Review Article

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Role of dietary fats in reproductive, health, and nutritional benefits in farm animals: A review

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Abstract: Dietary fats serve a multitude of purposes in both humans and animals. They are a component of membranes and support the regulation of cellular influx and egress. They aid in the production of hormones, milk, embryonic, and foetal development, movement, and storage of energy, as well as absorption of fat-soluble vitamins. The objective of this review is to describe how dietary fats contribute to improved livestock reproductive performance. Data for this review study were acquired from recently published works in different journals. Databases were accessed using electronic data sources such as Google Scholar, PubMed, Science Direct, Research Gate, Web of Science, and the Directory of Open Access Journals. It is believed that dietary fats added to animal diets enhance animal reproduction by boosting the quantity and size of ovarian follicles and concentration of hormone progesterone plasma, declining the production of prostaglandin metabolites and increasing the lifespan of corpus luteum, which is also crucial for semen maturation, motility, and acrosomal reactions in addition to reproductive hormones. Therefore, it is important to employ dietary fats effectively to boost livestock reproduction and maximise animal output, which will achieve the relevant Sustainable Development Goals and food security.

Keywords: vitamin absorption, reproductive hormones, animal reproduction, food security

1 Introduction

An animal's capacity to reproduce depends on a variety of factors, including its genetic makeup, age, on-farm management methods, and endocrine system [1]. Furthermore, nutritional energy helps increase animal fertility for higher reproductive performance [2,3]. Fats are therefore a major source of essential fatty acids, fat-soluble vitamins, and concentrated energy twice the quantity of carbohydrates or proteins and are present in many feeds. As a result, these dietary fats are of great importance in overall animal performance [4]. Historically, the amount of fat in cattle feed has been low. This was more evident in herbivore species, which received around 5% of the energy needed for digestion [5]. High-fat rations reduce feed intake as well as overall animal production due to less nutrient absorption [6]. By supplementing with fats, feed loses some of its powderiness and the absorption of vitamins improves [7]. As a result, an animal's reproductive system is regulated by fatty acid intake [8]. Furthermore, fertility is a significant issue when feeding high-yielding animals [9]. The precise nutrients necessary must be provided for the development of oocytes and spermatozoa, ovulation, fertilisation, embryo survival, and the establishment of pregnancy [10,11]. Moreover, one of the key nutrients that creates energy required for fertility and improves animal reproduction is dietary fat [12]. It indirectly affects fertility by affecting the levels of hormones and other nutrient-sensitive metabolites needed for the success of these processes [11]. Cholesterol, for example, is produced from dietary fats and is an antecedent for the production of steroid hormones, which control the oestrus cycle, ovulation, implantation, and pregnancy maintenance [13,14]. This is typically seen when mature animals consume low-calorie feed for extended periods, affecting libido and testosterone levels negatively [15]. Concerning reproductive function, several fatty acid sources have been investigated [16]. The frequent production of dietary fats is sourced mainly from oilseeds of various edible crops [17–19]. Even though fats are important nutrients that constitute fatty acids, which improve both human and animal reproduction [20,21], evidence of the effect of fats on farm animals' reproductive performance is lacking. This review is therefore aimed at (1) summarising the sources of fats and their importance; (2) outlining the health and nutritional benefits of fats in livestock production; and (3) describing the effects of fats in animal reproduction.

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2 Source of data

The data for this review were collected from articles published between 2011 and 2023 in various journals. Electronic data sources including Google Scholar, PubMed, Science Direct, Research Gate, Web of Science, and the Directory of Open Access Journals were used to access databases. Additionally, searches for other pertinent papers were conducted using the citations found in the database articles. The keywords “dietary fats; reproductive hormones; animal reproduction; food security” were used in the search engine.

3 Description and sources of dietary fats

Dietary fats are distinguished by their varied functions in both animal and human bodies. Fats aid in controlling what goes in and out of the cells by being part of the cell membranes [22]. These compounds aid the body’s functions, and therefore move and store energy, absorb vitamins (A, B, and E) and produce varied hormones [23]. Ingestion of some of the lipids in copious quantities is toxic to both animal and human health [24]. Dietary fats are the primary source of energy in both animal and human diets and therefore aid in maximum cell activities and body energy [25]. In addition, dietary fats aid in protecting the internal organs of the animals, thus warming up their bodies [26]. Fats have varied structures which contain organically soluble chemicals. Their significant chemical structure is built from hydrocarbon rings, primarily volatile fatty acids and steroids [27]. Fats are composed primarily of saturated and unsaturated fatty acids, coupled with a glycerol backbone in their natural state [28]. The eventual structure of fats is, however, affected by factors that include temperature, behaviour, oxygen exposure, level saturation, transition metals, H_2O, undissociated salts, and some of the non-lipid structures [27,29]. Furthermore, lipids are vital ingredients of triglycerides; nevertheless, some lipid structures may tamper with the qualities of their chemical and physical nature, including energy levels for animals [27,30,31].

Fats also have sources in the form of commercial and natural fats which are made up of animal-based and plant-based fats. Commercial fats are specialised formulations manufactured with either plant or animal fats [32]. Natural fats are mostly sourced naturally from various plant materials and less from animals. Oilseeds form the major source of fats in plants through the likes of cottonseed, soybeans, sunflower, and canola seeds [33]. Cottonseed is easy to work with due to its physical characteristics and is therefore included in a fully mixed diet. It is rich in essential nutrients including crude proteins, crude fibre, and crude energy, and therefore makes a well-balanced feed, especially for dairy cattle [34]. Soybean’s raw seed is said to contain the enzyme urease and should remain ungrounded yet mixed with urea [35,36]. Moreover, this seed stands a chance to be added to a fully mixed diet or grain mixtures [37] but should not be roasted as it will have a denatured enzyme urease, trypsin inhibitor, and lipoxygenase, which lowers the degradability of proteins in the rumen [38,39]. As a result, other oilseeds can be fed to dairy cattle [40]. Because they contain more oil than cottonseed and soybeans and because their oil content is higher, it is advised to feed these oilseeds at lower levels due to their highly unsaturated nature [18]. The primary animal fat contains prominent levels of saturated fatty acids compared to oilseeds, but due to its form at room temperature, it is difficult to handle [41]. Yellow grease is a waste grease from food-producing industries’ animal and vegetable fat mixtures and is used for animal feeding [42]. This is mostly seen in dairy cattle feeding where most animal-vegetable fat blends are used [43]. This kind of fat is categorised as calcium salts and processed tallow [44]. Other feeds contain a small amount of fats including fishmeal [45]. Fats such as sterols represent a moderate amount of natural fats, and thus have a high melting point [46,47]. Cholesterol is one main component of sterols in animal fat and fish oil which are the unsaponifiable constituents available in lipids [46]. This type of fat is also present in vegetable oils but in an exceedingly small quantity [48,49]. The types of fatty acids, their importance, and their functions are all displayed in Table 1.

4 Health and nutritional benefits of dietary fats in livestock production

Since fats contribute to different components of health, there is a rising interest in characterising a fatty acid profile and other advantageous healthy minor components [50]. The relevance of fats as a source of triacylglycerols, which are necessary for the synthesis of energy, as well as other minor nutrients such as phospholipids, sterols, and polyphenols, is therefore emphasised [51]. Phospholipids have been shown in several studies to have a significant influence on a variety of illnesses, including liver ailments,

Table 1: Selected sources of dietary fats, types of fatty acids, and their importance and uses

Sources of fats	Plant/animal species	Fat/ oil (%/DM)	Types of fatty acids	Examples of fatty acids	Importance and uses of the oil	Reference
Vegetables/crops	Soybean	19.0	Unsaturated fatty acids	Linolenic acid, linoleic acid, omega-3, omega-6	The majority of uses for soyabean oil are in the kitchen. As a source of vitamins K and E and a source of heart-healthy fats, it is crucial. Overall, it protects against bone loss, improves skin health, and lowers cholesterol levels	[52,53]
	Flaxseed	35–45	Saturated, monounsaturated and polyunsaturated fatty acids	Alpha-linolenic acid, omega-3, oleic acid, palmitic acid, and stearic acid	The oil may slow the growth of cancer cells in an animal; it lowers blood pressure levels, improves the elasticity of the arteries, treats constipation and diarrhoea, improves skin smoothness and hydration and contains anti-inflammatory properties	[54,55]
	Cotton	15–20	Polyunsaturated, unsaturated, and monounsaturated fatty acids	Linoleic acid, palmitic acid, myristic acid, palmitoleic acid, omega-6, stearic acid, and linolenic acid	Cottonseed oil has a high metabolizable energy content. It can be utilised as a natural cure for some illnesses and skin disorders. The oil contains gossypol, which decreases inflammation and protects against breast cancer and lowers the chance of developing cardiovascular illnesses	[56–58]
	Kenaf	20–25	Saturated, monounsaturated, polyunsaturated	Docosanoic acid, tetracosanoic acid, hexadecenoic acid, and linolenic acid	This is a vegetable oil with a content similar to cottonseed, but the kenaf oil is edible. As a result, it can be refined into cooking oil, margarine, and mayonnaise. It is advantageous to human health and aids in the fight against oxidative stress through antioxidant activities, particularly in heat-sensitive animals	[59–61]
	Moringa	36.7–40	Monounsaturated, saturated, and polyunsaturated acids	Oleic, gadoleic, palmitoleic, palmitic, behenic, stearic, and arachidic acids	Moringa seed oil is commonly used for skin cleansing and moisturizing, as well as acne and hair moisturizing. This oil is utilised for human consumption (frying and baking), cholesterol management, and has antioxidant and anti-inflammatory properties	[62–64]
Animals and edible insects	Fishmeal, termites, stink bugs, locusts, crickets, etc.	10–15	Saturated, monounsaturated, and unsaturated fatty acids	Lauric acid, linoleic, oleic acids, docosahexaenoic acid (DHA), and eicosapentaenoic acid	Insect and fishmeal fats are a sustainable source of energy and crude proteins for poultry, fish, and other livestock animals. They stimulate immune system activity	[45,65,66]

neurological conditions, and hepatic and colon malignancies [30]. Additionally, they include immunological functionality for the bodily systems, improving physical and mental performance [67]. A high-fat diet boosts animal output while lowering methane emissions into the atmosphere [68]. Free and esterified sterols are the two distinct types of sterols. Free sterols can generate sterol ester by esterifying with fatty acids, glycosides, and ferulic acid [69]. As a result, sterol esters have unique nutritional properties including antioxidants and hypolipidemia, which may be used to increase development and hypothalamic activity [70,71]. In studies utilising sterols, phytosterols have demonstrated the ability to inhibit the development of cancer cells, preventing colon, prostate, and breast cancers [72]. Through their antibacterial and antioxidant characteristics, polyphenols can counteract the consequences of heat stress [73]. Additionally, they enable the body's system to manufacture radical scavengers, which help fight cancer and some cardiovascular disorders [74].

5 Effect of dietary fats on animal reproductive performance

It has long been understood that adding fats to an animal's diet improves its ability to produce, particularly in cattle, poultry, and pigs. Consequently, there is a close connection between fatty acids and reproduction processes [75]. Animals enjoy feed with high-fat content. Moreover, fat not only specifically stores energy, but also helps temperature regulation in the body as well as the production of hormones [76,77], specifically to meet psychological demands. Higher fat content in animal diets would therefore result in better feed conversion efficiency and quicker development, particularly in cattle, pigs, and poultry [78]. Fats improve the odour, texture, and palatability of feed, which enhances high intake by animals [79]. Dietary fats are made up of fatty acids, which are formed when fats are broken down and absorbed into the bloodstream. Omega-6 (linoleic acid) and omega-3 fatty acids (alpha-linolenic acid) are the essential ones responsible for improving reproduction in various farm animals and are naturally found in dairy, beef, and vegetable oils [80,81]. Vitamins and their concentrations, as well as cholesterol, are essential in addition to fatty acids [82]. Moreover, the inclusion of fats in a diet is thought to enhance the production of ovarian follicles, progesterone concentrations, the release of prostaglandin chemicals and the longevity of the corpus luteum [83,84]. However, excess fats can induce obesity in animals as well as human beings and therefore have an impact on reproduction where ovulatory disorders are more commonly identified as a primary initiator of infertility, especially in women [85]. Dairy cow fat improves the reproductive efficiency non-dependent on any influence of the cow's energy balance. As a result, there is greater interest in providing fats from natural sources which are high in linoleic fatty acid mainly through calcium salts [86].

Fats contribute largely to the construction and function of animal cells. The membrane of mammalian spermatozoa is made up of fatty acids, which consist of about 30–50% polyunsaturated fatty acids [87,88]. Additionally, polyunsaturated fatty acids are crucial and responsible for semen maturation, motility, and acrosomal reactions; this is observed mainly in mammalian testes during puberty. These are integrated into developing germ cells by lysophosphatidic acid acyltransferase 3 [12]. The effectiveness of fat usage on the reproductive performance of various animal species is shown in Table 2, along with various study findings and conclusions.

5.1 Effect of dietary fats on the development of reproductive organs, fertility, and hormones

Typically, reproductive organs and hormones signify the animal's fertility and ability to reproduce [89]. Nutrition plays a critical role in this regard through the development of reproductive organs, the activation of reproductive hormones, and overall animal fertility [90]. Dietary fats have been recognised as necessary for both male and female reproductive organ growth and maintenance [91]. These chemicals are thought to aid in the formation and functioning of the reproductive organs, which include the ovaries, testes, uterus, and mammary glands. Limiting an animal's dietary fat intake may result in decreased organ development and diminished reproductive function [92,93]. Reduced fertility and pregnancy rates in farm animals are indicators of poor reproductive performance [94]. Some fatty acids, which include omega-3 and omega-6, are linked to increased fertility and reproductive efficiency. They regulate reproductive hormones as well as the integrity of reproductive cells (sperm and oocytes) [95]. It has been reported by Zachut et al. [96] that the inclusion of dietary fats in animal diets influences the size of the pre-ovulatory follicle positively and therefore increases its ability to produce oestradiol, mainly by introducing higher concentrations of cholesterol in follicular fluid and plasma. This further influences the size of follicles which

Table 2: Effect of fats on the reproduction performance of various animal species

Animal species	Sex	Findings/conclusions	References
Rats	Females	Female rats exposed to a high-fat diet (22% fat) for 4 weeks had an anovulation with a decreased fertility rate	[97]
		Female rats on a high-fat diet (both diet-induced obese and diet-resistant rats) for 6 weeks had an altered oestrus cycle, which was more prominent in diet-induced obese rats, but with low oestradiol levels	[98]
Sheep	Ewes	Ewes had abortions when linoleic acid was added to their food during the late stages of pregnancy	[99]
		The results observed in the study demonstrated that nuclear maturation and cumulus cell expansion were adversely affected by the inclusion of 200 μM of omega-3 α-linolenic acid (ALA) to the *in vitro* maturation medium of prepubertal sheep oocytes. At ALA doses of 50 and 100 μM, this detrimental effect was not present. Oocytes developed with ALA produced better male pronuclei and better-quality blastocysts but showed no difference in cleavage and blastocyst rates	[100]
	Rams	Dietary fish oil supplementation in rams' diet successfully changed the plasma *n*-6:*n*-3 ratio, although it had only a small impact on the sperm fatty acid composition. Supplementation did not affect the quality of the liquid-stored semen, even though it raised semen concentration	[101]
Rabbits	Bucks	The findings suggested that the rabbits are an appropriate model for the study of the spermatogenic process since dietary inclusion of *n*-3 polyunsaturated fatty acids led to an enrichment of DHA and eicosapentaenoic in rabbit sperm and testes	[25]
		Results showed improved serum testosterone, follicle-stimulating hormone (FSH), luteinising hormone in buck administered with3 ml of different sources of refined vegetable oil/buck/day for 7 weeks; also, the results showed higher prostaglandin (PGF2α) in bucks including the ones under control treatment	[102]
	Does	The major conclusions were that the inclusion of dietary *n*-3 fatty acids, either as a precursor or derivative, impacted rabbit does' fatty acid metabolism and enhanced their reproductive capacity	[103]
		Supplementing 35% of total fatty acids as polyunsaturated fatty acids *n*-3 enhanced progesterone levels of the rabbit does to a larger extent. Furthermore, these does with boosted diets had greater kid birth weights	[104]
Humans	Males	DHA supplementation in asthenozoospermic males raises DHA levels in serum and perhaps seminal plasma but has minimal effect on sperm DHA levels and no impact on sperm motility	[105]
Cattle	Bulls	Adding flaxseed oil (FSO) to the diet had a substantial good impact on the *in vitro* semen quality profiles, antioxidant level, oxidative stress profile, and percentage of apoptotic sperm in *Bos frontalis* (Mithun). FSO supplementation also reduced blood cortisol levels while increasing FSH, luteinizing hormone, testosterone, and thyroxin concentrations	[106]
		According to the study, *n*-3 long-chain polyunsaturated fatty acids from fish oil was successfully transferred to bulls' sperm, which could improve both fresh and post-thawed semen quality	[107]
	Cows	Algae is one of the sources of fatty acids, and studies have shown that supplementing with 10 g of DHA per dairy cow per day from an algae product improves reproductive performance by increasing the proportion of oestrus cyclicity and pregnancy	[108]
		Results showed that cows fed fat-based diets exhibited little effects on follicle development of cows. Furthermore, cows fed *n*-3 fatty acids had lower plasma progesterone and smaller corpora lutea than those fed control/conjugated linoleic acid (CLA)	[109]
Birds	Roosters	Altering the levels of fatty acids in the sperm cells of old roosters by the addition of FSO and vitamin E increased the quality of sperm and overall production performance in aged broiler breeder roosters	[95]
	Layers	According to the findings of a study looking at how dietary lipids affected layer fertility and hatchability, fish oil treatment resulted in the highest hatchability (76%) and highest egg fertility (84.6%). Additionally, the findings of the sunflower oil treatment showed the lowest hatchability (58.2%) and highest egg fertility (89.6%). This indicates that to reduce the number of embryos that die during incubation, breeder diets must take into account the dietary fatty acid content, particularly the levels of *n*-3 and *n*-6, in terms of concentration and ratio	[110]
Pigs	Sow	A study that looked at the relationship between back fat and reproductive success in distinct pig herds (A, B, and C) discovered that sows that had a greater number of stillborn piglets had less backfat density after the pregnancy period. This also shows that back fats can be used to track and enhance the production and capability of high-producing pig herds	[111]
		The meta-analysis results showed the supplementation of fats in a sow's diet in the late pregnancy and lactation intervals may be of great benefit to sow reproductive effectiveness	[112]

may have a pronounced effect on and be beneficial for the quality of oocytes and the function of the corpus luteum [113]. The introduction of higher cholesterol concentrations is therefore seen to increase the production of the hormone progesterone [114,115].

Evidence suggests that feed containing high quantities of fish oil (*n*-3 polyunsaturated fatty acid) has strong potential to reduce the development of endometrial cyclooxygenase-2, an important enzyme involved in prostaglandin manufacturing [116]. Fish oil has been shown to suppress progesterone synthesis in luteal cells cultivated *in vitro*. This was also validated in an *in vivo* investigation in which animals were fed a linseed-rich diet, which resulted in considerably lower plasma progesterone concentrations [117]. Furthermore, diets high in *n*-6 fatty acids boost prostaglandin (PGF2-) synthesis, which enhances an animal's uterine health [118]. As a result, it is critical to determine the precise sort of dietary fat supplement to maximise animal reproductive performance.

5.2 Effect of dietary fats on embryonic and foetal development and milk production

Dietary fats offer the necessary fatty acids required for effective cell divisions, organ development, and placental function, and therefore contribute considerably to embryo and foetal development and growth [11]. In recent times, it has been shown that supplementation of rumen-protected fats in dairy feed influences the energy intake during the early post-partum stage and therefore enhances fertility [119]. Moreover, the production of a high concentration of cholesterol in the follicular fluid not only influences the increase in follicular size and high production of progesterone, but it also supports the competent development of an embryo at an early growth stage [114,115]. As a result, nutrition appears to play a critical role, as the nutritional requirements during the early post-partum period, the restart of ovarian activity, and follicular growth differ from the maximal nutritional needs necessary for pregnancy and early embryo growth [120]. Several studies have shown that the deliberate addition of dietary fat to animal diets throughout the breeding process can forcefully reduce insulin levels while not overstimulating oocyte and zygote development [121]. Aside from introducing insignificant amounts of saturated or monounsaturated fatty acids in a diet to stimulate energy intake, it is becoming more customary for polyunsaturated fatty acids to be supplemented in animal feed to specifically enhance the levels of milk omega-3 (*n*-3) fatty acids. This can successfully disguise the release of prostaglandin through the endometrium, increasing the corpus luteum longevity and considerably benefiting embryo survival [115,122].

The incorporation of sunflower and linseed oils, which contain linoleic and linolenic acids, was shown to have a minor effect on *in vitro* maturation, subsequent oocyte quality, and embryo development [123]. Also, feed highly concentrated within *n*-3/*n*-6 can impact follicle linolenic acid and oestradiol concentrations and improve embryo cleavage rate [96]. CLA, on the other hand, slows embryo development by suppressing the production of stearoyl-CoA desaturase-1, the enzyme that transforms stearic acid into oleic acid [124]. Furthermore, additional dietary fat supplementation in animal diet influences milk production, which is most noticeable during lactation periods [125,126]. This is corroborated by a study using pigs (sows), which found that adding dietary lipids to a sow's diet during late gestation and lactation improved milk production and colostrum and milk fat levels, increasing piglet survival chances [127,128]. However, research on the effects of dietary lipids on foetal development is limited. More experiments in this area are encouraged.

6 Conclusion

Since livestock fertility is the key component of animal production, a variety of factors are crucial in this respect. One is the supplementation of dietary fats containing various fatty acids, which have a direct impact on an animal's ability to reproduce. Fatty acids might therefore be employed in the control of reproductive processes. Even while seeds from various fat sources such as sunflower, safflower, cottonseed, rice bran, soybeans, and fishmeal have been employed in the past and recent times as sources of proteins, they are sometimes disregarded as important sources of fatty acid supplements, which are obtained mostly through the oil generated. It is critical to understand that the kind and quality of dietary lipids can have a substantial impact on animal reproductive performance. For optimal results, a balanced and adequate ratio of different types of fatty acids is required. Specific requirements may differ depending on the species, breed, reproductive cycle stage, and other factors. It is necessary to consult with a veterinarian or animal nutritionist to establish an appropriate diet that matches the specific demands of farm animals for optimal reproductive function. However, knowledge of the function of dietary fatty acids in some animals is not sufficient. Additional studies are needed to determine the function and significance of dietary fats in livestock reproduction as well as their effects on health and nutrition.

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