for parturition, and may be reduce concentrations of circulating inflammatory cytokines (Tappia et al. 1997; Challis et al. 2002), leading to reduce the incidence of premature labour (Arntzen et al. 1998). In human, the diets high in n-3 PUFAs in late gestation period increased the gestation length (Olsen et al. 1992). In sheep the gestation length extended to two days when ewes fed a diet with FO during third trimester compared with Megalac (Capper et al. 2006), and with ewes supplemented algal that high in DHA (Pickard et al. 2008). Baguma-Nibasheka et al. (1999) reported, the gestation length increased when ewes supplemented diets with n-3 PUFAs from FO compared with n- 6. Plasma concentrations of PG, and myometrial PGHS-2 mRNA reduced by infused n-3 PUFAs in ruminant diets, thus reduced synthesis of $PGF_{2α}$. FA concentrations in reproductive tissues is another relationship between gestation length and n-3 PUFAs. During the last period of gestation, the concentration of EPA in ovine endometrium phospholipids reduced and thus reduces the synthesis of $PGF_{2α}$ and, hence, assists in the onset of parturition (Zhang et al. 1995). Mattos et al. (2004) reported the increase of EPA and DHA concentrations in caruncular tissue are also associated with later calving.

### 2.3.7. Effect of Fatty Acid During Pregnancy on Offspring Health and Immunity

Limited data available about the effects addition of FAs during pregnancy period on health and immune system of offspring. In human, during late pregnancy the consumed PUFAs in food led to presence amount of PUFAs in milk can prevent diabetes mellitus from developing (Das 2003). The consumed PUFAs in mid and late gestation period controlling many metabolic aspects such as alter gene expression and improve immune system in the early life of newborns (Enke et al. 2008). Petit and Berthiaume (2006) indicated that feeding cows fat in late pregnancy period decreased mortality rate postpartum and after weaning without effect on birth weight and average daily gain pre-weaning. In the last gestation period supplemented cows safflower seed and calves challenged to cold-stress conditions, the calves born from cows fed safflower seeds kept their body temperature throughout the stress period, and had lower cholesterol concentrations in plasma after 60 min of cold exposure, thus better heat production (Lammoglia et al. 1999). The lambs from ewes fed diets with 10% safflower seeds during pregnancy lower rate of mortality and greater number of lambs were weaned compared with lambs from ewes not have safflower seeds in diet (Encinias et al. 2004). Dietz et al. (2003) reported no difference in colostral concentrations of IgG and calf birth weight per cows fed safflower seeds or whole cottonseeds vs. cows feed ration without oil. The supplementation of FO in late gestation period to ewes improved lamb survival to weaning (Dawson and Edgar, 2006).

## 2.4. Fatty Acids and Sex Ratio

In sheep sector some farmers prefer males breeding because high growth rate and muscle accumulation, thus reaching higher market weight over a set time period. Other farmers prefer females breeding because higher sale price at weaning than males. Many studies reported that a variation from the expected 1:1 birth sex ratio in ruminants, the maternal diet and body condition were the most factors studied. The maternal condition before conception gives the stronger relationship in sex ratio than physiological and morphological measures of condition taken after conception (Cameron, 2004; Sheldon, and West, 2004; Rosenfeld, and Roberts, 2004).

The experiment in the sex ratio aspect of offspring separate into two fraction, the first focusing in dietary restriction and timing and the second focusing in dietary composition. The diet restriction to house mice and golden hamsters during pregnancy increased the number of females born and the supplementation of diets with oil and fat before pregnancy improved caloric intake and can increased the males born (Austad, and Sunquist, 1986; Rosenfeld et al. 2003).

**2.5. Effect of Supplemental Fatty Acids on Colostrums**

As above mentioned, because of poor dietary supply and high biohydrogenation of PUFA (DHA and EPA) in ruminants, limiting quantities of these FA is available for absorption (Wachira et al. 2000; Chikunya et al. 2004). Therefore, the milk of ruminant poor in DHA and EPA and enhancing the colostrum and milk content of DHA and EPA through diet could be beneficial. Kitessa et al. (2003), supplemented ovine with FO and reported increased in DHA and EPA in milk.

Pregnant ewes fed a diet with Ca salt of PO increase LA, C18:0, C18:1 trans, and OA in colostrums compare with pregnant ewes fed FO, and increase CLA c9 t11, ALA, EPA, and DHA in colostrums in pregnant ewes fed FO without difference between groups in C16:0 and AA, in FO group reduce the colostrums yield and total fat concentration (Capper et al. 2006).Cow's supplemented linseed in pre-partum period decreased C16:0 but increased proportions of C18:0, CLA c9 t11, and ALA. Proportions of OA, LA, AA, EPA, and DPA did not differ due to fat supplement (Santschi et al. 2009). Leiber et al. (2011) reported the supplementation of cows in pre-partum period with safflower seeds rich in LA or linseed rich in

ALA, increased the FAs in colostrums in linseed group without difference in EPA and DHA between groups.

**2.6. Fatty Acid and Milk Yield and Profile**

The milk quality is evaluated by the fat, protein and somatic cell content (SCC). Recently increase the focusing of dairy sheep producers on milk fat content this is because consumers of animal products have become very interested in the composition of these products and their impact on health. Many consumers prefer low fat food or low saturated fatty acids food content. Many factor affect on milk fat and FAs content, the first factor is the diet composition and availability, second factor the animal breed, lactation stage and body condition, and the last factor is the environment effects. The fat in the milk as different sizes of globules. The globules number and diameter depend on environmental, genetic, and physiological factors (Martini et al. 2004).

The major lipids in ruminant milk about 98% consist of triacylglycerols. The plasma uptake or de novo synthesis provides FAs synthesis and then secretion the FAs in milk. The FAs synthesis in milk originates from volatile FAs produced by rumen population. In mammary gland the acetate and beta hidroxybutyrate are the main carbon sources to short chain fatty acids (SCFA) and a portion of Palmitic acid (C16:0) synthesis. All of the long chain fatty acids (LCFA) and the another part of Palmitic acid in ruminants milk derive from fat in the blood, produced in the small intestine or mobilization of adipose tissue. The desaturase enzymes in mammary gland contribute to confer milk with FAs from 14 to 18 carbon chain (Vlaeminck et al. 2006).

The diet composition affect on milk fat concentration and composition, especially by factors affect on the diet ingredients during fermentation in the rumen. In the ruminants, the concentration of acetate, propionate and butyrate in the rumen fluid and the acetate: propionate ratio play a main role in milk fat production and composition. The volatile fatty acid profile in the rumen can influenced by the diets composition such as the source and content of neutral detergent fiber (NDF) and non-fibrous carbohydrates (NFC). In the dairy ewe rations, the level of the NDF must be between 32% and 43% of dry matter (DM), with NFC between 27% and 36% of DM in ewes that milk yield from 0.5 kg/d to 1.7 kg/d and 6.5% milk fat corrected. Also the NDF source can affect milk yield and fat composition, Araujo et al. (2008) replaced the NDF source from low fermentable NDF source with high fermentable NDF source and found the milk yield and fat composition increased with high fermentable NDF source. In the dairy ewes the replacing of NFC from cereal grains such as corn, barley and wheat grain (mostly starch) by NDF from soybean hulls or beet pulps, led to increased in milk production and increased in milk fat yield and concentration (Cannas et al. 1998; Zenou and Miron, 2005; Cannas et al. 2013). The by products such as soybean hulls or beet pulps, rich in digestible fiber stimulate milk fat synthesis (Cannas et al. 1998 and Zenou and Miron 2005).

The energy balance (EB) of ruminants may be affect on the milk fat profile, concentration and composition, as the EB in negative side the milk long chain fatty acids concentration and milk fat concentration increased due to the uptake of non-esterified fatty acids (NEFA) from body fat especially in early lactation (Bocquier and Caja, 2001; Cannas and Avondo, 2002; Pulina et al. 2006).Pulina et al. (2006) reported the supplemented dairy ewes during milking period with rumen bypass fat as soaps of fatty acids increase milk fat concentration, the milk yield and fat concentration increased by added Ca salts of PO to ruminant diets at level between 90 and 200 g/d, higher than this level lead to depress milk and fat yield. Using Ca salts of PUFAs from tuna oil or Ca soap of olive oil didn’t decrease milk fat content (Antongiovanni et al. 2002; Kitessa et al. 2003).Nudda et al. (2013), supplemented the small ruminants linseed, and reported that supplemented linseed decrease the milk fat concentration in early lactation period and increased milk fat concentration in mid lactation period.

In ewes and goats during milking period, the supplementation with rumen protected fat to about 8% DM of the diet led to improving milk fat concentration, and decreased protein percentage (Rotunno et al. 1998). In other study Casals et al. (1999) reported, the supplementation of dairy ewes during lactation period with 200g CSFA of PO, led to increased milk fat percentage and yield but decreased the milk protein percentage. Also Dobarganes Garcia et al. (2005) found that added 45g/day CSFA of olive oil to the dairy ewes increased milk fat percentage and yield, and not affect in milk protein(Dobarganes Garcia et al. 2005). Many studies reported that fed ruminants diets with CSFA increase the milk fat concentration and yield, but not found any effects on milk protein content and yield.

### 2.6.1. Manipulation of The Milk Fatty Acid Profile

Many studies reported that in ruminants, the diet is the most important factor for altering milk FAs profile. We cannot change the FAs concentration or profile of the milk or milk products by milk processing, and the FA concentration and profile of milk products is depend on the FA content of the raw milk (Nudda et al. 2005). The modification milk FAs composition and concentration can made be added oil to ruminant diets such as vegetable or marine oils, or by modification the amount and type of forages in the diets, because by these ways we can manipulate the rumen biohydrogenation of dietary fat especially USFAs.

The increased milk USFAs especially EPA, DHA and CLA, and α-linolenic acid (ALA) have healthy benefits and preferred from many customers in the world. Sofi et al. (2010) reported the intake about 200 g of sheep cheese rich in VA and RA for ten weeks, can have appositive effect on signs of atherosclerotic. In hyper cholesterolemic subjects Pintus et al. (2013reported that consumption of ewes cheese that have high level of conjugated linoleic acid (CLA) about 2.5 g of CLA/100 g of fat, led to decreased the LDL-cholesterol level.

### 2.6.2. Effects of Pasture on Milk Fatty Acid Profile

The pasture is the most effective feed in improve the milk FA to healthy spectrum and the major source of ALA (Nudda et al. 2003; Gómez-Cortés et al. 2009a). The high level of ALA in the pasture leads to increase the milk fat concentration of ALA, VA and CLA. In the rumen the ALA bio-hydrogenated into VA and then in the mammary gland converted to CLA. Therefore, the milk FA concentration and composition improved by pasture availability to dairy cattle (Nudda et al. 2003; de Renobales et al. 2012). De Renobales et al. (2012) reported the increased in the intake from pasture increasing in the milk content of ALA and CLA. Nudda et al. (2005) reported, the increased concentration of RA, VA and ALA in the milk of dairy ewes that fed on pasture in late winter and early spring, because high availability and quality of grass in this seasons and decreased the concentrations of RA, VA and ALA with decreasing pasture availability and quality.

Moreover the plant species in the pasture can affect on the milk FA profile and concentration. When legume is very high in pasture then the milk from ruminants that fed on this pasture is high level of CLA and ALA and with low levels of SFA contrasted with ryegrass field (Addis et al. 2005).

### 2.6.3. Effects of Using Vegetable oil on Milk Fatty Acid Profile

The using of vegetable oils in the ruminant diets is a good strategy to improve the diets energy and to enhance milk FA composition. Using of vegetable oils in the ruminant diets is extremely helpful in situation of low diet content of FAs and when low quality forages are using in feeding.

The vegetable oils are used commonly as a source of USFAs from plant origin to improve milk FAs content (CLA and unsaturated FA), and thus the improve milk FAs depend on the percentage of those ingredients in the diet (Table 2.6.). The adding of linseed in ruminants during lactation period increase milk content of VA, c9, t11 CLA and PUFA n-3 without any effects on milk production and composition (Luna et al. 2008; Gómez-Cortés et al. 2009b). In dairy ewes the supplementation of soybean oil more effective than linseed oil or sunflower oil in milk CLA content (Castro et al. 2009; Bodas et al. 2010). The ruminal biohydrogenation of USFAs more complete with linseed feeding than soybean and thus the amounts of CLA and VA in the duodenum from ration high level in linoleic acid higher than diets high in linolenic acid (Lock and Garnsworthy, 2002; Bu et al. 2007). The soybean oil more effective than the sunflower oil in increasing milk CLA because when added vegetable oils to diets its more effect in the form of free oil than seeds (Bodas et al. 2010), and may be to in the rumen when added as free oil it is more effective than when oil covering by seed coat (Chilliard et al. 2009). Gómez-Cortés et al. (2014) the milk CLA from diet with 70 g of free oil higher than milk CLA from diet with 70 g of extruded linseed. The processed lipid can be used in the ruminant diets such as rolled, roasted, and micronized seeds and may be more effective to increase CLA in the milk than raw seeds, because the oil content of the raw seeds more slowly disperse in the rumen (Mughetti et al. 2007; Doreau et al. 2009).

Table 2.5. Effects of some oil supplementation on CLA, Vaccenic acid, Linoleic acid and α-Linolenic acidin sheep milk.

| Treatments | g/d | CLA | Vaccenic acid | Linoleic acid | α-Linolenic acid | References |
|---|---|---|---|---|---|---|
| SFO-MO | 160 | 0.26 | 6.60 | 3.83 | 0.99 | Reynolds et al. (2006) |
| Silage | - | 0.81 | 4.93 | 4.96 | 0.41 | |
| SFO-MO | 140 | 0.91 | 9.30 | 4.62 | 0.52 | |
| Control | - | 1.00 | 0.91 | 2.31 | 0.91 | Zhang et al. (2006a) |
| WLS | 211 | 1.52 | 1.53 | 3.52 | 1.82 | |
| SFS | 180 | 2.33 | 1.52 | 4.12 | 1.43 | |
| LSO | 22 | 1.23 | 3.00 | 2.32 | 1.63 | Zhang et al. (2006b) |
| | 32 | 1.34 | 3.84 | 2.53 | 1.72 | |
| | 42 | 1.93 | 4.24 | 2.53 | 2.00 | |
| Control | - | 0.55 | 0.86 | 2.72 | 0.32 | Castro et al. (2009) |
| SFO | 27 | 0.62 | 1.22 | 3.03 | 0.44 | |
| HP | 27 | 0.62 | 0.94 | 2.94 | 0.44 | |
| PO | 62 | 0.38 | 0.77 | 1.97 | 0.53 | Bodas et al. (2010) |
| OO | 62 | 0.92 | 2.07 | 1.54 | 0.38 | |
| SBO | 62 | 2.57 | 6.53 | 3.16 | 0.54 | |
| LSO | 62 | 1.57 | 4.26 | 1.75 | 1.08 | |
| SBO | - | 0.82 | 1.87 | 2.47 | 0.37 | Gómez-Cortés et al. (2011b) |
| | 16 | 1.37 | 3.86 | 2.64 | 0.32 | |
| | 33 | 2.43 | 6.93 | 2.86 | 0.28 | |
| | 52 | 2.96 | 8.54 | 2.97 | 0.27 | |
| Control | - | 0.52 | 1.08 | 6.57 | 0.33 | Maia et al. (2011) |
| CAO | 3.00 | 1.27 | 3.46 | 6.93 | 0.34 | |
| SFO | 3.00 | 1.24 | 3.18 | 7.04 | 0.32 | |
| CO | 3.00 | 0.53 | 1.12 | 7.66 | 0.33 | |
| Control | 72 | 0.38 | 0.84 | 2.43 | 0.32 | Gómez-Cortés et al. (2014) |
| ELS | 72 | 0.87 | 3.02 | 1.84 | 0.93 | |

SFO :sunflower oil, MO :marine oil, WLS :whole linseed, SFS :sunflower seed, LSO :linseed oil, HP :hydro palm, OO :olive oil, SBO :soybean oil, PO :palm oil, CO :castor oil, CAO :canola oil, ELS :extruded linseed.

### 2.6.4. Effects of Marine oil Sources

The marine oil source is the highest in the milk composition of CLA, VA and omega-3 FAs among all types of fat source used in ruminant diets (Table 2.7.). In dairy ewes, the supplementation of FO at 30-45 g/day increased CLA concentration of the milk (Mozzon et al. 2002). The marine oils poor in CLA precursors but very effect in increasing milk concentration of VA and CLA by the manipulation of synthesis of 18:0 by the rumen population. Also the marine oils rich in EPA and DHA, and thus when ruminants supplemented marine oils lead to increase milk content of these long chain fatty acids (Mozzon et al. 2002; Kitessa et al. 2003; Ferreira et al. 2011). In dairy ewes the transfer of EPA and DHA from the diet to milk was higher than dairy cows or goats (Kitessa et al. 2001; Lock and Bauman, 2004).

The high amount of the PUFA n-3 (DHA and EPA) biohydrogenation within the rumen, and the poor dietary supply of those FA, lead to decrease the amount of those FA's availability for absorption (Wachira et al. 2000; Chikunya et al. 2004). Moreover, the milk of ruminants contains limited concentrations of DHA, the precursor of DHA and EPA, was also shown to be limited in sheep (Wright et al. 2003; Demirel et al. 2004). Many researchers in ruminant nutrition reported, the EPA and DHA maybe escape rumen biohydrogenation (Thatcher and Staples, 2007), and those PUFAs of omega-3 family found in higher amount in marine products, such as fish oil and meal (Thatcher and Staples, 2007). The PUSAs play an important role in many reproductive tissues, this importance comes from its role in fluidity of cell membrane (Wathes et al. 2007). However the long chain fatty acids in ruminant ration are commonly very low and rumen biohydrogenation in rumen very high and extensive (Chikunya et al. 2004), which may affect of availability in fetal tissues, milk and meat, especially during the late pregnancy period and in this period rapid fetal growth. The strategy to increase the supply of PUFAs of the n-3 family FAs in diets. Therefore, enhancing the DHA and EPA of omega-3 family concentration in colostrum, milk and milk products through added to ration could be good to suckling animals.

Table 2.6. Effects of marine oil on milk fatty acid profile

| Treatments | CLA | α-Linolenic acid | EPA | DHA | References |
|---|---|---|---|---|---|
| Control | 0.67 | 0.36 | 0.04 | - | Mozzon et al. (2002) |
| 30 g/d FO | 1.66 | 0.47 | 0.12 | 0.22 | |
| 45 g/d FO | 2.86 | 0.43 | 0.18 | 0.37 | |
| Control | - | - | 0.03 | 0.03 | Kitessa et al. (2003) |
| 6 g/d DHA | - | - | 0.48 | 1.93 | |
| Control | 0.45 | 0.52 | 0.12 | 0.04 | Toral et al. (2010) |
| 25 g SFO | 1.24 | 0.43 | 0.08 | 0.03 | |
| 25 g SFO+ 8 g MA | 2.77 | 0.38 | 0.13 | 0.18 | |
| 25 g SFO + 16 g MA | 2.56 | 0.37 | 0.12 | 0.47 | |
| 25 g SFO + 24 g MA | 3.23 | 0.33 | 0.14 | 0.58 | |
| 4% SBO | 1.34 | 0.27 | - | - | Ferreira et al. (2011) |
| 0.25% FO + 3.75% SBO | 1.48 | 0.27 | 0.02 | 0.03 | |
| 0.50% FO + 3.50% SBO | 1.64 | 0.28 | 0.02 | 0.02 | |
| 0.75% FO + 3.25% SBO | 1.46 | 0.23 | 0.03 | 0.02 | |
| 25 g FO | 2.43 | 0.47 | 0.03 | 0.04 | Bichi et al. (2013) |
| 25 g SBO + 8 g MA | 3.97 | 0.46 | 0.05 | 0.36 | |

SFO :sunflower oil, MA :marine algae, SBO :soybean oil

## 3. MATERIALS AND METHODS

### 3.1. Material

The experiment was conducted at Al-Khanasry Station for Livestock Research, National Centre for Agricultural Research and Extension (NCARE) in Jordan. The Station is located 50 km to the North of Amman at 31.5◦N latitude and at an altitude of 350 m, with an arid to semi-arid climate and annual rainfall of 170 mm.

#### 3.1.1. Animal Material

One hundred mature Awassi ewes at 2-4 years of age, parity ranging from 1 to 3 and body weight 57±1.5 kg were examined by a veterinarian to assure good health and udder status. Ewes were synchronized by using intravaginal sponge containing progesterone acetate for 14 days (60 mg; Veramix, Pharmacia and Upjohn Co., Orangeville, Canada). The second day of sponge removal, all ewes were randomly allocated into 10 equal groups (10 ewes/group). Ewes were naturally mated by 10 good fertile rams (1 ram/10 ewes). Pregnancy diagnosis was performed in the tenth week of pregnancy and discards all non-pregnant ewes. Numbers of the ewes in each groups were as fallows PO; n = 15, POFO; n = 16, FOPO; n = 16 and FO; n = 16. Ewes were housed under conditions of natural day light and temperature.

The gestation period was segmented to 2 periods, breeding to-65 days and 66 days to lambing. From the first day of mating, ewes were randomly assigned to one of the four dietary treatments. Treatments were 1) diet containing PO from 0-150 days of pregnancy (PO; $n$ = 25), 2)diet containing PO from 0-65 days of pregnancy, then diet containing FO 66-150 days of pregnancy (POFO; $n$ = 25), 3) diet containing FO from 0-65 days of pregnancy, then diet containing PO from 66-150 days of pregnancy (FOPO; $n$ = 25) and 4) diet containing FO from 0-150 days of pregnancy (FO; $n$ = 25).Ewes were housed with three replicates per treatment, every treatment divided to three subgroups in shaded pens (12 m ×6 m), every ewe take a space of about 33 cm at the feeder.

After birth ewes with their lambs were housed with three replicates per treatment, every treatment divided to three subgroups in shaded pens (12 m ×6 m) and all pens have an area for creep feeding. At the end of nursing period, lambs were separated from their dams, and continue with the same ewes groups to milking period and fattening for ram lambs, thirty two (average age = 70±0.99 d) Awassi ram lambs (average BW = 19 ±1.7 kg) were assigned to the same diet (Table 3.5); All lambs were separated to four groups (8 lamb/group) as the ewes group.

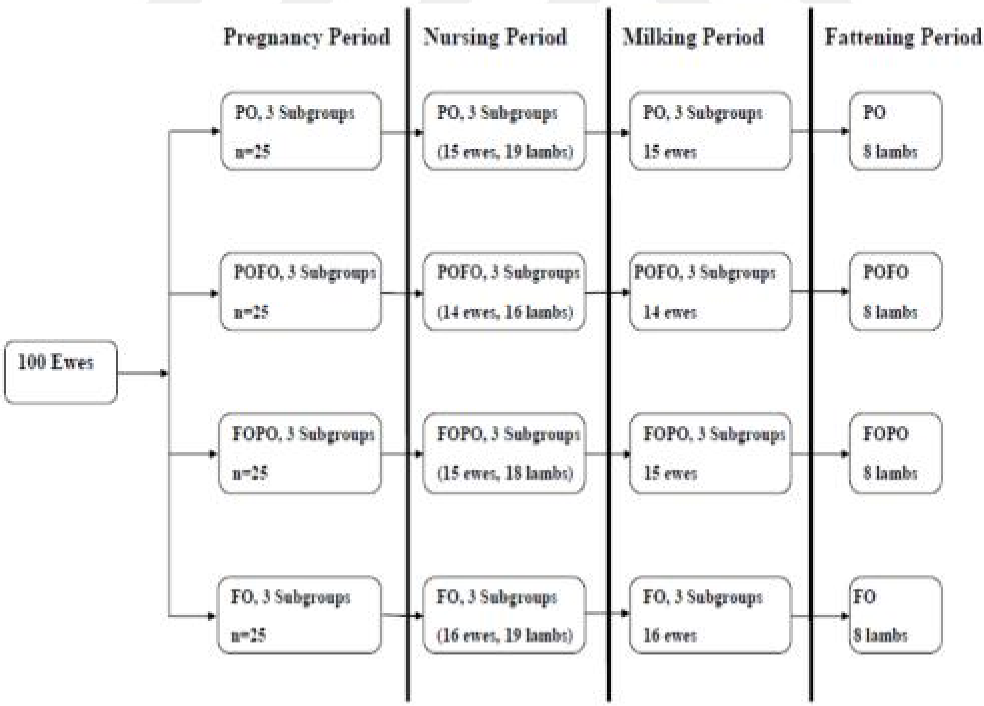


Figure 3.1. The diagram of general methods of the experiment

### 3.1.2. Experimental Diets

Rations were formulated to meet NRC (2007) requirements for gestation ewes in total mixed ration (TMR), as isonitrogenous (Table 3.1). Ewes were housed in shaded pens and fed their diets daily at 8:00 h and 15:00 h., as groups. Fat sources used in this study were PO and FO and they were used in 2.4% DM at early stage of gestation and in 2.1% DM at late stage of gestation, the FAs profile of the PO and FO are presented in Table 3.2. Ewes were fed ad libitum and had access to fresh water throughout the experiment.

Table 3.1. TMR content and nutrient composition used in the early and late pregnancy

| Ingredients (% DM) | Diets (Early Gestation) | | | |
|---|---|---|---|---|
| | PO | POFO | FOPO | FO |
| Barley grain | 23.40 | 23.40 | 23.40 | 23.40 |
| Soybean meal, 44%CP (Solvent Ext.) | 6.77 | 6.77 | 6.77 | 6.77 |
| Wheat straw | 54.09 | 54.09 | 54.09 | 54.09 |
| Wheat bran | 11.56 | 11.56 | 11.56 | 11.56 |
| Fish oil | - | - | 2.40 | 2.40 |
| Palm oil | 2.40 | 2.40 | - | - |
| Salt | 0.38 | 0.38 | 0.38 | 0.38 |
| Limestone | 1.00 | 1.00 | 1.00 | 1.00 |
| Mineral vitamin premix[a] | 0.40 | 0.40 | 0.40 | 0.40 |
| **Nutrient contents** | | | | |
| DM % | 91.31 | 90.62 | 90.59 | 89.69 |
| R:C | 55:45 | 55:45 | 55:45 | 55:45 |
| CP % | 10.18 | 9.52 | 9.84 | 9.44 |
| ADF % | 27.46 | 27.36 | 28.16 | 27.86 |
| NDF % | 48.14 | 48.51 | 48.36 | 49.12 |
| EE % | 4.17 | 4.22 | 4.36 | 4.18 |
| ME (Mcal/Kg)[b] | 2.43 | 2.61 | 2.36 | 2.33 |
| | **Late Gestation** | | | |
| | **PO** | **POFO** | **FOPO** | **FO** |
| Barley grain | 26 | 26 | 26 | 26 |
| Soybean meal, 44% CP (Solvent Ext.) | 6.5 | 6.5 | 6.5 | 6.5 |
| Wheat straw | 53.25 | 53.25 | 53.25 | 53.25 |
| Wheat bran | 10.85 | 10.85 | 10.85 | 10.85 |
| Fish oil | - | 2.1 | - | 2.1 |
| Palm oil | 2.1 | - | 2.1 | 0 |
| Salt | 0.5 | 0.5 | 0.5 | 0.5 |
| Limestone | 0.5 | 0.5 | 0.5 | 0.5 |

| | | | | |
|---|---|---|---|---|
| Mineral vitamin premix | 0.3 | 0.3 | 0.3 | 0.3 |
| **Nutrient contents** | | | | |
| DM % | 90.57 | 89.67 | 90.12 | 90.54 |
| R:C | 55:45 | 55:45 | 55:45 | 55:45 |
| CP % | 10.62 | 10.54 | 11.02 | 10.41 |
| ADF % | 26.62 | 27.12 | 26.51 | 26.86 |
| NDF % | 48.42 | 49.10 | 48.35 | 48.80 |
| EE % | 4.34 | 4.14 | 4.25 | 4.17 |
| ME (Mcal/Kg)[b] | 2.65 | 2.24 | 2.52 | 2.31 |

[a] Composition per kg contained (vitamin A, 2,000,000 IU; vitamin D3, 40,000 IU; vitamin E, 400 mg; Mn, 12.80 g; Zn, 9.00 g; I, 1.56 g; Fe, 6.42 g; Cu, 1.60 g; Co, 50 mg; Se, 32 mg).
[b] Calculated based on tabular values using NRC (2007).

The fatty acids profile of the PO and FO are presented in Table 3.2.

Table 3.2. Fatty acid profile of FO and PO

| Fatty acid | Fish oil | Palm oil |
|---|---|---|
| Lauric (C12:0) | - | 0.17 |
| Myristic (C14:0) | 6.2 | 0.94 |
| Pentadecanoic acid (C15:0) | 0.72 | - |
| Palmitic (C16:0) | 20.4 | 41.98 |
| Palmetoleic (C16:1) | 8.15 | 0.18 |
| Heptadecanoic (C17:0) | 1.1 | 0.08 |
| Heptadecenoic (C17:1) | 0.56 | 0.03 |
| Stearic (C18:0) | 5.4 | 2.2 |
| Oleic (C18:1) | 16.1 | 41.6 |
| Linoleic (C18:2) | 2.11 | 10.9 |
| Linolenic (C18:3) | 0.63 | 0.16 |
| Arachedic (C20:0) | 0.4 | 0.33 |
| Gadoleic (C20:1) | 0.8 | 0.12 |
| Behenic (C22:0) | - | 0.06 |
| Lignoceric (C24:0) | - | 0.06 |
| Arachidonic acid (ARA) (C20:4) | 2.7 | - |
| Eicosapentaenoic acid (EPA) (C20:5) | 10.1 | - |
| Dicosapentaenoic acid (DPA, C22:5) | 3.1 | - |
| Dicosahexaenoic acid (DHA ,C22:6) | 16.3 | - |

After lambing diets were formulate without FO and/or PO and to be isonitrogenous and the same for all ewes and lambs (Table 3.3 and 3.4). Diets were mixed every day, were sampled for laboratory analysis to ensure consistency in their chemical composition (triplicate). Ewes with their lambs were housed as groups and fed their diets daily at 8:00 h. Experimental diets is adequate for nursing ewes (NRC, 2007).

Table 3.3. TMR content and nutrient composition used in nursing for ewes.

| **Ingredients (% DM)** | **Diet** |
|---|---|
| Barley grain | 50 |
| Soybean meal, 44% CP (Solvent) | 15 |
| Wheat straw | 33 |
| Salt | 1 |
| Limestone | 0.9 |
| Mineral vitamin premix[a] | 0.1 |
| **Nutrient Contents** | **%** |
| Dry matter | 90.7 |
| Organic matter | 89.7 |
| Crude protein | 14.5 |
| Neutral detergent fiber | 37.4 |
| Acid detergent fiber | 19.9 |
| R:C | 33:67 |
| ME (Mcal/kg)[b] | 2.50 |

[a] Composition per kg contained (vitamin A, 2,000,000 IU; vitamin D3, 40,000 IU; vitamin E, 400 mg; Mn, 12.80 g; Zn, 9.00 g; I, 1.56 g; Fe, 6.42 g; Cu, 1.60 g; Co, 50 mg; Se, 32 mg).
[b]Calculated based on tabular values using NRC (2007).

Table 3.4. TMR content and nutrient composition used in nursing period for lambs

| **Ingredients (% DM)** | **Diet** |
|---|---|
| Barley grain | 50 |
| Soybean meal, 44% CP (Solvent) | 19 |
| Wheat straw | 5 |
| Wheat bran | 15 |
| Corn | 9 |
| Salt | 1 |
| Limestone | 0.9 |
| Mineral vitamin premix[a] | 0.1 |
| **Nutrient Contents** | **%** |
| Dry matter | 89.4 |
| Crude protein | 18.3 |
| Neutral detergent fiber | 20.05 |
| Acid detergent fiber | 9.87 |
| ME (Mcal/kg)[b] | 2.84 |

[a] Composition per kg contained (vitamin A, 2,000,000 IU; vitamin D3, 40,000 IU; vitamin E, 400 mg; Mn, 12.80 g; Zn, 9.00 g; I, 1.56 g; Fe, 6.42 g; Cu, 1.60 g; Co, 50 mg; Se, 32 mg).
[b]Calculated based on tabular values using NRC (2007).

After weaning, thirty two (average age = 70±0.99 d) Awassi ram lambs (average BW = 19 ±1.7 kg) were assigned to the same diet (Table 3.5); All lambs were separated to four groups (8 lamb/group) as the ewes group.

Table 3.5. TMR content and nutrient composition used in fattening period

| Ingredients (% DM) | Diet |
|---|---|
| Barley grain | 50 |
| Soybean meal, 44% CP (Solvent) | 14 |
| Wheat hay | 19 |
| Wheat bran | 13 |
| Salt | 1 |
| Dicalcium phosphate | 1.5 |
| Calcium carbonate | 1 |
| Mineral vitamin premix[a] | 0.1 |
| **Nutrient Contents** | **%** |
| Dry matter | 89.8 |
| Organic matter | 88.3 |
| Crude protein | 15.8 |
| Neutral detergent fiber | 31.63 |
| Acid detergent fiber | 15.14 |
| ME (Mcal/kg)[b] | 2.59 |

[a]Composition per kg contained (Dicalcium phosphate, 800 g; sodium chloride, 60 g; trace elements mixture, 20 g (Zn, Mn, Fe, Cu, Co, Se); magnesium oxide, 20 g; vit. A, 500,000 IU; vit. D3, 85,000 IU, vit. E, 200 IU.).
[b]Calculated based on tabular values using NRC (2007).

### 3.2. Methods

The study lasted 11 months in total (5 months of pregnancy, 4 months of nursing and milking period and 2 months of fattening period).The study was carried out in a special designed shaded pen. During the experimentation, animals were housed in 12 pens (12 m ×6 m) of groups.

#### 3.2.1. Data Collection During Pregnancy Period

Ewes were housed in shaded pens and fed daily at 8:00 h and 15:00 h., as groups. Ewes were weighed monthly before morning feeding throughout the study. Ewes were fed ad libitum and had access to fresh water throughout the experiment.

To measure nutrient intakes, orts were collected daily and sampled for chemical analysis. Feeders were managed to let no more than 10% of feed per animal to remain 1 h prior to feeding and if the feeders were empty, 10% of feed was added to the previous amount offered on the day before the next voluntary feed intake. Pregnancy, lambing, abortion and mortality were recorded.

### 3.2.2. Data Collection During Nursing and Milking Period

Ewes were given 1 week adaptation to the pens and to the diets. Following adaptation, the diets were fed to the ewes and their lambs for 8 weeks. Ewes and lamb intake was measured and weight were recorded and continued biweekly before morning feeding. Lambs intake was measured by partitioning a section of the pen or area with a gate or openings through which the lambs can fit, but not the ewes. This accomplished by used openings that are adjustable from 15 to 25 cm, set in a panel at least 50 cm high, so that ewes cannot jump over. Average daily gain before weaning (ADGW) calculated using the biweekly body weights for each lamb. Ewes and lambs were fed their diets ad libitum and on the basis of the animals established consumption pattern during adaptation period and had access to fresh water throughout the experiment.

Two colostrums samples (approximately 50 mL from each half of the udder) were collected by hand-milking into plastic bottles at 1 h and 12 h after parturition and stored at -20 °C till analysis. Colostrums production was determined by milking the ewes at 1 h after parturition.

During the second week of lactation, milk production measurements were made and continued biweekly thereafter. Milk production over a period of 12 h was estimated biweekly throughout the study at 08:00 h by hand milking. Lambs were separated from their dams 12 h before milking. Then, milk production was calculated over 24 h (Awawdeh et al. 2009). For chemical composition of milk, a

125 ml sample was collected biweekly from each ewe and frozen at −20 ◦C for later analysis.

### 3.2.3. Data Collection During Fattening Period

After weaning, thirty two (average age = 70±0.99 d) Awassi ram lambs (average BW = 19 ±1.7 kg) were assigned to the same diet (Table 3.5); all lambs were separated to four groups (8 lamb/group) as the ewes group. The experimental period lasted for 56 days. Diets were fed as totally mixed rations once daily at 9:00 h in amounts to ensure 10% orts. The amount of feed offered and refused for each group was recorded weekly. Clean drinking water was available in plastic buckets and animal pens were cleaned weekly. Lamb weights were recorded weekly before feeding to monitor body weight change throughout the experiment. Experimental diets were mixed weekly and were sampled upon mixing to ensure proper mixing.

### 3.2.4. Chemical Analysis

#### 3.2.4.1. Chemical Analysis of Feeds

Composited diets and orts samples were dried at 55 °C in a forced air oven to constant weight, air equilibrated and then ground to pass a 1 mm screen (Barbender Ohg Duisdurg, Kulturstrase 51–55, type 880845, Nr 958084, Duisdurg, Germany) and kept for further analysis. Ground samples were analyzed for DM (100 °C in air-forced oven for 24 h; method 967.03), and N (Kjeldahl procedure; method 976.06) of AOAC (1990). In addition, all samples were analyzed for neutral detergent fiber(NDF) and acid detergent fiber(ADF) according to procedures described by Van Soest et al. (1991) with modifications for use in the Ankom2000 fiber analyzer apparatus (Ankom Technology Corporation, Macedon, NY,). Neutral detergent fiber analysis included sodium sulfite and a heat stable alpha amylase. Both NDF and ADF are expressed with residual ash content.

**3.2.4.2. Colostrums and Milk Analysis**

The colostrums samples were diluted by one-half or one-third with distilled water, depending on their viscosity. The samples were warmed to room temperature and then analyzed for the concentrations of fat and protein. Samples were analyzed for solids not fat (SNF), fat and CP. Solids-not-fat contents were calculated according to David (1977) using Lactometer. Crude protein (N × 6.38) was determined using a Kjeldahl procedure (method 976.06; AOAC, 1990). Fat content was analyzed according to Gerber method (Gerber Instru-ments, K. Schnider and Co. AG; 8307 Langhag, Effretikon).

Concentrations of colostral IgG were measured as representative of the immunoglobulin content of the colostrums. The colostrums IgG concentrations were determined using the Brix Refractometer (Quigley et al. 2013). Pregnancy rate was calculated as number of ewes lambing per ewes mated, lambing rate was calculated as number of lambs born per ewes mated, abortion rate was calculated as number of ewes aborted per ewes mated and mortality rates was calculated as the number of mortalities prior to weaning per number of lambs born.

Milk samples were thawed and bulked for each ewe. Then, the samples were warmed to room temperature and then analyzed for the concentrations of solids not fat (SNF), fat and protein using an infrared milk analyzer (Milkana superior plus).

Milk fatty acid profile was performed. Fat from milk samples was extracted. After separation fat then transesterification into fatty acid methyl esters by methylation at room temperature with NaOH (2 M) in methanol (Palmquist and Jenkins, 2003), and then analyzed for FA profile by gas chromatography (GC) as in Shimadzu 2010 way, with flame ionization detector. Milk FA compositions were analyzed by GC according to Sanz Sampelayo et al. (2006), the Supelcowaxs-10 fused silica capillary column (60 m_0.75 mm i.d, phase thickness 1.0 mm; Supelco Inc., Bellefonte, PA). The carrier gas was nitrogen. Initial oven temperature was programmed from 60 to 70 °C at 2 °C/min, and from 70 to 230 °C at 20 °C/min. Injector and detector temperatures were 250 °C and nitrogen flow rate was 1.2 ml/min (Sanz Sampelayo et al. 2006).

### 3.2.5. Statistic Analysis

The analyses were performed by IBM SPSS statistical package version 23.0 (IBM SPSS Inc., Chicago, IL). P values $\leq 0.05$ were considered significant, and $0.05 < P \leq 0.10$ were considered a tendency. Least square difference (LSD) was used to further identify differences among groups. ANOVA was used to primarily analyze the differences between treatment groups in term of the initial body weight. Random effect of initial body weight was significant on final BW, WG and ADG. Thus, ANCOVA with initial BW as Covariate. Pregnancy, number of lambs born, number of ewes lambed, number of lambs weaned, aborted, and mortality were all analyzed using Chi-square test with Fisher's exact test for cell counts less than 5.

# 4. RESULTS AND DISCUSSION

## 4.1. Effects of Feeding Omega-3 Fatty Acids During Pregnancy on Ewes

### 4.1.1. Effect on Pregnancy Performance

Gestation length (day) is presented in (Table 4.1). Awassi ewes fed the FO and POFO was longer (P< 0.05) in gestation period than other treatment groups. Initial and final live weights of ewes were not differ among treatments and averaged 57 kg and 71.6 kg, respectively (P>0.05). Dry matter intake and BWG were, also, similar among treatments.

Table 4.1. Effect of feeding omega-3 fatty acids during gestation on maternal performance

| | Treatments[1] | | | | | |
|---|---|---|---|---|---|---|
| | PO | POFO | FOPO | FO | SEM[2] | P-value |
| Gestation length, day | 145[a] | 147[b] | 146[a] | 149[b] | 0.48 | <0.001 |
| Dry matter intake, g/day | 1294 | 1282 | 1291 | 1287 | 10.08 | 0.952 |
| Initial body weight, kg | 55.4 | 58.0 | 58.0 | 56.5 | 1.77 | 0.523 |
| Final body weight, kg | 70.0 | 72.1 | 73.0 | 71.1 | 1.46 | 0.432 |
| Ewe BWG, kg | 14.5 | 14.2 | 15.1 | 14.6 | 1.29 | 0.734 |

[1]Treatment diets were 1) diet containing PO from 0-150 days of pregnancy (PO; n = 25), 2)diet containing PO from 0-65 days of pregnancy, then diet containing FO 66-150 days of pregnancy (POFO; n = 25),3)diet containing FO from 0-65 days of pregnancy, then diet containing PO from 66-150 days of pregnancy (FOPO; n = 25)and 4) diet containing FO from 0-150 days of pregnancy (FO; n = 25).
[2]SE: Standard error of pooled means.
[ab] Means within row with different superscripts differ (P<0.05)

The gestation length of the FO and POFO groups were higher than the other groups. In agreement, the inclusions of PUFA n-3 in sheep (Pickard et al. 2004) led to extension of gestation length, and are thought to be associated with a reduction in the synthesis of two series prostaglandins, due to increased EPA concentrations (Abayasekara and Wathes, 1999; Pickard et al. 2004). Capper et al. (2006) reported the ewes fed a diet containing FO during third trimester of gestation increased gestation length two days compared with protected fat source. Baguma-Nibasheka et al. (1999) reported, the gestation length increased when ewes supplemented diets with n-3 PUFAs from FO compared with n- 6.The AA and EPA act as major prostaglandin (PG) precursors within the ruminant; the bioactive dienoic $PGE_2$ and $PGF_{2\alpha}$ are synthesized from AA, whereas $PGE_3$ is produced from EPA, when increase in the ratio of EPA to AA available to the ewe results in a shift in PG production from bioactive dienoic PG, which have an established role in the induction of parturition, toward less active trienoic PG (Calder 2001), and is thought to be associated with a reduction in uterine muscle contractility by an increased supply of DHA (Olsen et al. 1990), in another study Baguma-Nibasheka et al.(1999) demonstrated a delay in the initiation of glucocorticoid-induced parturition in ewes infused with FO, with concurrent reductions in maternal estradiol and prostaglandin-H-synthetase-2.No differences in gestation length between PO and FOPO, because the ration of those two groups did not have FO in late period of gestation, and not have the effect of FO in gestation length.

No differences in DMI and BWG were observed among ewes fed the different treatment diets. Capper et al. (2007) also reported that supplementing ewes with FO during late pregnancy and lactation has no effect on DMI and the dietary fat source had no significant effect in the daily intake of pregnant and lactating ewes.

Although many studies reported that inclusion of FO in ruminant rations led to reduction in DMI (Donovan et al. 2000; Annett et al. 2004), but dietary fat source had no significant effect upon the daily DMI of pregnant ewes within the current study. However, the previous studies did not include a control fat source in the control diet; therefore it is possible that the observed results may have resulted from similar effects of FO and PO upon DM intake. The depressive effect of PUFAs upon DMI has been attributed to toxic effects of PUFAs to rumen microbes, although the use of protected FOs appears to negate these effects (Kitessa et al. 2001). Therefore PUFA supplementation may have metabolic effects upon DMI via shifts in ruminal biohydrogenation leading to an increased supply of USFAs at the duodenum (Shingfield et al. (2006).

### 4.1.2. Effect on Colostrums and Milk, Yield and Composition

The results of colostrums yield, fat%, protein% and IgG (g/l) are presented in Table 4.2. Colostrums yield, fat content and protein content was higher (P < 0.05) for ewes fed the PO and FOPO than ewes fed the FO and POFO diets, while IgG had lower (P < 0.05) for ewes fed the PO and FOPO than ewes fed the POFO and FO diets.

Table 4.2. Effect of feeding omega-3 fatty acids during gestation on colostrum parameters

| | Treatments | | | | | |
|---|---|---|---|---|---|---|
| | PO | POFO | FOPO | FO | SE | P-value |
| Colostrums yield (kg/d) | $1.6^{a}$ | $1.3^{b}$ | $1.5^{a}$ | $1.2^{b}$ | 1.45 | <0.001 |
| Fat % | $10.1^{a}$ | $8.2^{b}$ | $10.2^{a}$ | $8.1^{b}$ | 0.15 | <0.001 |
| Protein % | $13.0^{a}$ | $11.6^{b}$ | $13.0^{a}$ | $11.4^{b}$ | 0.06 | <0.001 |
| IgG (g/L) | $59.2^{b}$ | $77.2^{a}$ | $60.6^{b}$ | $78.5^{a}$ | 1.24 | <0.001 |

$^{ab}$ Means within row with different superscripts differ (P<0.05)

In the current study, differences in colostrums yield, fat and protein observed between Awassi ewes fed diets containing FO or PO in different stage of gestation. The colostrum yield, fat and protein had a lower in groups that have a FO in ration at late period of gestation than groups that not have FO in ration at late period of gestation. Conversely, IgG had a lower in groups that not have FO in ration at late period of gestation. In agreement to our results, Annett et al. (2008), (2009); Capper et al. 2006 observed, often the colostrums yield, fat and protein is reduced following n- 3 supplementation with FO. The combined effects of a large reduction in colostrums fat and protein (Pattinson et al. 1995).

Studies in sheep have shown that supplementation of diets with FO, a source of PUFA, during late pregnancy reduced colostrum yield, fat concentration, and fat and protein yield (Capper et al. 2006). The observed reduction in colostrums production and composition in early stage of milking period is consistent with reports in other studies, where milk and colostrums production, fat and protein percentage have been shown to decrease in response to FO supplements (Chilliard and Doreau, 1997; Offer et al. 1999; Chikunya et al. 2002 and Capper et al. 2006). The most widely accepted hypothesis for the cause of diet-induced milk fat depression in dairy ruminants involves direct inhibition of lipid synthesis in the mammary gland, in response to FA intermediates (trans-C18:1 and related metabolites, such as conjugated linoleic acid, CLA), formed during partial biohydrogenation of USFAs in the rumen (Bauman and Griinari, 2001).

The results of milk fat%, SNF% and protein% are presented in Table 4.3. Milk fat, SNF and protein percentage was higher ($P < 0.05$) for PO and FOPO than FO and POFO during first 15 days of lactation, and from 45 days of lactation no differences occurred ($P > 0.05$) in milk the constituent.

Table 4.3. Effect of FO during pregnancy on milk fat, SNF and protein composition

| | PO | POFO | FOPO | FO | SEM[1] | P-value |
|---|---|---|---|---|---|---|
| **Fat%** | | | | | | |
| 15 day | 7.42[a] | 6.37[b] | 7.26[a] | 6.29[b] | 0.10 | <0.001 |
| 45 day | 6.54 | 6.45 | 6.70 | 6.48 | 0.08 | 0.715 |
| 90 day | 6.16 | 6.02 | 6.17 | 6.31 | 0.10 | 0.781 |
| **SNF%** | | | | | | |
| 15 day | 11.43[a] | 10.68[b] | 11.15[a] | 10.42[b] | 0.08 | <0.001 |
| 45 day | 10.80 | 10.51 | 10.66 | 10.58 | 0.06 | 0.387 |
| 90 day | 10.62 | 10.35 | 10.41 | 10.32 | 0.06 | 0.251 |
| **Protein%** | | | | | | |
| 15 day | 4.22[a] | 3.82[b] | 4.36[a] | 3.66[b] | 0.05 | <0.001 |
| 45 day | 3.80 | 3.75 | 3.69 | 3.72 | 0.03 | 0.661 |
| 90 day | 3.40 | 3.55 | 3.69 | 3.46 | 0.04 | 0.071 |

[ab] Means within row with different superscripts differ ($P<0.05$)

Depression observed in this study is consistent with other studies, where milk production, fat and protein percentage have been shown to decrease in response to FO supplements (Chilliard and Doreau, 1997; Offer et al. 1999 and Chikunya et al. 2002). Shingfield et al.(2006) demonstrated, the inclusion of FO in ruminant diets lead to decreased milk content of fat and protein, and this decreased associated with the increasing of CLA in milk by biohydrogenation. In many studies, the reduction of milk fat content with FO diets was reported as modify ruminal lipid metabolism, leading to changes in the profile of biohydrogenation intermediates leaving the rumen (Cattaneo et al. 2001; Shingfield et al. 2006).

The results of milk yield during lactation period are presented in Table 4.4. Awassi ewes fed the PO and FOPO was greater ($P < 0.05$) in milk production than other treatment groups in first 30 days of lactation, with no differences between groups after 30 days of lactation. In average Awassi ewes fed the PO and FOPO was greater ($P < 0.05$) in milk production than other treatment groups.

Table 4.4. Effect of FO during pregnancy on milk yield (Kg) during lactation period

| Lactation days | PO | POFO | FOPO | FO | SEM | P-value |
|---|---|---|---|---|---|---|
| 15 | 1.70[a] | 1.32[b] | 1.69[a] | 1.27[b] | 0.03 | <0.001 |
| 30 | 1.81[a] | 1.39[b] | 1.83[a] | 1.38[b] | 0.03 | <0.001 |
| 45 | 1.62 | 1.51 | 1.58 | 1.52 | 0.02 | 0.122 |
| 60 | 1.46 | 1.42 | 1.48 | 1.40 | 0.02 | 0.524 |
| 75 | 1.36 | 1.36 | 1.39 | 1.32 | 0.02 | 0.731 |
| 90 | 1.33 | 1.30 | 1.33 | 1.27 | 0.02 | 0.810 |
| Average | 1.54[a] | 1.38[b] | 1.55[a] | 1.36[b] | 0.03 | <0.001 |

[ab] Means within row with different superscripts differ ($P<0.05$)

In this study, the inclusion of FO in diet of ewes especially in late gestation reduced milk yield. This effect was seen just in the first 30 days of lactation period and after 30 days of milking period all groups had similar milk yield, the reduction in milk production and composition was over short timescale, associated with the presence of FO in diet. Shingfield et al. (2003), supplemented FO to lactation cattle has been reported to reduce milk composition and milk yield .The reduced milk yield or composition have been reported as result of reduced in feed intake in cattle and ewes (Donovan et al. 2000; Annett et al. 2004).The effect of FO on milk yield in those researches resulted from reduction of feed intake, but in current study we not have significant difference in DMI between treatments, however, in current study the rations during lactation period without FO or PO. For this reason maybe in current study we did not have differences between groups in DMI. Judith et al. (2006) supplemented FO to pregnant ewes at late gestation period and demonstrated a reduction in milk yield and milk composition. The negative effect of FO on milk production attributed to hydrogenation intermediaries including trans-10 18:1 and trans-10, cis-12 CLA and milk yield (Chikunya et al. 2002).

FO supplementation to ewes reduced the concentrations of C16:0, C18:0 and C18:1 cis-9 within milk fat ($P < 0.01$; Table 4.5.) in the 14 days after lambing. By contrast, concentrations of C18:1 trans ($P < 0.01$), CLA (cis-9, trans-11) ($P < 0.01$),C18:3 (n-3) ($P < 0.01$), C20:5 (n-3) ($P < 0.01$) and C22:6 (n-3) ($P < 0.01$) were increased, without effect in C 18:2 n-6 and C 20:4 n-6 in milk FA profile by the provision of FO in the diet. There was no effect of FO supplementation of ewes in the 90 days after lambing of milk FAs profile; this resulted because after birth the ewes offered same diet without FO.

Table 4.5. Effect of FO during pregnancy on milk FA composition

| Fatty acid (g/100 g fatty acid) | PO | POFO | FOPO | FO | SEM | P-value |
|---|---|---|---|---|---|---|
| Day 14 | | | | | | |
| C 16:0 | 25.2[a] | 20.4[b] | 25.6[a] | 20.6[b] | 0.52 | <0.001 |
| C 18:0 | 13.8[a] | 8.0[b] | 13.7[a] | 8.00[b] | 0.60 | <0.001 |
| C 18:1 trans | 3.7[a] | 5.5[b] | 3.6[a] | 5.5[b] | 0.21 | <0.001 |
| C 18:1 cis-9 | 26.7[a] | 22.1[b] | 26.8[a] | 21.9[b] | 0.50 | <0.001 |
| C 18:2 n-6 | 1.8 | 1.6 | 1.7 | 1.5 | 0.05 | 0.089 |
| CLA(cis-9, trans11) | 1.02[a] | 1.45[b] | 0.96[a] | 1.50[b] | 0.06 | <0.001 |
| C 18:3 n-3 | 0.37[a] | 0.61[b] | 0.36[a] | 0.60[b] | 0.03 | <0.001 |
| C 20:4 n-6 | 0.01 | 0.19 | 0.10 | 0.18 | 0.05 | 0.123 |
| C 20:5 n-3 EPA | 0.03[a] | 0.61[b] | 0.04[a] | 0.60[b] | 0.06 | <0.001 |
| C 22:6 n-3 DHA | 0.02[a] | 0.69[b] | 0.03[a] | 0.66[b] | 0.07 | <0.001 |
| Day 90 | | | | | | |
| C 16:0 | 24.7 | 24.8 | 24.9 | 24.7 | 0.08 | 0.798 |
| C 18:0 | 13.3 | 13.1 | 13.0 | 12.8 | 0.07 | 0.103 |
| C 18:1 trans | 3.25 | 3.05 | 3.25 | 3.05 | 0.05 | 0.368 |
| C 18:1 cis-9 | 25.9 | 25.7 | 25.7 | 25.7 | 0.11 | 0.897 |
| C 18:2 n-6 | 1.4 | 1.4 | 1.4 | 1.3 | 0.04 | 0.603 |
| CLA (cis-9, trans-11) | 0.96 | 0.95 | 0.95 | 0.96 | 0.006 | 0.990 |
| C 18:3 n-3 | 0.32 | 0.30 | 0.30 | 0.29 | 0.006 | 0.350 |
| C 20:4 n-6 | 0.08 | 0.08 | 0.07 | 0.09 | 0.003 | 0.084 |
| C 20:5 n-3 | 0.03 | 0.09 | 0.03 | 0.02 | 0.001 | 0.476 |
| C 22:6 n-3 | 0.02 | 0.02 | 0.02 | 0.01 | 0.002 | 0.660 |

[ab] Means within row with different superscripts differ ($P<0.05$)

As expected, the inclusion of FO in pregnant ewes in late pregnancy period led to increase in C18:1 trans, CLA (cis-9, trans-11), C18:3 (n-3), EPA C20:5 (n-3) and DHA C22:6 (n-3) and decrease in C16:0, C18:0 and C18:1 cis-9 , without effect in C 18:2 n-6 and C 20:4 n-6. Agreement with previous results in dairy cattle, Shingfield et al. (2003), reported the inoculation of FO in dairy cattle led to increase amount of 20:5n-3 and 22:6n-3 in milk.

Many studies reported the supplementation of rumen-protected marine oil, which is rich in EPA and DHA, was able to noticeably increase the concentration of these LCFA in milk fat compared with that of milk from untreated sheep (Mozzon et al. 2002; Kitessa et al. 2003; Ferreira et al. 2011). Nevertheless, the transfer of EPA and DHA from the diet into milk was markedly higher than that reported for dairy cows (Lock and Bauman, 2004) and dairy goats (Kitessa et al. 2001). Another study found the 20:5n-3 and 22:6n-3 exceeding 0.2 g/100 g of milk FA when FO was added to the diet at 2% of DM (AbuGhazaleh et al. 2002). In agreement to results observed by Capper et al. (2007), in the current study the concentration of C16:0 within milk fat appeared to be depressed in ewes offered FO. However, rather than a depressive effect of PUFA supplementation per se, this may be attributed to the high dietary concentration of this FA in the diets that have PO in late pregnancy.

The transfer of EPA and DHA to milk is agreement with Gulati et al. (1999) and Capper et al. (2007), Gulati et al. (1999) reported that EPA and DHA were transferred into milk at rates between 6.8% and 8.1% of dietary intake, Capper et al. (2007) reported that transfer 10% for EPA and 17% for DHA in ewes fed FO.

In present study, the increase of CLA (cis-9, trans-11) led to increase in 18:1 trans in milk fat, induced by 18:1 trans which is mainly endogenously produced by the mammary desaturation of 18:1 trans by stearoy l-CoA desaturase enzyme (Bauman and Griinari, 2001), and by inhibition of 18:1 trans-biohydrogenation in the rumen (Shingfield et al. 2003). In present study, there was no effect of FO supplementation of ewes in the 90 days after lambing of milk FAs profile. The reduction in milk production and composition were over short timescale, associated with the presence of FO in diet.

### 4.2. Effects of Feeding Omega-3 Fatty Acids During Pregnancy on Lambs Performance

#### 4.2.1. Effect on Lamb Performance Before Weaning

The effect of feeding omega-3 fatty acid during gestation on ewes and their lambs performance during lactation period are presented in Table 4.6. Birth weight was higher (P < 0.05) for FO, POFO and FOPO than PO, without differences between PO and FOPO. Without any significant difference (P > 0.05) with respect to the lambs intake during nursing period (93.5 g), ewes intake during lactation period (1806 g/d), ewes BWC during lactation (-2.75 kg).

Table 4.6. Effect of omega-3 fatty acids during pregnancy on ewes and their lambs performance during nursing period

| | Treatments | | | | SEM | P- |
|---|---|---|---|---|---|---|
| **Parameters** | **PO** | **POFO** | **FOPO** | **FO** | | **value** |
| Birth weight (kg) | $4.3^{a}$ | $4.9^{b}$ | $4.8^{ab}$ | $5.0^{b}$ | 0.10 | 0.049 |
| Lamb intake (g/day) | 93.5 | 93.5 | 93.5 | 93.4 | 0.48 | 1.000 |
| Ewes DMI during lactation (g/day) | 1802 | 1801 | 1802 | 1819 | 3.38 | 0.232 |
| Ewes BWC during lactation (kg) | -2.8 | -2.8 | -2.9 | -2.5 | 0.09 | 0.601 |

$^{ab}$ Means within row with different superscripts differ (P<0.05)

Birth weight of the lambs born to ewes fed FO during gestation period was higher than PO. Similar to results obtained herein, Hamada et al. (2013) reported that supplementing ewes with FO during late pregnancy has the potential to increase lamb birth weight. Moreover the increase in the birth weight of lambs may be attributed to the long gestation period. Since a relationship between fetal growth rates and gestation length was existed and the foetal growth rates during the late stage of pregnancy were 0.15 – 0.2 kg/day. This increase in gestation length may be resulted in a physiologically more mature lamb at parturition. (Nibasheka et al. 1999; Mahboub et al. 2012). Rashid et al. (2010) showed that lambs born to FO supplemented ewes had greater plasma content of EPA and DHA than lambs born to the control ewes, which may have a beneficial effect on lamb survival rate through increased gestation length or enhanced neural tissue development or both. Although, Capper et al. (2002) and Annett et al. (2008) demonstrated no evidence of a lamb survival benefit due to FO supplementation. Many researchers reported that inclusion of FO in diets of pregnant ewes, improved plasma content of EPA and DHA than lambs born from ewes not supplemented FO. The increase in gestation length may be associated with an increase birth weight where increasing birth weight of lambs that come from ewes supplemented FO and thus negatively correlated with mortality rates (Pickard et al. 2005; Capper et al. 2006; Rashid et al. 2010). Moreover, weak lambs with low birth weight were unable to suckle a sufficient amount of colostrum, and the immunoglobulin level in their serum was low. The physical weakness and low immunoglobulin lead to increased mortality in lambs with a low birth weight (Ahmad et al. 2000). In our results the lower mortality rate in groups that have a FO in diets in late pregnancy period (numerically),thus the increasing lamb birth weight is negatively correlated with mortality rates, this agree with results of many researchers supplemented ewes FO in late pregnancy (Childs et al. 2008b).

The results of number of lambs, ewes lambed, lambs weaned, abortion and mortality are presented in Table 4.7., The treatments were not significantly different ($P > 0.05$) fornumber of lambs at lambing, ewes lambed, and lambs weaned, abortion and mortality.But supplementing ewes with FO at late pregnancy decrease ewes abortion and mortality of their lambs numerically.

Table 4.7. Number of lambs, ewes lambed, lambs weaned, abortion and mortality

| | Treatments | | | | |
|---|---|---|---|---|---|
| | **PO** | **POFO** | **FOPO** | **FO** | **P-value** |
| Number of lambs | 18 | 19 | 18 | 19 | 0.054* |
| Ewes lambed | 14 | 16 | 15 | 16 | 0.180* |
| Lambs weaned | 15 | 18 | 16 | 19 | 0.588* |
| Abortion | 1 | 0 | 1 | 0 | 1.000** |
| Mortality | 3 | 1 | 2 | 0 | 1.000** |

* Chi-square test
** Fisher's exact test for cell counts less than 5.

Diet high in omega-3 may improve the embryo survival by reducing $PGF_{2\alpha}$synthesis which may prevent regression of the CL, allowing continued secretion of $P_4$ (Inskeep, 2004). Caldari-Torres et al. (2006) reported that appositive effect of n-3 on embryo survival. In our study we had a numerically reduce in abortion in ewes that has FO in late gestation period without effect on lambing rate, the lamb mortality rate before weaning in the current study was 11% FOPO, 5% POFO and 0% FO those rates were lower than which mentioned in reviews.

The results of lamb ADGW before weaning are presented in Table 4.8. Lamb ADGW was greater (P < 0.05) in first 15 days for PO and FOPO than FO and POFO. From 15 days to 30 days no differences occurred (P > 0.05) in lamb ADGW. From 30 days to 60 days ADGW was greater (P < 0.05) for FO and POFO than PO and FOPO. In average no differences occurred (P > 0.05) in lamb ADGW.

Table 4.8. Effect of FO during pregnancy on lamb ADGW before weaning

| Period (day) | PO | POFO | FOPO | FO | SEM | P-value |
|---|---|---|---|---|---|---|
| 1-15 (g) | 247[a] | 204[b] | 258[a] | 183[b] | 0.006 | <0.001 |
| 15-30 (g) | 245 | 247 | 253 | 221 | 0.005 | 0.150 |
| 30-45 (g) | 241[a] | 287[b] | 247[a] | 269[ab] | 0.006 | 0.034 |
| 45-60 (g) | 243[a] | 288[b] | 242[a] | 272[ab] | 0.006 | 0.015 |
| 1-60 (g) | 244 | 256 | 250 | 236 | 0.005 | 0.531 |

[ab] Means within row with different superscripts differ (P<0.05)

FO supplementation for ewes in late pregnancy and lactation period reduced the lamb growth rate, and this reduced as a result of reduced milk yield and composition (Shingfield et al. 2003; Capper et al. 2007). The milk is the only nutrient source available to sucking lambs within first period of life and milk yield and composition reduced by effect of FO in ewe's diet. Therefore, the lamb growth rate also reduced (Capper et al. 2007). However, in our study the lamb ADGW from ewes fed FO in late pregnancy period in the first 30 days less than lamb ADGW for ewes fed PO in late pregnancy period, after that the lamb ADGW was greater for ewes that have a FO in diets in late pregnancy period, but in average no difference between groups in ADGW. The reduced in ADGW for lamb in the first

30 days may related to reduced in milk production and composition in first 30 days of lactation period, after that the milk production and composition same for all groups, and then the lamb return to the normal gain.

### 4.2.2. Effect on Lamb Performance in Fattening Period

No differences between groups during fattening period in lamb initial body weight, final body weight, weight gain and average daily gain (Table 4.9).

Table 4.9. Effect of FO during pregnancy on lamb initial body weight, final body weight, weight gain and average daily gain during fattening period

| | PO | POFO | FOPO | FO | SEM | P-value |
|---|---|---|---|---|---|---|
| Initial body weight (kg) | 19.89 | 21.97 | 20.27 | 20.80 | 0.48 | 0.451* |
| Final body weight (kg) | 39.94 | 41.94 | 40.90 | 41.25 | 0.95 | 0.066** |
| Weight gain (kg) | 20.05 | 19.96 | 20.63 | 20.45 | 0.50 | 0.066** |
| Average daily gain (g/d) | 222.78 | 221.81 | 229.21 | 227.21 | 5.57 | 0.066** |

* ANOVA was used to primarily analyze the differences between treatment groups in term of the initial body weight.

** ANCOVA with initial BW as Covariate (Random effect of initial body weight was significant on final BW, WG and ADG).

In current study all groups had a same ration in fattening period, without oils to find out if the feeding dams omega-3 during pregnancy period any affect on their lambs performance at fattening period. These results agree with Annett et al. (2008) who reported that daily weight gain were not influenced by FO supplementation to the ewe in late gestation. Thus, even though FO supplementation did not improve the growth performance of lambs, the data from this study indicate that FO supplementation not reduce growth performance.

## 5. CONCLUSIONS

The study was conducted to evaluate the effects of feeding Omega-3 during pregnancy on maternal performance, lamb birth weight, colostrums production and quality, milk production and composition, lambs performance after birth and on milk fatty acid profile of Awassi ewes.

Results from the study are summarized below:

1. The feeding FO ration did not adversely affect animal health or nutrient intakes during pregnancy period,
2. Including FO in diet of Awassi ewes during pregnancy increased gestation length and lamb birth weight with increased in colostrums IgG content especially in late gestation period, without negatively affecting BWC and DMI of ewes,
3. The colostrums yield, fat and protein of ewes fed diets containing FO in late gestation period was decreased.
4. The effect of inclusion FO in diet of pregnant ewes on milk production and composition and on lamb growth rate, where over short timescale, associated with the presence of FO in diet.
5. The supplementing ewes with FO at late pregnancy decreased the abortion for ewes during pregnancy period and mortality of their lambs numerically,
6. Support the sustainable use of FO to improve the milk fat content of ewes to decrease SFA and increase PUFA spatially n-3 PUFAs, of DHA, EPA and CLA, which is considered beneficial to human health.

Therefore, including FO in the diets of pregnant Awassi ewes in about 2.3% DM, did not have any adversely affect animal health or nutrient intakes, appears to be beneficial in terms of increased birth weight as well as improved IgG, in spite of negative effect on milk colostrums yield, fat and protein. Thus, it can be an intervention to enhance production profitability in arid and semi-arid areas of the world.

The results of the current study demonstrated that the inclusion of FO in diet of pregnant ewes, effect over short timescale, associated with the presence of FO in diet. However, the result of birth weight and mortality was very important for the ruminants holder to increase profitability. The reduce in milk fat is comfortable by consumers whose interesting in healthier food products. Thus, the inculcation of FO in diet of pregnant ewes, spatially in late pregnancy, may increase the profitability of animal holders and improve the milk quality for consumers without any negative effect on lamb growth weight.

The reduce in milk fat is comfortable by consumers whose interesting in healthier food products. Thus, the inculcation of FO in diet of pregnant ewes, especially in late pregnancy, may increase the profitability of animal holders and improve the milk quality for consumers without any negative effect on lamb growth weight.

In milk FA profile, the maternal dietary composition affected the FAs profile of milk in dietary ewes, our results show that it is possible to enhance ewes milk in n-3 PUFAs, CLA, EPA and DHA, by inclusion of FO in ewes diet during late gestation, which is considered beneficial to human health. Also, these findings support ideas that high transfer efficiencies into ewes milk for EPA and DHA than other species and/ or than other n-3 PUFA sources.

## REFERENCES


Abayasekara, D.R. and Wathes, C.D., 1999. Effects of altering dietary fatty acid composition on prostaglandin synthesis and fertility. Prostaglandins, Leukotrienes and Essential Fatty Acids, Vol.61, No.5, pp. 275-287.

Abd El-Rahman H.M., El-Nour H.H., ELWakeel S.A., and Aly A.H., 2008. Effect of calcium soap of fatty acids and recombinant bovine somatotropin on productive and reproductive performance of Baladi goats during early lactation. Veterinary Medical Journal Giza, vol. 56, pp. 367– 385.

AbuGhazaleh, A.A., Schingoethe, D.J., Hippen, A.R., Kalscheur, K.F. and Whitlock L.A., 2002. Fatty acid profiles of milk and rumen digesta from cows fed fish oil, extruded soybeans or their blend. Journal of Dairy Science, 85:2266–2276.

Abu Zanat, M.M., Mekdadi, H.A., Tabbaa, M.J., 2005. Production systems of small ruminants in middle badia of Jordan. Dirasat, 32, 205–213.

Achard, D., Gilbert, M., Benistant, C., Slama, S.B., DeWitt, D.L., Smith, W.L. and Lagarde, M., 1997. Eicosapentaenoic and docosahexaenoic acids reduce PGH synthase 1 expression in bovine aortic endothelial cells. Biochemical Biophysical Research Communications, pp. 513-518.

Addis, M., Cabiddu, A., Pinna, G., Decandia, M., Piredda, G., Pirisi, A. and Molle, G., 2005. Milk and cheese fatty acid composition in sheep fed Mediterranean forages with reference to conjugated linoleic acid cis-9,trans-11. Journal of Dairy Science 88:3443-3454.

Ahmad, R., Khan, A., Javed, M.T. and Hussain, I., 2000. The level of immunoglobulins in relation to neonatal lamb mortality in Pak- Karakul sheep. Vet arhiv 70, 129-139.

Amanlou, H., Karimi, A., Mahjoubi, E. and Milis, C., 2010. Effects of supplementation with digestible undegradable protein in late pregnancy on ewe colostrum production and lamb output to weaning. Journal of Animal Physiology and Animal nutrition,95:616-622.

Ambrose, D.J., Kastelic, J.P., Corbett, R., Pitney, P.A., Petit, H.V., Small, J.A., Zalkovic, P., 2006. Lower pregnancy losses in lactating dairy cows fed a diet enriched in alpha-linolenic acid. Journal of Dairy Science, 89, 3066–3074.

Annett, R.W., Carson, A.F. and Dawson, L.E.R., 2004. Effects of concentrate DUP content and fish oil inclusion on colostrum production and lamb output from mature ewes. Proceedings of the Agricultural Research Forum, Tullamore, Ireland on 1–2 March 2004, p. 22.

Annett, R.W., Carson, A.F. and Dawson, L.E.R., 2008. Effects of digestible undegradable protein (DUP) supply and fish oil supplementation of ewes during late pregnancy on colostrum production and lamb output. Animal Feed Science and Technology, Volume 146, Issues 3–4, Pages 270-288.

Annett, R.W.; Dawson, L.E.R.; Edgar, H. And Carson, A.F., 2009. Effects of source and level of fish oil supplementation in late pregnancy on feed intake, colostrums production and lamb output of ewes. Animal Feed Science and Technology 154: 169–182.

Antongiovanni, M., Mele, M., Buccioni, A., Petacchi, F., Serra, A., Melis, M. P., Cordeddu, L., Banni, S. and Secchiari, P., 2004. Effect of forage/concentrate ratio and oil supplementation on C18:1 and CLA isomers in milk fat from Sarda ewes. Journal of Animal and Feed Sciences 13(Suppl.1):669-672.

Antongiovanni, M., Secchiari, P., Mele, M., Boccioni, A., Serra, A., Ferruzzi, G., Rapaccini, S. and Pistoia, A., 2002. Olive oil calcium soaps and rumen protected methionine in the diet of lactating ewes: effect on milk quality. Italian Journal of Animal Science 1:55-63.

Araujo, R.C., Pires, A.V., Susin, I., Mendes, C.Q., Rodrigues, G.H., Packer, I.U., and Eastridge, M.L., 2008. Milk yield, milk composition, eating behavior, and lamb performance of ewes fed diets containing soybean hulls replacing coastcross (Cynodon species) hay. Journal of Animal Science 86:3511-3521.

Arntzen, K.J., Brekke, O.L., Vatten, L., Austgulen, R., 1998. Reduced production of PGE2 and $PGF_{2\alpha}$from decidual cell cultures supplemented with n-3 polyunsaturated fatty acids. Prostaglandins Other Lipid Mediat. 56, 183–195.

Austad, S.N. and Sunquist, M.E., 1986. Sex ratio manipulation in the common opossum. Nature 1986, 324:58-60.

AOAC, 1990. Official Methods of Analysis, 15th ed. Assoc. Anal. Chem., Arlington, VA, USA.

Awawdeh, M.S., Obeidat, B.S., Kridli, R.T., 2009. Yellow grease as an alter-native energy source for nursing Awassi ewes and their suckling lambs. Animal Feed Scienceand Technology 152, 165–174.

Avila, C.D., DePeters, E.J., Perez-Monti, H., Taylor, S.J., and Zinn R.A., 2000. Influences of saturation ratio of supplemental dietary fat on digestion and milk yield in dairy cows. Journal of Dairy Science, 83:1505-1519.

Bader, J.F.; Felton, E.E.; Kerley, M.S.; Simms, D.D. and Patterson, D.J., 2000. Effects of postpartum fat supplementation on reproduction in primiparous 2-year-old and mature cows. Journal of Animal Science, Vol.78, Suppl. No.1, pp. 224. Journal of Dairy Science, Vol.83, Suppl. No.1, pp. 224.

Baguma-Nibasheka, M., Brenna, J.T. and Nathanielsz, P.W., 1999. Delay of preterm delivery in sheep by omega-3 long-chain polyunsaturates. Biology of Reproduction 60, 698–701.

Ballou, M.A., Gomes, R.C., Juchem, S.O., and DePeters, E.J., 2009. Effects of dietary supplemental fish oil during the peripartum period on blood metabolites and hepatic fatty acid compositions and total triacylglycerol concentrations of multiparous Holstein cows. Journal of Dairy Science,92:657-669.

Barker, D.J.P., Martyn C.N., Osmond C., Hales C.N., and Fall C.H.D., 1993. Growth in uterus and serum cholesterol concentrations in adult life. British Medical Journal. 307:1524-1527.

Barker, D.J.P., 1994. Mothers, Babies and Disease in Later Life. London: British Medical Journal, Publishing Group.

Bauchart, D., 1993. Lipid absorption and transport in ruminants. Journal of Dairy Scienc,76:3864-3881.

Bauchart, D., Le Gay Carmier, F., Doreau, M., Gaillard, B., 1990. Lipid metabolism of liquid associated and solid adherent bacteria in rumen contents of dairy cows offered lipid supplemented diets. British Journal of Nutrition., 63:563-578.

Bauman, D.E. and Griinari, J.M., 2001. Regulation and nutritional manipulation of milk fat: low-fat milk syndrome. Livestok Production Science 70, 15–29.

Bell, A.W., 1995. Regulation of organic nutrient metabolism during transition form late pregnancy to early lactation. Journal of Dairy Science, 73: 2804- 2819.

Bell, A.W., 2006: Prenatal programming of postnatal productivity and health of livestock: a brief review. Australian journal of experimental agriculture 46: 725-732.

Belkacemi, L., Nelson D.M., Desai M., and Ross M.G., 2010. Maternal undernutrition influences placental-fetal development. Biology Reproduction83:325-331.

Belluzzi, A., Boschi, S., Brignola, C., Munarini, A., Cariani, G., Miglio F., 2000. Amirican Journal of Clinical Nutrition, 71 339S–42S.

Bernal, S.G., O'Donnell, A.M., Vicini, J.L., Hartnell, G.F. and Bauman, D.E., 2010. Enhancing omega-3 fatty acids in milk fat of dairy cows by using stearidonic acid-enriched soybean oil from genetically modified soybeans. Journal of Dairy Science, Vol.93, No.1, pp. 32-37.

Bilby, T.R., Block, J., do Amaral, B.C., Sa, O., Silvestre, F.T., Hansen, P.J., Staples, C.R., Thatcher, W.W., 2006a. Effects of dietary unsaturated fatty acids on oocyte quality and follicular development in lactating dairy cows in summer. Journal of Dairy Science, 89, 3891–3903.

Bilby, T.R., Sozzi, A., Lopez, M.M., Silvestre, F.T., Ealy, A.D., Staples, C.R. and Thatcher, W.W., 2006b. Pregnancy, bovine somatotropin, and dietary n-3 fatty acids in lactating dairy cows: I. ovarian, conceptus, and growth hormone-insulin-like growth factor system responses. Journal of Dairy Science, Vol.89, No.9, pp. 3360- 3374.

Binelli, M., Thatcher, W.W., Mattos, R., Baruselli, P.S., 2001. Antiluteolytic strategies to improve fertility in cattle. Theriogenology, Vol.56, No.9, pp. 1451- 63.

Bocquier, F. and Caja, G., 2001. Production et composition du lait de brebis: effets de l'alimentation. Inra Productions Animales 14:129-140.

Bodas, R., Manso, T., Mantecón, A.R., Juárez, M., De La Fuente, M.A. and Gómez-Cortés, P., 2010. Comparison of the fatty acid profiles in cheeses from ewes fed diets supplemented with different plant oils. Journal of Agricultural and Food Chemistry 58:10493-10502.

Bolet, G., 1986. Timing and extent of embryonic mortality in pigs, sheep, and goats: Genetic variability: Pages 12–43 in Embryonic Mortality in Farm Animals. J. M. Sreenan, and M. G. Diskin, ed. Dordrecht, Boston, MA.

Borwick, S., Rhind, S., McMillen, S. and Racey, P.A., 1997. Effect of undernutrition of ewes from the time of mating on fetal development in mid gestation Reproduction, Fertility and Development, 9 711–715.

Bottger, J., Hess B., Alexander B., Hixon D., Woodard L., Funston R., Hallford D., and Moss G. 2002. Effects of supplementation with high linoleic or oleic cracked safflower seeds on postpartum reproduction and calf performance of primiparous beef heifers. Journal of Dairy Science, 80:2023–2030.

Bott, R., Ashley, R., Henkes, L., Antoniazzi, A., Bruemmer, J., Niswender, G., Bazer, F., Spencer, T., Smirnova, N., Anthony, R.V. and Hansen, T.R., 2010. Uterine vein infusion of interferon Tau (IFNT) extends luteal life span in ewes. Biology of Reproduction, Vol.82, No.4, pp. 725-735.

Boure, J., 2005. Effect of increasing the omega-3 fatty acid in the diets of animals on the animal products consumed by humans. Medical Science. 21: 773–779.

Bouwstra, H., Dijck-Brouwer, D.A.J., Wildeman, J.A.L., Tjoonk, H.M., van der Heide, J.C., Boersma, E.R., Muskiet, F.A.J., Hadders-Algra, M., 2003. Long chain polyunsaturated fatty acids have a positive effect on the quality of general movements of healthy term infants. American Journal of Clinical Nutrition;78:313–8.

Boyazoglu J.,Morand-Fehr P. 2001. Mediterranean dairy sheep and goat products and their quality. A critical review. Small RuminantResearch Apr;40(1):1-11.

Brenna, J. and Lapillonne, A. 2009. Background paper on fat and fatty acid requirements during pregnancy and lactation. Annals of Nutrition Metabolism, 55: 97-122.

Bu, D., Wang, J., Dhiman, T. and Liu, S. 2007. Effectiveness of oils rich in linoleic and linolenic acids to enhance conjugated linoleic acid in milk from dairy cows. Journal of Dairy Science 90:998-1007.

Burke, J., Carroll, D., Rowe, K., Thatcher, W., Stormshak, F. 1996. Intravascular infusion of lipid into ewes stimulates production of progesterone and prostaglandin. Biology of Reproduction. 55, 169–175.

Burns, P., Engle, T., Harris, M., Enns, R., Whittier, J.2003. Effect of fish meal supplementation on plasma and endometrial fatty acid composition in nonlactating beef cows. Journal of Animal Science, Vol.81, No.11, pp. 2840-2846.

Burr, G., and Burr M. 1929. A new deficiency disease produced by the rigid exclusion of fat from the diet. Journal of Biological Chemistry. 82:345-367.

Burr, G., and Burr M., 1930. On the the nature and role of the fatty acids essential in nutrition. Journal of Biological Chemistry. 86:587-621.

Caldani, M., Antoine, M., Batailler, M. and Duittoz, A., 1995. Ontogeny of GnRH systems Journal of Reproduction and Fertility Supplement 49 147–162.

Caldari-Torres, C., Rodriguez-Sallaberry, C., Greene, E.S., Badinga, L., 2006. Differential effects of n-3 and n-6 fatty acids on prostaglandin $F_2$ production by bovine endometrial cells. Journal of Dairy Science 89, 971–977.

Calder, P.C.2001. Fatty acid metabolism and eicosanoid synthesis Clinical Nutrition.

Calder, P. and Grimble, R., 2002. Polyunsaturated fatty acids, inflammation and immunity. European Journal of Clinical Nutrition. 56 (Suppl. 1), S14–S19.

Cannas, A. and Avondo, M., 2002. Relationships among milk fat content, energy balance and NDF intake in lactating ewes fed at pasture. p.55. In: Book of Abstracts of the 53rd Annual Meeting of the EAAP - European Association of Animal Production, Cairo, Egypt.

Cannas, A., Cabiddu, A., Bomboi, G., Ligios, S., Floris, B. and Molle, G., 2013. Decreasing dietary NFC concentration during mid-lactation of dairy ewes: Does it result in higher milk production?. Small Ruminant Research 111:41-49.

Cannas, A., Pes, A., Mancuso, R., Vodret, B. and Nudda, A., 1998. Effect of dietary energy and protein concentration on the concentration of milk urea nitrogen in dairy ewes. Journal of Dairy Science 81:499-508.

Cannas, A., Van Soest, P. and Pell, A. 2003. Use of animal and dietary information to predict rumen turnover. Animal Feed Science and Technology 106:95-117.

Cameron, E. 2004. Facultative adjustment of mammalian sex ratios in support of the Trivers-Willard hypothesis: evidence for a mechanism. Proceedings of the Royal Society - Biological Sciences, 271(1549):1723-1728.

Cant, J., Fredeen, A., MacIntyre, T., Gunn, J., Crowe, N. 1997. Effect of fish oil and monensin on milk composition in dairy cows. Can. Journal of Animal Science, 77, 125–131.

Capper, J., Wilkinson, R., Sinclair, L., Pattinson, S. and Mackenzie, A. 2002. The effect of long-chain polyunsaturated fatty acid and vitamin E supplementation of ewes on neonatal lamb vigour, lamb growth and colostrum parameters. Proceedings of The British Society of Animal Science., p.7.

Capper, J., Wilkinson R., Mackenzie A. and Sinclair L., 2007. The effect of fish oil supplementation of pregnant and lactating ewes on milk production and lamb performance. Animal, 1: 889-898.

Caroprese, M., Albenzio, M., Bruno, A., Fedele, V., Santillo, A. and Sevi, A., 2011. Effect of solar radiation and flaxseed supplementation on milk production and fatty acid profile of lactating ewes under high ambient temperature. Journal of Dairy Science 94:3856-3867.

Casals, R., Caja, G., Such, X., Torre, C. and Calsamiglia, S., 1999. Effect of calcium soaps and rumen undegradable protein on the milk production and composition of dairy ewes. Journal of Dairy Research. 66: 177- 191.

Castellano, C., Audet, I., Bailey, J., Chouinard, P., Laforest, J., Matte, J. 2010. Effect of dietary n-3 fatty acids (fish oils) on boar reproduction and semen quality. Journal of Animal Science, Vol.88, No7, pp. 2346-2355.

Castro, T., Manso, T., Jimeno, V., Del Alamo, M. and Mantecón, A.R., 2009. Effects of dietary sources of vegetable fats on performance of dairy ewes and conjugated linoleic acid (CLA) in milk. Small Ruminant Research 84:47-53.

Cattaneo, D., Savoini, G., Agazzi, A., Mancin, G., Dell'Orto, V., 2001. Dietary fish oil and fatty acid composition of bovine milk. In: Proceedings of the A.S.P.A.XIVCongress on Recent Progress in Animal Production Science, vol. 2, Firenze, Italy, June 12–15, pp. 240–242.

Cattaneo, D., Dell'Orto V., Varisco G., Agazzi A. and Savoini G., 2006. Enrichment in n-3 fatty acids of goat's colostrum milk by maternal fish oil supplementation. Small Ruminant Researh, 64: 22-29..Small Rumres.2005.03.013.

Caton, J., Reed J., Aitken R., Milne J., Borowicz P., Reynolds L., Redmer D.,and Wallace J., 2009. Effects of maternal nutrition and stage of gestation on bodyweight, visceral organ mass, and indices of jejunal cellularity, proliferation, andvascularity in pregnant ewe lambs. Journal of Animal Science,87:222-235.

Caton, J. and Hess B., 2010. Maternal plane of nutrtion: Impacts on fetal outcomes andpostnatal offspring responses. In: Proc. 4th Grazing Livestock Nutrition Conference. West Sect. American Society of Animal Science, 104-122.

Cavalli, G. and Paro, R., 1998. The Drosophila Fab-7 chromosomal element conveys epigenetic inheritance during mitosis and meiosis Cell 93 505–518.

Cerri, R., Juchem, S., Chebel, R., Rutgliano, H., Bruno, R., Galva, K., Thatcher, W. and Santos, J. 2009. Effect of fat source differing in fatty acid profile on metabolic parameters, fertilization, and embryo quality in highproducing dairy cows. Journal of Dairy Science, Vol.92, No.4, pp. 1520- 1531.

Challis, J., Sloboda, D., Alfaidy, N., Lye, S., Gibb, W., Patel, F., Whittle, W., Newnham, J., 2002. Prostaglandins and mechanisms of preterm birth. Reproduction 124, 1–17.

Chikunya, S., Demirel, G., Enser, M., Wood, J.D., Wilkinson, R.G., Sinclair, L.A., 2004. Biohydrogenation of dietary n-3 PUFA and stability of ingested vitamin E in the rumen, and their effects on microbial activity in sheep. British Journal of Nutrition; 91:539–550.

Chikunya, S., Sinclair, L., Wilkinson, R., 2002. Influence of dietary n-3 polyunsaturated fatty acids on milk fat composition and performance of lactating Friesland ewes. British Society of Animal Science Annual Meeting 2002. Penicuik: BSAS;.p. 11.

Childs, S., Carter, F., Lynch, C., Sreenan, J., Lonergan, P., Hennessy, A. and Kenny, D., 2008b. Embryo yield and quality following dietary supplementation of beef heifers with n-3 polyunsaturated fatty acids (PUFA). Theriogenology, Vol.70, No.6 (October 2008), pp. 992-1003.

Childs, S., Hennessy, A., Sreenan, J., Wathes, C., Cheng, Z., Stanton, C.; Diskin, M. and Kenny, D., 2008a. Effect of level of dietary n-3 polyunsaturated fatty acid supplementation on systemic and tissue fatty acid concentrations and on selected reproductive variables in cattle. Theriogenology, Vol.70, No.4 (September 2008), pp. 595-611.

Childs, S., Lynch, C., Hennessy, A., Stanton, C., Wathes, D., Sreenan, J., Diskin, M. and Kenny, D., 2008c. Effect of dietary enrichment with either n-3 or n-6 fatty acids on systemic metabolite and hormone concentration and ovarian function in heifers. Animal, Vol.2, No.6, pp. 883-893.

Chilliard, Y. and Doreau, M., 1997. Effects of ruminal and postruminal fish oil supply on cow milk yield and composition. Reproduction Nutrition Development, 37, 338–339.

Chilliard, Y., Ferlay, A., Mansbridge, R., Doreau, M., 2000. Ruminant milk fat plasticity: nutritional control of saturated, polyunsaturated, trans and conjugated fatty acids. Annales Zootechnie. 49, 181–205.

Chilliard, Y., Martin, C., Rouel, J. and Doreau, M., 2009. Milk fatty acids in dairy cows fed whole crude linseed, extruded linseed, or linseed oil, and their relationship with methane output. Journal of Dairy Science 92:5199-5211.

Chin, S., Storkson, J., Ha,Y., Pariza,M. 1992. Dietary sources of conjugated dienoic isomers of linoleic acid, a newly recognised class of anticarcinogens. Journal of Food Composition and Analysis. 5, 185–197.

Clayton, E., Wynn, P., Mailer, R., Piltz, J. 2010. Total lipid and fatty acid profiles in fresh and ensiled forages grown in Australia. In 'Proceedings of the Australian Society for Animal Production'.. (Eds RC Dobos, PL Greenwood , JV Nolan). Vol. 28, pp. 56. (Australian Society for Animal Production: Armidale, NSW)

Cooper, S.L., Sinclair, L.A., Wilkinson, R.G., Enser, M. and Wood, J.D., 2004. Manipulation of the n-3 polyunsaturated fatty acid content of muscle and adipose tissue in lambs. Journal of Animal Science, 82:1461–70.

Capper, J.L., Wilkinson, R.G., Mackenzie, A.M. and Sinclair, L.A., 2006. Polyunsaturatedfatty acid supplementation during pregnancy alters neonatal behaviour insheep. The Journal of Nutrition 136, 397–403.

Cullens, F.M., 2005. Effects of the timing of initiation of fat supplementation on productive and reproductive responses of periparturient dairy cows during summer. MSc. Thesis. University of Florida, USA. Pp.146.

Da Silva, P., Aitken, R.P., Brooks, A.N., Rhind, S.M. and Wallace, J.M., 1998. Perturbed pituitary gonadotrophin gene expression and gonadal development in growth restricted fetal lambs at day 128 of gestation Journal of Reproduction and Fertility Abstract Series 22 10.

Das, U.N., 2003. Can perinatal supplementation of long-chain polyunsaturated fatty acids prevent diabetes mellitus?. European Journal of Clinical Nutrition. 57:218-226.

Das, U.N., 2000. Prostaglandins Leukot. Essent. Fatty Acids, 63 1–362.

Davis, C.L., 1990. Fats in Animal Feeds. Barnaby Inc., Sycamore, IL.

Dawson, L.E.R., Carson, A.F. and Kilpatrick, D.J., 1999. The effect of digestible undegradable protein concentration of concentrates and protein source offered to ewes in late pregnancy on colostrum production and lamb performance. Animal Food Science and Technology, 82: 21- 36.

Dawson, L.E.R. and Edgar, H., 2006. Effect of source and level of fish oil for ewes in late pregnancy on subsequent performance. Proceedings of the British Society of Animal Science, 141.

De Fries, C.A., Neuendorff, D.A., Randel, R.D., 1998. Fat supplementation influences postpartum reproductive performance in Brahman cows. Journal of Animal Science, Vol.76, No.3 (March 1998), pp. 864-870.

de Renobales, M., Amores, G., Arranz, J., Virto, M., Barrón, L.J.R., Bustamante, M.A., Ruiz De Gordoa, J.C., Nájera, A.I., Valdivielso, I., Abilleira, E., Beltrán De Heredia, I., Pérez-Elortondo, F.J., Ruiz, R., Albisu, M. and Mandaluniz, N., 2012. Part-time grazing improves sheep milk production and its nutritional characteristics. Food Chemistry 130:90-96.

Demirel, G., Wachira, A.M., Sinclair, L.A., Wilkinson, R.G., Wood, J.D. and Enser, M., 2004. Effects of dietary n-3 polyunsaturated fatty acids, breed and dietary vitamin E on the fatty acids of lamb muscle, liver and adipose tissue. British Journal of Nutrition, 91:551–565.

Department of Health, 2003. Food and Health Action Plan: Food and health problem analysis.

Dijck-Brouwer, D.A., Hadders-Algra, M., Bouwstra, H., Decsi, T., Boehm, G., Martini, I.A., Boersma, E.R., Muskiet, F.A.J., 2005. Lower fetal status of docosahexaenoic acid, arachidonic acid and essential fatty acids is associated with less favorable neonatal neurological condition. Prostaglandins Leukot Essent Fatty Acids;72: 21–8.

Dietz, R.E., Hall J.B., Whittier W.D., Elvinger F., and Eversole D.E., 2003. Effects of feeding supplemental fat to beef cows on cold tolerance in newborn calves. Journal of Animal Science,81:885-894.

Dixon A., Knights M., Winkler J., Marsh D., Pate J., Wilson M., Dailey R., Seidel G.and Inskeep E. 2007. Patterns of late embryonic and fetal mortality and association with several factors in sheep. Journal of Animal Science, 85:1274-1284.

Dobarganes García, C., Pérez Hernández, M., Cantalapiedra, G., Salas, J.M. and Merino, J.A., 2005. Bypassing the rumen in dairy ewes: the reticular groove reflex vs. calcium soap of olive fatty acids. Journal of Dairy Science 88:741-747.

Donovan, G.A., Dohoo, L.R., Montgomery, D.M. and Bennet, F.L., 1998. Associations between passive immunity and morbidity and mortality in dairy heifers in Florida, USA. Preventive Veterinary Medicine. 34:41-46.

Donovan, D.C., Schingoethe, D.J., Baer, R.J., Ryali, J., Hippen A.R. and Franklin S.T., 2000. Influence of dietary fish oil on conjugated linoleic acid and other fatty acids in milk fat from lactating dairy cows. Journal of Dairy Science 83, 2620–2628.

Doreau, M. and Ferlay A., 1994. Digestion and utilization of fatty-acids by ruminants. Animal Feed Science and Technology,45:379-396.

Doreau, M., Bauchart, D. And Chilliard, Y., 2011. Enhancing fatty acid composition of milk and meat through animal feeding. Animal Production Science, Vol.51, No.1 (December 2010), pp. 19-29.

Doreau, M., Demeyer, D.I., and Van Nevel C.J., 1997. Transformation and effects of unsaturated fatty acids in the rumen: consequences on milk fat secretion. In: R. A. S. Welch, D. J. W. Burns, S. R. Davis, A. I. Popay, and C. G. Prosser (Eds.) Milk Composition, Production and Biotechnology. pp. 73-92. CAB International, Wallinford, Oxfordshire, UK.

Doreau, M., Laverroux, S., Normand, J., Chesneau, G. and Glasser, F., 2009. Effect of linseed fed as rolled seeds, extruded seeds or oil on fatty acid rumen metabolism and intestinal digestibility in cows. Lipids 44:53-62.

Drackley, J.K., and Andersen J.B., 2006. Splanchnic metabolism of long-chain fatty acids in ruminants. Pages 199-224 in Ruminant Physiology: Digestion, Metabolism and Impact of Nutrition on Gene Expression, Immunology and Stress. K. Sejrsen, T. Hvelplund, and M. O. Nielsen, ed. Wageningen Academic Publishers. Wageningen, the Netherlands.

Dubois, V., Breton, S., Linder, M., Fanni, J., and Parmentier, M., 2007. Fatty acid profiles of 80 vegetable oils with regard to their nutritional potential. European Journal of Lipid Science and Technology.

Dunn, G.A. and Bale, T.L., 2011. Maternal high-fat diet effects on thirdgeneration female body size via the paternal lineage. Endocrinology;152:2228 –36.

Dutta-Roy, A.K., 2000. Transport mechanisms for long-chain polyunsaturated fatty acids in the human placenta. American Journal of Clinical Nutrition. 71:315S–322S.

Eastridge, M., 2002. Effects of feeding fats on rumen fermentation and milk composition. Pages 47-57 in Proc. 37th Annual Pacific Northwset animal nutrition conference. Vancouver, Canada.

El-Shahat, K.H. and Abo-El maaty, A.M., 2010. The effect of dietary supplementation with calcium salts of long chain fatty acids and/or l-carnitine on ovarian activity of Rahmani ewes. Animal Reproduction Science, Vol.117, No.1, pp. 78- 82.

Enke, U., Seyfarth L., Schleussner E., and Markert U.R., 2008. Impact of PUFA on early immune and fetal development. British Journal of Nutrition, 100:1158-1168.

Encinias, H.B., Lardy G.P., Encinias A.M. and Bauer M.L., 2004. High linoleic acid safflower seed supplementation for gestating ewes: effects on ewe performance, lamb survival, and brown fat stores. Journal of Animal Science,82:3654-3661.

Enser M. 2001. The role of fats in human nutrition. In B. Rossell (Ed.), Oils and fats, Vol. 2. Animal carcass fats (pp. 77–122). Leatherhead, Surrey, UK: Leatherhead Publishing.

Enser, M., Scollan, N., Gulati, S., Richardson, I., Nute, G. And Wood, J., 2001. The effects of ruminally-protected dietary lipid on the lipid composition and quality of beef muscle. Proceedings of the 47th International Congress of Meat Science and Technology, 1, 12–13.

FAO (Food and Agriculture Organization of the United Nations)., 2010. Fats and fatty acids in human nutrition Report of an expert consultation. FAO, Rome, Italy.

Ferguson, J.D., Sklan, D., Chalupa, W.V. and Kronfeld, D.S., 1990. Effects of hard fat on in vitro and in vivo rumen fermentation, milk production, and reproduction in dairy cows. Journal of Dairy Science; Vol.73, No.10 (October 1990), pp. 2864-2879.

Ferreira, E.M., Pires, A.V., Susin, I., Maia, M.O., Gentil, R.S. and Nolli, C.P., 2011. Perfil de ácidos graxos do leite de ovelhas recebendo óleo de soja e óleo de peixe como fontes de gordura suplementar. In: Anais da 48a Reunião Anual da Sociedade Brasileira de Zootecnia. Sociedade Brasileira de Zootecnia, Belém.

Fievez, V., Dohme, F. Danneels, M. Raes, K.and Demeyer D., 2003. Fish oils as potent rumen methane inhibitors and associated effects on rumen fermentation in vitro and in vivo. Animal Feed Science and Technology,104:41–58.

Filley, S.J., Turner, H.A. and Stormshak F., 2000. Plasma fatty acids, prostaglandin F2α metabolite, and reproductive response in postpartum heifers fed rumen bypass fat. Journal of Animal Science, Vol.78, No.1, pp. 139-144.

Fisher, A.V., Enser, A., Richardson, R.I., Wood, J.D., Nute, G.R., Kurt, E., Sinclair, L.A., Wilkinson, R.G., 2000. Fatty acid composition and eating quality of lamb types derived from four diverse breed_production systems. Journal of Meat Science, 55, 141– 147.

Funston, R. and Filley, S., 2002. Effects of fat supplementation on reproduction in beef cattle. Proceedings of The Applied Reproductive Strategies in Beef Cattle Workshop, September 5-6, 2002, Manhattan, Kansas. USA. 1-8 p.

Funston, R.N., 2004. Fat supplementation and reproduction in beef females. Journal of Animal Science, 82, E154–E161.

Gabory A., Attig L., Junien C., 2011. Developmental programming andepigenetics. American Journal of Clinical Nutrition, 94:1943S–52S.

Galal, S., Gürsoy, O., Shaat, I., 2008. Awassi sheep as a genetic resource and efforts for their genetic improvement—A review. Small Ruminant Research, 79, 99–108.

Galbreath, C.W., Scholljegerdes, E.J., Lardy, G.P., Odde, K.G., Wilson, M.E., Schroeder, J.W., Vonnahme, K.A., 2008. Effect of feeding flax or linseed meal on progesterone clearance rate in ovariectomized ewes. Domestic Animal Endocrinology. 35, 164–169.

Gallaher, B.W., Breier, B.H., Keven, C.L., Harding, J.E. and Gluckman, P.D., 1998. Fetal programming of insulin-like growth factor (IGF)-1 and IGF-binding protein-3: evidence for an altered response to undernutrition in late gestation following exposure to preconceptual undernutrition in the sheep Journal of Endocrinology 159 501–508.

Gargouri, A., Caja, G., Casals, R. and Mezghani, I., 2006. Lactation evaluation of effects of calcium soaps of fatty acids on dairy ewes. Small Rumin. Research. 66: 1- 10.

Ghattas, T.A. and Nasra, A.A., 2010. Effects of rumen-protected polyunsaturated fatty acid on some reproductive performance in out of breeding season ewes. Egyptian Journal of Basic and Applied Physiology, vol. 9, pp. 291–305.

Ghoreishi, S.M., Zamiri, M.J., Rowghani, E. and Hejazi H., 2007. Effect of a calcium soap of fatty acids on reproductive characteristics and lactation performance of fat-tailed sheep. Pakistan Journal of Biological Sciences, vol. 10, no. 14, pp. 2389– 2395.

Gibney, M.J., Hunter, B., 1993. The effects of short- and long-term supplementation with fish oil on incorporation of n-3 polyunsaturated fatty acids into cells of the immune system in healthy volunteers. European Journal of Clinical Nutrition, 47, 255–259.

Givens, D.I., Cottrill, B.R., Davies, M., Lee P.A., Mansbridge, R.J. and Moss, A.R., 2001. Sources of n-3 polyunsaturated fatty acids additional to fish oil for livestock diets—a review. Nutrition Abstracts and Reviews Journal; Series B 71:55R–83.

Godfrey, K.S., Robinson, D.J.P., Barker, C., Osmond, and Cox V., 1996. Maternal nutrition in early and late pregnancy in relation to placental and fetal growth. British Medical Journal, 312:410-414.

Godfrey, K.M., and Barker D.J., 2000. Fetal nutrition and adult disease. American Journal of Clinical Nutrition, 71(Suppl):1344S-1352S.

Godfrey, K. and Robinson, S., 1998. Reproduction and Development Group Symposium on ‘Early environmental, genetic and nutritional influences on adult disease’ Maternal nutrition, placental growth and fetal programming. Proceedings of the Nutrition Society (1998), 57, 105-111 105.

Gogos, C.A., Skoutelis, A., Kalfarentzos F., 2000. Journal of Nutrition Health and Aging, 4 172–175.

Gonzalez, S., Nervi, A.M., Peluffo, P.O., 1986. Effects of estradiol and environmental-temperature changes on rat-liver delta-6 microsomal desaturase activity. Lipids 21, 440–443.

Gómez-Cortés, P., Frutos, P., Mantecón, A.R. Juárez, M., De La Fuente, M.A. and Hervás, G., 2009a. Effect of supplementation on grazing dairy ewes with a cereal concentrate on animal performance and milk fatty acid profile. Journal of Dairy Science 92:3964-3972.

Gómez-Cortés, P., Bach, A., Luna, P., Juárez, M. and De La Fuente, M.A., 2009b. Effects of extruded linseed supplementation on n-3 fatty acids and conjugated linoleic acid in milk and cheese from ewes. Journal of Dairy Science 92:4122-4134.

Gómez-Cortés, P., De La Fuente, M.A., Toral, P.G., Frutos, P., Juárez, M., and Hervás, G., 2011. Effects of different forage:concentrate ratios in dairy ewe diets supplemented with sunflower oil on animal performance and milk fatty acid profile. Journal of Dairy Science 94:4578-4588.

Gómez-Cortés, P., Gallardo, B., Mantecón, A.R., Juárez, M., de la Fuente, M.A. and Manso, T., 2014. Effects of different sources of fat (calcium soap of palm oil vs. extruded linseed) in lactating ewes' diet on the fatty acid profile of their suckling lambs. Meat Science 96:1304-1312.

Greenwood, P.L., Hunt A.S., Hermanson J.W., and Bell A.W., 2000. Effects of birth weight and postnatal nutrition on neonatal sheep: II. Skeletal muscle growth and development. Journal of Animal Science. 78:50-61.

Greenwood, P.L., Hearnshaw H., Cafe L.M., Hennessy D.W., and Harper G.S., 2004. Nutrition in utero and pre-weaning has longterm consequences for growth and size of Piedmontese and Wagyu-sired steers. Journal of Animal Science, 82, Suppl. 1. 722.

Griinari, J.M., and D. Bauman., 2006. Milk fat depression: Concepts, mechanisms and management applications. Pages 389–417 in Ruminant Physiology: Digestion, Metabolism and Impact of Nutrition on Gene Expression, Immunology and Stress. K. Sjersen, T. Hvelplund, and M. O. Nielsen, ed. Wageningen Academic Publishers, Wageningen, the Netherlands.

Gürsoy, O., 2005. Small ruminant breeds of Turkey. In: Characterization of the Small Ruminant Breeds inWest Asia and North Africa.Vol. 1. West Asia (L. Iniguez ed.). International Center for Agricultural Research in the Dry Areas(ICARDA), Aleppo, Syria. p: 239–416.

Gulati, S.K., Ashes, J.R., Scott, T.W., 1999. Animal Feed Science and Technology, 79 57–64.

Gulliver, C.E., Friend, M.A., King B.J. and Clayton E.H., 2012. The role of omega-3 polyunsaturated fatty acids in reproduction of sheep and cattle. Animal Reproduction Science, 131 9– 22.

Gunn, R.G., Sim, D. and Hunter, E.A., 1995. Effects of nutrition in utero and in early life on the subsequent lifetime reproductive performance of Scottish Blackface ewes in two management systems. Animal Science, 60 223–230.

Gurr, M.I., Harwood, J.L. and Frayn, K.N., 2002. Lipids: definition, isolation, separation, and detection. Pages 1-65 in Lipid Biochemistry: An introduction, education Blackwell Science Ltd, Oxford, UK.

Hamada, D.H., Mahboub, Sameh, G.A., Ramadan, Ragab, A., Darwish, Mohamed, A., 2013. Fish oil supplementation and selenium-vitamin E injection of Egyptian ewes and their Finnish landrace crossbred during late pregnancy, lambs response. Assiut Veterinary Medical Journal, Vol. 59 No. 138.

Harding, J.E., 2001. The nutritional basis of the fetal origins of adult disease. International journal of epidemiology 30: 15-23.

Harfoot, C.G., and Hazlewood G.P., 1997. Lipid metabolism in the rumen. In: P. N. Hobson and C. S. Stewart (ed.) The Rumen Microbial Ecosystem. pp 382-426. Chapman and Hall, London, UK.

Harrison, J.H., Kincaid, R.L., McNamara, J.P., Waltner, S., Loney, K.A., Riley, R.E. and Cronrath, J.D., 1995. Effect of whole cottonseeds and calcium salts of long-chain fatty acids on performance of lactating dairy cows. Journal of Dairy Science, Vol.78, No.1 (January 1995), pp. 181-193.

Harris, M.A., Hansen, R.A., Vidsudhiphan, P., Koslo, J.L., Thomas, J.B., Watkins, B.A. and Allen, K.G. (2001). Effects of conjugated linoleic acids and docosahexaenoic acid on rat liver and reproductive tissue fatty acids, prostaglandins and matrix metalloproteinase production. Prostaglandins Leukotrienes and Essential Fatty Acids, Vol.65, No.1, pp. 23-29.

Hayat, H.M., El-Nour, Soad, M., Nasr and Walid, R., Hassan, 2012. Effect of Calcium Soap of Fatty Acids Supplementation on SerumBiochemical Parameters and Ovarian Activity during Out-of-the-Breeding Season in Crossbred Ewes. The ScientificWorld Journal Volume 2012.

Hegazy, M.A., Ezzo, O.H. and El-Ekhnawy, K.E., 1999. Productive and reproductive performance of Barki ewes fed on diets containing calcium soaps of fatty acids or hydrogenated oil. Journal of the Egyptian-German Society of Zoology, 28: 201 -218.

Herrera-Camacho, J., Aké-Lopez, J.R., Ku-Vera, J.C., Williams, G.L. and Quintal-Franco, J.A., 2008. Respuesta ovulatoria, estado de desarrollo y calidad de embriones de ovejas Pelibuey superovuladas suplementadas con لcidos grasos poliinsaturados. Tecnica Pecuaria en Mexico, Vol.46, No.2, pp. 107-117.

Heravi Moussavi, A.R., Danesh Mesgaran, M., Soleimani, A., Vafa, T., 2008. Effect of supplemental fish meal on reproduction and immunology responses in early lactating Holstein dairy cows. Journal of Animal and Veterinary Advances, 7, 520–525.

Heravi-Moussavi, A.R.; Gilbert, R.O.; Overton, T.R.; Bauman, D.E. and Butler, W.R., 2007. Effect of feeding fish meal and n-3 fatty acids on ovarian and uterine responses in early lactating dairy cows. Journal of Dairy Science, Vol.90, No.1, pp. 145-154.

Hocquette, J.F., and Bauchart D., 1999. Intestinal absorption, blood transport and hepatic and muscle metabolism of fatty acids in preruminant and ruminant animals. Reproduction Nutrition Development, 39:27-48.

Hoffman, D.R. and Birch, D.G., 1998. World Review of Nutrition and Dietetics, 83 52–60.

Homa, S.T., Brown, C.A., 1992. Changes in linoleic-acid during follicular development and inhibition of spontaneous breakdown of germinal vesicles in cumulus-free bovine oocytes. Journal of Reproduction and Fertility, Suppl. 94, 153–160.

Howard, J.J., Scott, R.G., Britt, J.H., 1990. Associations among progesterone, estradiol-17b, and prostaglandin in cattle treated with hCG during diestrus to extend corpus luteum function. Prostaglandins, Vol.40, No.1, pp. 51-70.

Hristov, A., Oh J., Firkins J., Dijkstra J., Kebreab E., Waghorn G., Makkar H., Adesogan A., Yang W., Lee C., Gerber P., Henderson B., and Tricarico J. 2013. Mitigation of methane and nitrous oxide emissions from animal operations: I. A review of enteric methane mitigation options. Journal of Animal Science,91:5045–5069.

Hsieh, A.T. and Brenna J.T., 2009. Dietary docosahexaenoic acid but not arachidonic acid influences central nervous system fatty acid status in baboon neonates. Prostaglandins Leukot. Essent. Fatty Acids, 81: 105-110.

Hu, F., Manson, J., Willet, W., 2001. Types of dietary fat and risk of coronary heart disease: a critical review. Journal of the American College of Nutrition, 20 (1), 5 – 19.

Huang, M. and Craig-Schmidt, M.C., 1996. Arachidonate and docosahexaenoate added to infant formula influence fatty acid composition and subsequent eicosanoid production in neonatal pigs. Journal of Nutrition. 126: pp. 2199-2208.

Huuskonen, A., Khalili, H., Kiljala, Joki-Tokola, J.,E., and Nousiainen, J., 2005. Effects of vegetable fats versus lard in milk replacers on feed intake, digestibility, and growth in finnish Ayrshire bull calves. Journal of Dairy Science,88:3575-3581.

Hyttel, P., Laurincik, J., Viuff, D., Fair, T., Zakhartchenko, V., Rosenkranz, C., Avery, B., Rath, D., Niemann, H., Thomsen, P.D., Schellander, K., Callesen, H., Wolf, E., Ochs, R.L. and Greve, T., 2000. Activation of ribosomal RNA genes in pre-implantation cattle and swine embryos Animal Reproduction Science 60–61 49–60.

Ikemoto, A., Ohishi, M., Sato, Y., Hata, N., Misawa, Y., Fujii, Y., Okuyama, H., 2001. Reversibility of n-3 fatty acid deficiency-induced alterations of learning behaviour in the rat: level of n-6 fatty acids as another critical factor. Journal of Lipid Research, 42: 1655–63.

Inskeep, E.K., 2004. Preovulatory, postovulatory, and postmaternal recognition effects of concentrations of progesterone on embryonic survival in the cow. Journal of Animal Science, 82, E24–E39.

Ip, C., Dong, Y., Thompson, H.J., Bauman, D.E., Ip, M.M., 2001. Conjugated linoleic acid isomers and mammary cancer prevention. Nutrition and Cancer Journal, 39, 233– 238.

IUPAC Compendium of Chemical Terminology (2nd ed.). International Union of Pure and Applied Chemistry. 1997.

Jammes, H., Junien, C., Chavatte-Palmer, P., 2011. Epigenetic control of development and expression of quantitative traits. Journal of Reproduction Fertility and Development,23:64 –74.

Joshi, S., Rao, S., Girigosavi, S., Daware, M., Kale A., Hegde, M., 2004. Differential effects of fish oil and folic acid supplementation during pregnancy in rats on cognitive performance and serum glucose in their offspring. Nutrition;20:465–72.

Juchem, S.O., Cerri, R.L.A., Villaseoor, M., Galvo, K.N., Bruno, R.G.S., Rutigliano, H.M., DePeters, E.J., Silvestre, F.T., Thatcher, W.W. and Santos, J.E.P., 2010. Supplementation with calcium salts of linoleic and trans-octadecenoic acids improves fertility of lactating dairy cows. Reproduction in Domestic Animals, Vol.45, No.1, pp. 55-62.

Kehoe, S.I. and Heinrichs, A.J., 2007. Bovine colostrum nutrient composition. CAB. Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 2: No. 029:1-10.

Kenyon, P.R. and Webby, R.W., 2007. Pastures and supplements in sheep production systems. In: Rattray, P.V., Brookes, I.M., Nicol A.M. eds. Pasture and supplements for grazing animals. New Zealand Society of Animal Production. Occasional Publication Number 14. 255–274.

King, S.S., AbuGhazaleh, A.A., Webel, S.K. and Jones, K.L., 2008. Circulating fatty acid profiles in response to three levels of dietary omega-3 fatty acid supplementation in horses. Journal of Animal Science,86:1114-1123.

Kitessa, S.M., Gulati, S.K., Ashes, J.R., Fleck, E., Scott, T.W. and Nichols, P.D., 2001. Utilisation of fish oil in ruminants I. Fish oil metabolism in sheep. Animal Feed Science and Technology 89, 189–199.

Kitessa, S.M., Peake, D., Bencini, R. and Williams A.J., 2003. Fish oil metabolism in ruminants: III. Transfer of n-3 polyunsaturated fatty acids (PUFA) from tuna oil into sheep's milk. Animal Feed Science and Technology 108:1-14.

Kleemann, D.O. and Walker S.K., 2005. Fertility in South Australian commercial Merino flocks: Sources of reproductive wastage. Theriogenology 63:2075–2088.

Klusmeyer, T.H. and Clark, J.H., 1991. Effects of dietary fat and protein on fatty acid flow to the duodenum and in milk produced by dairy cows. Journal of Dairy Science, 74:3055-3067.

Knickerbocker, J.J., Thatcher, W.W., Foster, D.B., Wolfenson, D., Bartol, F.F. and Caton, D., 1986. Uterine prostaglandin and blood flow responses to estradiol-17 in cyclic cattle. Prostaglandins, Vol.31, No.4, pp. 757-776.

Knights, M., Baptiste Q.S., Dixon A.B., Pate J.L., Marsh D.J.,. Inskeep E.K, and Lewis P.E., 2003. Effects of dosage of FSH, vehicle and time of treatment on ovulation rate and prolificacy in ewes during the anestrous season. Small Ruminant Research,50:1–9.

Kolanowski W., Swiderski F., Lis E. And  Berger S. 2001. Enrichment of spreadable fats with polyunsaturated fatty acids omega-3 using fish oil. International Journal of Food Science and Nutrition, 52, 469–476.

Koletzko B., 1992. Fats for brains. European Journal of Clinical Nutrition 46,S51–S62.

Kotsampasi. B., Balaskas, C., Papadomichelakis, G., Chadio, S.E., 2009a. Reduced Sertoli cell number and altered pituitary responsiveness in male lambs undernourished in utero. Animal Reproduction Science, 114:135– 47.

Kotsampasi, B., Chadio, S., Papadomichelakis, G., Deligeorgis, S., Kalogiannis, D., Menegatos, I., 2009b. Effects of maternal undernutrition on the hypothalamic-pituitary-gonadal axis function in female sheep offspring. Reprodutive in Domestic Animal, 44:677– 84.

Krauss, R.M., Deckelbaum, R.J., Ernst, N., Fisher, E., Howard, B.V., Knopp, R.H., 1996. Dietary guidelines for healthy American adults: a statement for health professionals from the Nutrition Committee, American Heart Association. Circulation 94, 1795– 1800.

Lammoglia, M.A., Bellows R.A., Grings E.E., and Bergman J.W., 1999. Effects of prepartum supplementary fat and muscle hypertrophy genotype on cold tolerance in newborn calves. Journal of Animal Science,77:2227-2233.

Lands, W.E., 1992. Biochemistry and physiology of n-3 fatty acids. FASEB J. 6, 2530–2536.

Leiber, F., Hochstrasser, R., Wettstein, H.R. and Kreuzer, M., 2011. Feeding transition cows with oilseeds: effects on fatty acid composition of adipose tissue, colostrum and milk. Livestok Science, 138:1–12.

Liel, A.Z.A., Abd El-Rahman, H.M.A., and El-Nour, H.H.M., 2010. Laparoscopic examination of ovarian activity and some metabolic changes in ewes supplemented with protected fat and growth hormone during estrous cycle," Egyptian Journal of Basic and Applied Physiology, vol. 9, pp. 307–323.

Ling, S.C. and Griffiths, A.M., 2000. Current Opinion in Clinical Nutrition and Metabolic Care, 3 339–344.

Lock, A.L. and Bauman, D.E., 2004. Modifying milk fat composition of dairy cows to enhance fatty acids beneficial to human health. Lipids 39:1197-1206.

Lock, A.L. and Garnsworthy, P.C., 2002. Independent effects of dietary linoleic and linolenic fatty acids on the conjugated linoleic acid content of cows' milk. Animal Science 74:163-176.

Lopes, N., Scarpa, A.B., Cappellozza, B.I., Cooke, R.F. and Vasconcelos, J.L.M., 2009. Effects of rumen-protected polyunsaturated fatty acid supplementation on reproductive performance of Bos indicus beef cows. Journal of Animal Science, Vol.87, No.12 (December 2009), pp. 3935-3943.

Lucy, M.C., De La Sota, R.L., Staples, C.R. and Thatcher, W.W., 1993. Ovarian follicular populations in lactating dairy cows treated with recombinant bovine somatotropin (sometribove) or saline and fed diets differing in fat content and energy. Journal of Dairy Science; Vol.76, No.4, pp. 1014-1027.

Lumey, L.H., 1992. Decreased birthweights in infants after maternal in utero exposure to the Dutch famine of 1944–1945 Paediatric and Perinatal Epidemiology 6 240–253.

Lumey, L.H., 1998. Reproductive outcomes in women prenatally exposed to undernutrition: a review of findings from the Dutch famine birth cohort. Proceedings of the Nutrition Society, 57:129 –35.

Luna, P., Bach, A., Juárez, M. and de La Fuente, M.A., 2008. Influence of diets rich in flax seed and sunflower oil on the fatty acid composition of ewes' milk fat especially on the content of conjugated linoleic acid, n-3 and n-6 fatty acids. International Dairy Journal 18:99-107.

MacLaren, L.A., Guzeloglu, A., Michel, F., Thatcher, W.W., 2006. Peroxisome proliferator-activated receptor (PPAR) expression in cultured bovine endometrial cells and response to omega-3 fatty acid, growt hormone and agonist stimulation in relation to series 2 prostaglandin production. Domestic Animal Endocrinology, 30, 155–169.

Magre, S., Vigier, B., 2001. Développement et différentiation sexuelle de l'appareil génital. In: La reproduction chez les mammifères et chez l'homme, Thibault C, Levasseur M-C (Eds.). Ellipses, pp. 235–55.

Mahadik, S.P., Evans, D., Lal, H., 2001. Progress in Neuro Psychopharmacol Biol Psychiatry, 25 463–493.

Mahboub, H.D.H., Ragab, A.D., Mabrouk, A.A., El- Kholya, S.Z., Said, I.F. and Ashmawy, T.A.M., 2012. Fish oil and selenium-vitamin E supplementation of Egyptian sheep and its Finnish Landrace crossbred during late pregnancy: Ewe response. Proceeding of the 7th scientific conference, 24-27 April, Menoufia University, Sadat city branch, p. 147-162.

Martin, J.L., Vonnahme K.A., Adams D.C., Lardy G.P., and Funston R.N., 2007. Effects of dam nutrition on growth and reproductive performance of heifer calves. Journal of Animal Science. 85:841-847.

Martin, L., Rodriguez. P., Rota, A., Pascual, M. R., Paton, D. and Tovar. J., 1999. Effect of protected fat supplementation to lactation goats on growth and fatty acid composition of perirenal fat in goat kids. Journal of Animal Science, 68: 195- 200.

Martín, N.P., Kenyon, P.R., Morel, P.C.H., Pain, S.J., Jenkinson, C.M.C., Hut-ton, P.G., Morris, S.T., Peterson, S.W., Firth, E.C., Blair, H.T., 2012. Ewe nutrition in early and mid- to late pregnancy has few effects on fetaldevelopment. Animal Production Science 52 (6–7), 533–539.

Martini, M., Scolozzi, C., Cecchi, F., and Abramo, F., 2004. Morphometric analysis of fat globules in ewe's milk and correlation with qualitative parameters. Italian Journal of Animal Science 3:55-60.

Mattos, R., Staples, C.R., Arteche, A., Wiltbank, M.C., Diaz, F.J., Jenkins, T.C. and Thatcher, W.W., 2004. The effects of feeding fish oil on uterine secretion of PGF2, milk composition, and metabolic status of periparturient Holstein cows. Journal of Dairy Science, Vol.87, No.4, pp. 921-932.

Mattos, R., Guzeloglu, A., Badinga, L., Staples, C.R., Thatcher, W.W., 2003. Polyunsaturated fatty acids and bovine interferon-tau modify phorbol ester-induced secretion of prostaglandin F2_ and expression of prostaglandin endoperoxide synthase-2 and phospholipase-A2 in bovine endometrial cells. Biology of Reproduction 69, 780–787.

Mattos, R., Staples, C.R. and Thatcher, W.W., 2000. Effects of dietary fatty acids on reproduction in ruminants. Reviews of Reproduction, Vol.5, No.1, pp. 38-45.

Mauleon, P., 1973. Kinetics of oogenesis in mammals Archives Anatomie Microscopie Morphologie Experimentation 56 125–150.

Mauleo,n P. and Mariana, J.C., 1977. Oogenesis and folliculogenesis. In Reproduction in Domestic Animals Edn 3 pp 175–198 Eds HH Cole and PT Cupps. Academic Press, New York.

Mauleon, P., Bezard, J. and Terqui, M., 1977. Very early and transient 17b-estradiol secretion by the fetal sheep ovary Annales Biologie Animales Biochemie Biophysiques 17 399–401.

Mc Giure, T.C., Regnier, J., Kellom, T., and Gates, N., 1983. Failure in passive transfer of immunoglobulin G1 to lambs: measurement of immunoglobulin G1 in ewe colostrums. American Journal of Veterinary Research, 44 (6): 1064-7.

McCracken, J.A., Carlson, J.C., Glew, M.E., Goding, J.R., Baird, D.T., Green, K., Samuelsson, B., 1972. Prostaglandin F2_ identified as a luteolytic hormone in sheep. Nature New Biology, 238, 129–134.

McEvoy, T.G., Coull, G.D., Broadbent, P.J., Hutchinson, J.S.M. and Speake, B.K., 2000. Fatty acid composition of lipids in immature cattle, pig and sheep oocytes with intact zona pellucida. Journal of Reproduction and Fertility, Vol.118, No.1, pp. 163-170.

McMillen I.C., MacLaughlin S.M., Muhlhausler B.S., Gentili S., Duffield J.L., Morrison J.L., 2008. Developmental origins of adult health and disease: the role of periconceptional and foetal nutrition. Basic Clin Pharmacol Toxicol;102:82–9.

Mellor, D.J., 1983. Nutritional and placental determinants of foetal growth rate in sheep and consequences for the newborn lamb. British veterinary journal 139: 307-324.

Merrell, B.G., 1998. The effects on lamb survival rate of supplementing ewes with vitamin E during late pregnancy. Sheep Veterinary Society Proceedings. 1998;22:57–61.

Mughetti, L., Acuti, G., Antonini, C., De Vincenzi, S., Olivieri, O. and Trabalza Marinucci, M., 2007. Effects of feeding raw or extruded linseed on the ruminal ecosystem of sheep. Italian Journal of Animal Science 6(Suppl. 1):327-329.

MOA, 2012. Ministry of Agriculture, Jordan. Annual report.

Moore, J.H. and Christie W.W., 1984. Digestion, absorption and transport of fats in ruminant animals. In: J. Wiseman (Ed.) Fats in Animal Nutrition. pp. 123-149. Butterworths, London, UK.

Morgane, P.J., Austin-La, France R., Bronzino, J., Tonkiss, J., Diaz-Cintra, S., Cintra, L., Kemper, T. and Galler, J.R., 1993. Prenatal malnutrition and the development of the brain Neuroscience Biobehaviour Reviews 17 91–128.

Mozzon, M., Frega, N.G., Fronte, B. and Tocchini, M., 2002. Effect of dietary fish oil supplements on levels of n-3 polyunsaturated fatty acids, trans acids and conjugated linoleic acid in ewe milk. Food Technology and Biotechnology 40:213-219.

Neuringer, M., Anderson, G.J., Connor W.E., 1998. Annual Review of Nutrition, 8 517–541.

Nissen, P.M., Danielson V.O., Jorgensen P.F., and Oksbjerg N., 2003. Increased maternal nutrition of sows has no beneficial effects on muscle fiber number or postnatal growth and has no impact on the meat quality of the offspring. Journal of Animal Sciences, 81:3018-3027.

Noble, R.C., 1981. Digestion, transport and absorption of lipids. In: W.W. Christie (Ed.) Lipid metabolism in ruminant animals. pp. 57-93. Pergamon Press Ltd., Oxford, UK. Palmquist, D.L. and T.C. Jenkins. 2003. Challenges with fats and fatty acid methods. Journal of Animal Sciences, 81:3250-3254.

NRC, 2007. Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervide, and New World Camelids. National Academy of Sciences Press, Washington, DC, USA.

Nudda, A., Battacone, G., Atzori A.S., Dimauro, C., Rassu, S.P.G., Nicolussi, P., Bonelli, P. and Pulina, G., 2013. Effect of extruded linseed supplementation on blood metabolic profile and milk performance of Saanen goats. Animal 7:1464-1471.

Nudda, A., Fancellu, S., Porcu, F., Boe, F. and Cannas, A., 2004. Responses of milk fat composition to dietary non-fiber carbohydrates in Sarda dairy sheep. Journal of Dairy Science 87(Suppl. 1):310.

Nudda, A., McGuire, M.A., Battacone, G. and Pulina, G., 2005. Seasonal variation in conjugated linoleic acid and vaccenic acid in milk fat of sheep and its transfer to cheese and ricotta. Journal of Dairy Science 88:1311-1319.

Nudda, A., Mele, M., Battacone, G., Usai, M.G. and Macciotta, N.P.P., 2003. Comparison of conjugated linoleic acid (CLA) content in milk of ewes and goats with the same dietary regimen. Italian Journal of Animal Science 2(Suppl. 1):515-517.

Nudda, A., Mereu, A., Fancellu, S. and Cappio-Borlino, A., 2007. Meta-analysis of nutritional effects on conjugated linoleic acid (CLA) in milk fat of dairy cows. Italian Journal of Animal Science 6 :330-332.

Offer, N.W., Marsden, M., Dixon, J., Speake, B.K., Thacker, F.E., 1999. Effect of dietary fat supplements on levels of n−3 polyunsaturated fatty acids, trans acids and conjugated linoleic acid in bovine milk. Journal of Animal Sciences, 69, 613–625.

Oldick, B.S., Staples, C.R., Thatcher, W.W. and Gyawu, P., 1997. Abomasal infusion of glucose and fat-effect on digestion, production, and ovarian and uterine function of cows. Journal of Dairy Science, Vol.80, No.7 (July 1997), pp. 1315-1328.

Olsen, S.F., Hansen, H.S., Sorensen. J.D., Jensen, B., Secher, N.J., Sommer, S. and Knudsen, L.B., 1986. Intake of marine fat rich in polyunsaturated fatty acids may increase birthweight by prolonging gestation. The Lancet 2, 367–369.

Olsen, S.F., Hansen, H.S., Jensen, B., 1990. Fish oil versus arachis oil food supplementation in relation to pregnancy duration in rats. Prostaglandins Leukot Essent Fatty Acids ;40:255–60.

Olsen, S.F., Sorensen, J.D., Secher, N.J., Hedegaard, M., Henriksen, T.B., Hansen, H.S., Grant, A., 1992. Randomised controlled trial of effect of fish-oil supplementation on pregnancy duration. Lancet 339, 1003–1007.

Onetti, S.G., Shaver,R.D., McGuire, M.A., Palmquist, D.L., and Grummer, R.R., 2002. Effect of supplemental tallow on performance of dairy cows fed diets with different corn silage:alfalfa silage ratios. Journal of Dairy Science, 85:632-641.

Oqla, H.M., Kridli, R.T. and Haddad, S.G., 2004. The effect of dietary fat inclusion on nutrient intake and reproductive performance in postpartum Awassi ewes," Asian-Australasian Journal of Animal Sciences, vol. 17, no. 10, pp. 1395–1399.

Palmquist, D.L. and Jenkins, T.C., 2003. Challenges with fats and fatty acid methods. Journal of Animal Sciences, 81, 3250-3254.

Park, Y., Albright, K.J., Liu, W., Storkson, J.M., Cook, M.E., Pariza, M.W., 1997. Effect of conjugated linoleic acid on body composition in mice. Lipids 32, 853–858.

Paten, A.M., Kenyon, P.R., Lopez-Villalobos, N., Peterson, S.W., Jenkinson,C.M.C., Pain, S.J., Blair, H.T., 2013. Maternal nutrition during early andmid-to-late pregnancy: comparative effects on milk production oftwin-born ewe progeny during their first lactation. Journal of Animal Sciences, 91,676–684.

Pattinson, S.E., Davies, D.A.R., Winter, A.C., 1995. Changes in the secretion rate and production of colostrum by ewes over the first 24 h postpartum. Journal of Animal Sciences, 61:63–8.

Patra, A.K., and Yu. Z., 2013. Effects of coconut and fish oils on ruminal methanogenesis, fermentation, and abundance and diversity of microbial populations in vitro. Journal of Dairy Science,96:1782–1792.

Perez-Alba, L. M., Cavalcanti, S. D., Hernandez, M.P., Marin, A. M. and Marin, G. F., 1997. Calcium soaps of fatty acids in the diets of Manchega dairy ewes: Effect on digestibility and production. Journal of Dairy Science,80: 3316-3324.

Petit, H.V. and Berthiaume, R., 2006. Effect of feeding different sources of fat during gestation and lactation on reproduction of beef cows and calf performance. Can. Journal of Animal Science, 86:235-243.

Petit, H.V., Dewhurst, R.J., Scollan, N.D., Proulx, J.G., Khalid, M., Haresign, W., Twagiramungu, H., Mann, G.E., 2002. Milk production and composition, ovarian function, and prostaglandin secretion of dairy cows fed omega-3 fats. Journal of Dairy Science,85, 889–899.

Petit, H.V., Germiquet, C., Lebel, D., 2004. Effect of feeding whole, unprocessed sunflower seeds and flaxseed on milk production, milk composition, and prostaglandin secretion in dairy cows. Journal of Dairy Science,87, 3889–3898.

Petit, H.V. and Twagiramungu, H., 2006. Conception rate and reproductive function of dairy cows fed different fat sources. Theriogenology 66, 1316–1324.

Pickard, R.M., Beard, A.P., Cain, P.J., Madgwick, S., Hawken, P.A.R. and Edwards, S.A., 2004. Supplementation of ewe gestation diets with algal DHA and effects on neonatal lamb viability. Proceedings of the 3rd Euro Fed Lipid Congress and Expo, 312.

Pickard, R.M., Beard, A.P., Seal, C.J. and Edwards, S.A., 2005. Supplementation of ewediets with algal biomass rich in docosahexaenoic acid for different time periodsbefore lambing affects measures of lamb viability. Proceedings of the BritishSociety of Animal Science Annual Meeting 2005, p. 89.

Pickard, R.M., Beard, A.R., Seal, C.J., Edwards, S.A., 2008. Neonatal lamb vigour is improved by feeding docosahexaenoic acid in the form of algal biomass during late gestation. Animal 2, 1186–1192.

Pintus, S., Murru, E., Carta, G., Cordeddu, L., Batetta, B., Accossu, S., Pistis, D., Uda, S., Ghiani, M.E., Mele, M., Secchiari, P., Almerighi, G., Pintus, P. and Banni, S., 2013. Sheep cheese naturally enriched in α-linolenic, conjugated linoleic and vaccenic acids improves the lipid profile and reduces anandamide in the plasma of hypercholesterolaemic subjects. British Journal of Nutrition 109:1453-1462.

Pulina, G., Nudda, A., Battacone, G. and Cannas, A., 2006. Effects of nutrition on the contents of fat, protein, somatic cells, aromatic compounds, and undesirable substances in sheep milk. Animal Feed Science and Technology 131:255-291.

Quigley, J.D.III and Drewry, J.J., 1998. Nutrient and immunity transfer from cow to calf pre- and postcalving. Journal of Dairy Science,81:2779-2790.

Quigley, J.D., Lago, A., Chapman, C., Erickson, P. and Polo, J., 2013. Evaluation of the Brix refractometer to estimate immunoglobulin G concentration in bovine colostrum. Journal of Dairy Science 69:1148-1155.

Rae, M.T., Rhind, S.M., Kyle, C.K., Fowler, P.A., Miller, D.W. and Brooks, A.N., 2000. Maternal undernutrition during early pregnancy up-regulates fetal testicular steroidogenesis in sheep Journal of Reproduction and Fertility Abstract Series 25 Abstract 38.

Rae, M.T., Palassio, S., Kyle, C.E., Brooks, A.N., Lea, R.G., Miller, D.W., 2001. Effect of maternal undernutrition during pregnancy on early ovarian development and subsequent follicular development in sheep fetuses. Reproduction;122:915–22.

Rae, M.T., Kyle, C.E., Miller, D.W., Hammond, A.J. Brooks, A.N., Rhind, S.M., 2002. The effects of undernutrition, in utero, on reproductive function in adult male and female sheep. Animal Reproduction Science,72:63–71.

Rashid, M.M., Fisher, R., Karrow, N., Alzahal, O. and McBride, B.W., 2010. Fatty acid profile of colostrum and milk of ewes supplemented with fish meal and the subsequent plasma fatty acid status of their lambs. Journal of AnimalScience,Jun; 88(6):2092-102.

Rattray, P.V., Garrett, W.N., East, N.E. and Hinman, N., 1974: Growth, development and composition of ovine conceptus and mammary-gland during pregnancy. Journal of Animal Science, 38: 613-626.

Rego, A.O., Portugal, V.P., Sousa B.M., Rosa H.J.D., Vozuela M.C., Borba E.S.A. and Bessa, R.J.B., 2004. Effect of diet on the fatty acid pattern of milk from dairy cows. Animal Research, Vol.53, No.3, pp. 213-220.

Rhind, S.M., Elston, D.A., Jones, J.R., Rees, J.R., McMillen, S.R. and Gunn, R.G., 1998. Effects of restriction of growth and development of Brecon Cheviot ewe lambs on subsequent lifetime reproductive performance Small Ruminant Research 30 121–126.

Rhind, S.M., 2004. Effects of maternal nutrition on fetal and neonatal reproductive development and function. Animal reproduction science 82-83: 169-181.

Rhind, S.M., Rae, M.T., Brooks, A.N., 2001: Effects of nutrition and environmental factors on the fetal programming of the reproductive axis. Reproduction 122: 205-214.

Robinson, J.J., Sinclair, K.D., McEvoy, T.G., 1999. Nutritional effects on foetal growth. Animal science 68: 315-331.

Robinson, R.S., Pushpakumara, P.G.A., Cheng, Z., Peters, A.R., Abayasekara, D-E-E., Wathes, D.C., 2002. Effects of dietary polyunsaturated fatty acids on ovarian and uterine function in lactating dairy cows. Reproduction, Vol.124, No.1, pp. 119-131.

Roche, J.R., Lee, J.M., Berry, D.P., 2006. Pre-conception energy balance and secondary sex ratio – Partial support for the Trivers-Willard hypothesis in dairy cows. Journal of Dairy Science, 89:2119-2125.

Rooke, J.A, Sinclair, A.G., Edwards, S.A., 2001. Feeding tuna oil to the sow at different times during pregnancy has different effects on piglets long-chain polyunsaturated fatty acid composition at birth and subsequent growth. British Journal of Nutrition,86:21–30.

Rose, D.P. and Connolly, J.M., 2000. Nutrition and Cancer Journal, 37 119–127.

Rosenfeld, C.S. and Roberts, R.M., 2004. Maternal diet and other factors affecting offspring sex ratio: A review. Biology of Reproduction, 71:1063-1070.

Rosenfeld, C.S., Grimm, K.M., Livingston, K.A., Brokman, A.M., Lamberson, W.E., Roberts, R.M., 2003. Striking variation in the sex ratio of pups born to mice according to whether maternal diet is high in fat or carbohydrate. Proceedings of the National Academy of Sciences of the United States of America, 100:4628-4632.

Rotunno, T., Sevi, A., Di Caterina, R. and Muscio, A., 1998. Effects of graded levels of dietary rumen-protected fat on milk characteristics of Comisana ewes. Small Rumin Research 30: 137- 145.

Ryan, D.P., Bao, B., Griffith, M.K. and Williams, G.L., 1995. Metabolic and luteal sequelae to heightened dietary fat intake in postpartum beef cows. Journal of Animal Science, Vol.73, No.7, pp. 2086-2093.

Ryan, D.P., Spoon, R.A., Griffith, M.K. and Williams, G.L., 1994. Ovarian follicular recruitment, granulosa cell steroidogenic potential, and growth hormone/insulinlike growth factor-1 relationships in beef cows consuming high lipid diets: Effects of graded differences in body condition maintained during the puerperium. Domestic Animal Endocrinology, Vol.11, No.2, pp. 161-174.

Ryan, D.P., Spoon, R.A. and Williams, G.L., 1992. Ovarian follicular characteristics, embryo recovery, and embryo viability in heifers fed high fat diets and treated with folliclestimulating hormone. Journal of Animal Science, Vol.70, No.11; p. 3505-3513.

Saldanha, L.G., Jr N.S. and Brenna J.T., 2009. Prostaglandins Leukot. Essent. Fatty Acids, 81: 233-236.

Sanudo, C., Enser, M., Campo, M.M., Nute, G.R., Maria, G., Sierra, I., and Wood, J.D., 2000. Fatty acid composition and fatty acid characteristics of lamb carcasses from Britain and Spain. Meat Science, 54, 339–346.

Santos, J.E.P., Bilby, T.R., Thatcher, W.W., Staples, C.R. and Silvestre, F.T., 2008. Long chain fatty acids of diet as factors influencing reproduction in cattle. Reproduction in Domestic Animals, Vol.43, No. Suppl. 2, pp. 23-30.

Santschi, D.E., Wettstein H.R., Leiber F., Witschi A.K.M., and Kreuzer K., 2009. Colostrum and milk fatty acids of dairy cows as influenced by extruded linseed supplementation during the transition period. Can. Journal of Animal Science,89:383–392.

Sanz Sampelayo, M.R., Ferandez, J.R., Ramos, E., Hermoso, R., Gil Extremera, F., Boza, J., 2006. Effect of providing a polyunsaturated fatty acid — protected fat to lactating goats on growth and body composition of suckling goat kids. Journal of Animal Science, 82, 337–344.

Scollan, N.D., Choi, N.J., Kurt, E., Fisher, A.V., Enser, M., Wood, J.D., 2001. Manipulating the fatty acid composition of muscle and adipose tissue in beef cattle. British Journal of Nutrition, 85, 115–124.

Silveira, P.P., Portella, A.K., Goldani, M.Z., Barbieri, M.A., 2007. Developmental origins of health and disease (DOHaD). J Pediatr (Rio J). 83:494 –504.

Sinclair, L.A., Cooper, S.L., Chikunya, S., Wilkinson, R.G., Hallett, K.G., Enser, M., Wood JD., 2005. Biohydrogenation of n-3 polyunsaturated fatty acids in the rumen and their effects on microbial metabolism and plasma fatty acid concentrations in sheep. Journal of Animal Science, 81:239–48.

Sima, A. and Sourander, P., 1978. The effect of pre- and postnatal undernutrition on axonal growth and myelination of central motor fibers. A morphometric study on rat cortico–spinal tract Acta Neuropathologica (Berlin) 26 15–18.

Sharma, S.K., Nayar, U., Maheshwari, M.C. and Singh, B., 1987. Effect of undernutrition on developing rat cerebellum. Some electrophysiological and neuromorphological correlates Journal of Neurological Sciences 78 261–272.

Sharpe, R.M., 1994. Regulation of spermatogenesis. In The Physiology of Reproduction pp 1363–1434 Eds E Knobil and JD Neill. Raven Press, New York.

Sharpe, R.M. and Franks, S., 2002. Environment, lifestyle and infertility–aninter-generational issue. Nature cell BiologyJournals, 4(Suppl):s33– 40.

Sheldon, B.C. and West, S.A., 2004. Maternal dominance, maternal condition, and offspring sex ratio in ungulate mammals. American Naturalist Journal, 163:40-54.

Shingfield, K.J., Ahvenjarvi, S., Toivonen, V., Arola, A., Nurmela, K.V.V., Huhtanen, P., Griinari, J.M., 2003. Effect of dietary fish oil on biohydrogenation of fatty acids and milk fatty acid content in cows. Journal of Animal Science, 77, 165–179.

Shingfield, K.J., Ahvenjarvi, S., Toivonen, V., Vanhatalo, A., Huhtanen, P. and Griinari, J.M., 2008. Effect of incremental levels of sunflower-seed oil in the diet on ruminal lipid metabolism in lactating cows. British Journal of Nutrition,99:971–983.

Shingfield, K.J., Reynolds, C.K., Hervas, G., Griinari, J.M., Grandison, A.S. and Beever, D.S., 2006. Examination of the persistency of milk fatty acid composition responses to fish oil and sunflower oil in the diet of dairy cows. Journal of Dairy Science 89, 714–732.

Simopoulos, P., Can, J., 1997. Journal of Physiology and Pharmacology, 75 234–239.

Singer, D., 1998. Thermometry calorimetry in the recent advances in monitoring research. Thermochimica Acta., 309: 39-47.

Slee, J., 1981. A review of genetic aspects of survival and resistance to cold in newborn lambs. Livestock Production Science 8, 419–429.

Smith, S.S., Neuringer, M. and Ojeda, S.R., 1989. Essential fatty acid deficiency delays the onset of puberty in the female rat. Endocrinology, 125:1650-1659.

Smuts, C.M., Huang, M., Mundy, D., Plasse, T., Major, S., Carlson, S.E., 2003. A randomised trial of docosahexaenoic acid supplementation during the third trimester of pregnancy. Obstet Gynecol; 101:469–79.

Sofi, F., Buccioni, A., Cesari, F., Gori, A.M., Minieri, S., Mannini, L., Casini, A., Gensini, G.F., Abbate, R. and Antongiovanni, M., 2010. Effects of a dairy product (pecorino cheese) naturally rich in cis-9, trans-11 conjugated linoleic acid on lipid, inflammatory and haemorheological variables: a dietary intervention study. Nutrition, Metabolism and Cardiovascular Diseases 20:117-124.

Sreenan, J.M., Diskin, M.G. and Morris, D.G., 2001. Embryo survival rate in cattle: a major limitation to the achievement of high fertility. In: Fertility in the high producing dairy cow. British Society of Animal Science, Vol.1, pp. 93-105.

Staples, C.R., Thatcher, W.W., 2005. Effects of fatty acids on reproduction of dairy cows. In: Garnsworthy PC, Wiseman, J. (Eds.), Recent Advances in Animal Nutrition. Nottingham University Press, Nottingham, UK, 229-256 p.

Staples, C.R., Burke, J.M. and Thatcher, W.W., 1998. Influence of supplemental fats on reproductive tissues and performance of lactating cows. Journal of Dairy Science, Vol.81, No.3, pp. 856-871.

Stewart M., Michael T. and Nigel A., 2001. Effects of nutrition and environmental factors on the fetal programming of the reproductive axis. Reproduction (2001) 122, 205–214.

Stocco, D.M., 2000. The role of the StAR protein in steroidogenesis: challenges for the future. J Endocrinol;164:247–53.

Stocco, D.M., Wang, X., Jo, Y. and Manna, P.R., 2005. Multiple signaling pathways regulating steroidogenesis and steroidogenic acute regulatory protein expression: more complicated than we thought. Molecular Endocrinology, Vol.19, No.11, pp. 2647-2659.

Sullivan T.M., Micke G.C., Greer R.M., 2009. Irving-Rodgers HF, Rodgers RJ, Perry VEA. Dietary manipulation of Bos indicus heifers during gestation affects the reproductive development of their heifer calves. Reproduction Fertility and Development,21:773– 84.

Sweeney T., Saunders P.T.K., Millar M.R. and Brooks A.N., 1997. Ontogeny of anti-Müllerian hormone, 3b-hydroxysteroid dehydrogenase and androgen receptor expression during ovine fetal gonadal development Journal of Endocrinology 153 27–32.

Symonds, M.E., Stephenson, T., Gardner, D.S., Budge, H., 2007. Long-term effects of nutritional programming of the embryo and fetus: mechanisms and critical windows. Reproduction, Fertility and development 19: 53-63.

Talavera, F., Park, C.S. and Williams, G.L., 1985. Relationships among dietary lipid intake, serum cholesterol and ovarian function in Holstein heifers. Journal of Animal Science, Vol.60, No.4, pp. 1045-1051.

Tappia, P.S., Ladha, S., Clark, D.C., Grimble, R.F., 1997. The influence of membrane fluidity, TNF receptor binding, cAMP production and GTPase activity on macrophage cytokine production in rats fed a variety of fat diets. Molecular and Cellular Biochemistry, 166, 135–143.

Thangavelu, G., Colazo, M.G., Ambrose, D.J., Oba, M., Okine, E.K. and Dyck, M.K., 2007. Diets enriched in unsaturated fatty acids enhance early embryonic development in lactating Holstein cows. Theriogenology 68:949-957.

Thatcher, W.W., Macmillan, K.L., Hansen, P.J. and Bazer, F.W., 1994. Embryonic losses: causes and prevention. In: Fields, M.J.S., Sand, R.S. Editors. Factors affecting calf crop. Boca Raton, FL: CRC Press; 135-153 p.

Thatcher, W.W. and Staples, R.C., 2007. Using fats and fatty acids to enhance reproductive performance. Proceedings of the 5th Mid-Atlantic Nutrition Conference.. 115 Zimmermann, N.G., ed., University of Maryland, College Park, MD 20742. USA. 116-129 p.

Theurer, M.L., Block, E., Sanchez, W.K., and McGuire, M.A., 2009. Calcium salts of polyunsaturated fatty acids deliver more essential fatty acids to the lactating dairy cow. Journal of Dairy Science,92:2051-2056.

Thomas, M.G., Bao, B. and Williams, G.L., 1997. Dietary fats varying in their fatty acid composition differentially influence follicular growth in cows fed isoenergetic diets. Journal of Animal Science, Vol.75, No.9, pp. 2512-2519.

Umhau, J.C. and Dauphinals, K.M., 2007. Omega-3 Polyunsaturated Fatty Acids and Health. In:[ L. L'abate (ed)] Low-cost Approaches to Promote Physical and Mental Health, pp. 87-101. Springer Science and Business Media, New York.

Vatansever, L., Kurt, E., Enser, M., Nute, G.R., Scollan, N. D., Wood, J. D. and Richardson, R.I., 2000. Shelf life and eating quality of beef from cattle of different breeds given diets differing in n-3 polyunsaturated fatty acid composition. Animal Science, 71, 471–482.

van der Linden, D.S., Kenyon, P.R., Blair, H.T., Lopez-Villalobos, N., Jenk-inson, C.M.C., Peterson, S.W., MacKenzie, D.D.S., 2009. Effects of ewesize and nutrition on fetal mammary gland development and lacta-tional performance of offspring at their first lactation. Journal of Animal Science, 87,3944–3954.

van der Linden, D.S., Kenyon, P.R., Lopez-Villalobos, N., Jenkinson, C.M.C.,Peterson, S.W., Blair, H.T., 2010. Effects of ewe size and nutrition dur-ing pregnancy on performance of 2-year-old female offspring. Journal of theAgriculturalScience, 148, 465–475.

Van Soest, P.J., Robertson, H.B., Lewis, B.A., 1991. Methods for dietary fiber and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science, 74, 3583–3597.

Vlaeminck, B., Fievez, V., Tamminga, S., Dewhurst, R.J., van Vuuren, A., De Brabander, D., and Demeyer, D., 2006. Milk odd- and branched-chain fatty acids in relation to the rumen fermentation pattern. Journal of Dairy Science 89:3954-3964.

Wachira, A.M., Sinclair, L.A., Wilkinson, R.G., Hallett, K., Enser, M. and Wood, J.D., 2000. Rumen biohydrogenation of n-3 polyunsaturated fatty acids and their effects on microbial efficiency and nutrient digestibility in sheep. Journal of Agricultural Science 135:419-428.

Wachira, A.M., Sinclair, L.A., Wilkinson, R.G., Enser, M., Wood, J.D., Fisher, A.V., 2002. Effects of dietary fat source and breed on the carcass composition, n-3 polyunsaturated fatty acid and conjugated linoleic acid content of sheep meat and adipose tissue. British Journal of Nutrition, 88, 697– 709.

Wallace, J.M., Bourke D.A., and Aitken R.P., 1999. Nutrition and fetal growth; paradoxical effects in the overnourished adolescent sheep. Journal of Reproduction and Fertility, 54(Suppl. 1):385-399.

Wathes, D.C., Lamming, G.E., 1995. The oxytocin receptor, luteolysis and the maintenance of pregnancy. Journal of Reproduction and Fertility, 49, 53–67.

Wathes, D.C., Abayasekara, D.R. and Aitken, R.J., 2007. Polyunsaturated fatty acids in male and female reproduction. Biology of Reproduction, Vol.77, No.2 (August 2007), pp. 190-201.

Wehrman, M.E., Welsh, T.H.Jr. and Williams, G.L., 1991. Diet-induced hyperlipidemia in cattle modifies the intrafollicular cholesterol environment, modulates ovarian follicular dynamics, and hastens the onset of postpartum luteal activity. Biology of Reproduction, Vol.45, No.3 (September 1991), pp. 514-522.

Whorwood, C.B, Firth K.M., Budge H., and Symonds M.E., 2001. Maternal undernutrition during early to midgestation programs tissue-specific alterations in the expression of the glucocorticoid receptor, 11β-hydroxysteroid dehydrogenase isoforms, and type 1 angiotensin II receptor in neonatal sheep. Endocrinology. 142:2854-2864.

Williams, C.M., 2000. Dietary fatty acids and human health. Annales Zootechnie, 49, 165–180.

Williams, G.L. and Amstalden, M., 2010. Understanding postpartum anestrus and puberty in the beef female. Proceedings, Applied Reproductive Strategies in Beef Cattle. January 28- 29, 2010; San Antonio, TX. USA. 55-71 p.

Williams, G.L., 1989. Modulation of luteal activity in postpartum beef cows through changes in dietary lipid. Journal of Animal Science, Vol.67, No.3 (March 1989); pp. 785-793.

Wonnacott, K.E., Kwong, W.Y., Hughes, J.; Salter, A.M., Lea, R.G., Garnsworthy, P.C. and Sinclair, K.D., 2010. Dietary omega-3 and -6 polyunsaturated fatty acids affect the composition and development of sheep granulosa cells, oocytes and embryos. Reproduction, Vol.139, No.1, pp. 57-69.

Wonsil, B.J., Herbein, J.H., Watkins, B.A., 1994. Dietary and ruminally derived trans-18:1 fatty acids alter bovine milk lipids. The Journal of Nutrition, 124, 556–565.

Wood, J.D., 1984. Fat deposition and the quality of fat tissue in meat animals. In J. Wiseman (Ed.), Fats in animal nutrition (pp. 407– 435). London: Butterworths.

Wood, J.D.; Richardson, R.I.; Nute, G.R.; Fisher, A.V.; Campo, M.M.; Kasapidou, E.; Sheard, P.R. and Enser, M., 2003. Effects of fatty acids on meat quality: a review. Meat Science, Vol.66, No.1, pp. 21-32.

Woodward, S.L., Waghorn, G.C. and Thomson N. A., 2006. Supplementing dairy cows with oils to improve performance and reduce methane—Does it work? Proceedigs of the New Zealand Society of Animal Production,66:176– 181.

Wright, T.C., Holub, B.J., Hill, A.R. and McBride, B.W., 2003. Effect of combinations of fish meal and feather meal on milk fatty acid content and nitrogen utilization in dairy cows. Journal of Dairy Science,86:861–869.

Wu, G., Bazer F.W., Wallaxe J. M., and Spencer T. E., 2006. Intrauterine growth retardation: implications for the animal sciences. Journal of Animal Science,84:2316-2337.

Wynder, E.L., Cohen, L.A. and Winters, B.L., 1997. The challenges ofn assessing fat intake in cancer research investigations. Journal of the American Dietetic Association, 97, S5–S8.

Youdim, K.A., Martin, A. and Joseph, J.A., 2000. Essential fatty acids and the brain: possible health implications. International Journal of Developmental Neuroscience, 18:383–99.

Zenou, A. and Miron, J., 2005. Milking performance of dairy ewes fed pellets containing soy hulls as starchy grain substitute. Small Ruminant Research 57:187-192.

Zeron, Y., Sklan, D. and Arav, A., 2002. Effect of polyunsaturated fatty acid supplementation on biophysical parameters and chilling sensitivity of ewe oocytes. Molecular Reproduction and Development, Vol.61, No.2, pp. 271-278.

Zhang, Q., Wu, W.X., Nathanielsz, P.W., Brenna, J.T., 1995. Distribution of arachidonic, eicosapentaenoic, docosahexaenoic and related fattyacids in ovine endometrial phospholipids in late-gestation and labor. Prostaglandins Leukot. Essent.

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