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Effects of Nutritive and Non-nutritive Feed Supplements on Feed Utilization, Growth and Reproductive Performances in Mammals

A.A. Mohammed[1], I. AlGherair[1], S. Al-Suwaiegh[1],
S. Al-Khamis[1], F. Alessa[2], A. Al-Madni[3], A. Al-Ghamdi[4]

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ABSTRACT

Background: The feed supplements to ruminant animals have gained great attention of nutritionists to improve feed utilization, growth and reproductive performances during the past decades.

Methods: The animals feed supplements were classified into nutrient and non-nutrient feed additives. They include substances, micro-organisms or preparations. The feed supplements and their purified constituents were fed to give animals' nutritional requirements and to improve the quality of feed and animal products.

Result: Changes in animals' production, reproduction and therapeutic performances have been confirmed over feeding supplements. Numerous purified components include β-carotene, antioxidant and others. The supplements change feed intake, nutrient digestibility and rumen fermentation products. Such enhancements in feed utilization and growth performances resulted in improvements of oocytes, embryos and feti quality. Furthermore, blood corpuscles and plasma parameters, immunity and therapeutic performances were altered due to feeding supplements. Hence, the current review article was designed to collect, consolidate and discuss the effects of feed supplements on productive, reproductive and therapeutic performances on mammalian species.

Key words: Embryos, Feed utilization, Growth, Immunity, Oocytes, Reproduction.

INTRODUCTION

Significant strides of development has made in nutritive and non-nutritive feed supplements over the past couple of decades for the purposes of increasing productive and reproductive performances or treatment of dysfunctions (Kholif *et al.*, 2016, 2019; Ali *et al.*, 2021; Al-Mufarji and Mohammed, 2022; Al-Mufarji *et al.*, 2022 a,b,c; Mohammed *et al.*, 2020, 2021; Mohammed, 2022; Al Suwaiegh, 2023). A feed supplement or additive is a single substance or mixture of substances used in small quantities to improve the quality of the feed. It is classified into nutrient and non-nutrient supplement and it is given at less than one percent level of the compounded feeds (Mohammed and Attaai *et al.*, 2011; Senosy *et al.*, 2017, 2018; Halmemies-Beauchet-Filleau *et al.*, 2018; Mohammed and Al-Suwaiegh, 2023). It is given to ruminant and non-ruminant animals for different purposes including changes in feed intake and rumen micro-organisms, nutrient digestibility and body weight gain (Ali *et al.*, 2021; Al-Mufarji *et al.*, 2022 a,b,c), ovarian follicle development and the resulting oocyte and embryo quality (Mohammed, 2018; Mohammed and Farghaly *et al.*, 2018) in addition to treatment or alleviate dysfunctions (Mohammed *et al.*, 2012; Mohammed, 2019; Mohammed and Al-Hozab, 2020; Ali *et al.*, 2021; Al Masruri *et al.*, 2022c). The beneficial components of supplements includes proteins, polysaccharides, lipids, pigments, vitamins, minerals and other active substances (Fig 1). Therefore, this review was designed to collect and consolidate the current knowledge of feed supplements on productive and reproductive performances in addition to therapeutic purposes of ruminant animals.

[1]Department of Animal and Fish Production, College of Agriculture and Food Sciences, King Faisal University, P.O. Box 402, Al-Ahsa 31982, Kingdom of Saudi Arabia.
[2]Department of Food Science and Nutrition, College of Agriculture and Food Sciences, King Faisal University, P.O. Box 402, Al-Ahsa 31982, Kingdom of Saudi Arabia.
[3]Ministry of Environment, Water and Agriculture, Kingdom of Saudi Arabia.
[4]Abdulrahman Bin Faisal University, Kingdom of Saudi Arabia.

Corresponding Author: A.A. Mohammed, Department of Animal and Fish Production, College of Agriculture and Food Sciences, King Faisal University, P.O. Box 402, Al-Ahsa 31982, Kingdom of Saudi Arabia. Email: aamohammed@kfu.edu.sa

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MATERIALS AND METHODS

The current study was carried out according to the procedure approved by Deanship of Scientific Research, King Faisal University, Saudi Arabi from May to November 2023.

RESULTS AND DISCUSSION

Probiotic effects

Probiotics are preparations made from live yeast, bacteria and fungi. The commonly probiotic bacterial strains preparations are included Leuconostoc, Lactobacillus, Bifidobacterium, Pediococcus and Streptococcus whereas the yeast stains are included Saccharomyces and the fungi strains are included Aspergillus. Probiotics beneficially affect the rumen and intestinal microbial balances of host animals by improving their feed intake, nutrient digestibility, growth performances and the resulting milk production and reproductive performances (Kassab *et al.*, 2017; Al Suwaiegh *et al.*, 2023). The inclusion of probiotics in animals' diets is increasing because it is an effective approach to improve productivity and health (Kassab and Mohammed, 2013).

Bacillus spp. are spore-forming bacteria resistant to digestive enzymes (Carlin, 2011). They have beneficial effects on ruminant productivity (Al Suwaiegh, 2023). *Bacillus subtilis* has been recognized as an effective probiotic in the livestock production. The earlier studies found enhancement of feed utilization and growth performance of calves (Al-Suwaiegh, 2023) through rumen development in addition to improvement of milk production and in dairy cattle (Sun *et al.*, 2013). *B. subtilis* has been suggested to enhance an anaerobic condition in the gastrointestinal tract due to rapid oxygen utilization resulting from fermentation (Hoa *et al.,* 2000).

Lactic acid bacteria and bifidobacteria, are used frequently as probiotics. These health beneficial bacteria could compete with pathogen and modify the digestive system microbiota and they exhibit immunomodulatory and anti-cancer activities (Das *et al.*, 2022). They had been concluded that probiotics improve the epithelial barrier function (Das *et al.*, 2022) (Fig 2). In addition, antioxidant activity of Lactobacillus and Pediococcus in response to lactic acid stress was found (Zhang *et al.*, 2021).

Yeast and yeast derivatives in feed additives

Numerous yeasts and yeast products are commercially produced around the world and they are used in animal feeds (Kassab and Mohammed, 2013; Caruso *et al.*, 2022; Baker *et al.*, 2022). Numerous studies has been carried out to investigate the benefits of yeasts and yeast products on growth performance and health of different animal species (Shurson, 2018; Caruso *et al.*, 2022; Das *et al.*, 2022). Active dry yeasts were used alone or with beneficial bacteria (Shurson, 2018). Nutritional yeasts are characterized by their contents of high protein and amino acid, energy and micronutrients (bioavailable selenium) in addition to nutraceutical compounds such as β-glucans and mannan oligosaccharides (de Ondarza, 2022). The diverse available yeast products make difficulties for nutritionists to differentiate the optimal feeding applications due to differences in composition of probiotics and nutraceutical compounds with different modes of action. Therefore, because of increasing interests of using yeast products in animal feeds, accurate analytical methods of yeast content and their biologically active components to contribute their roles in growth performance, health and proposed mechanisms of action are required.

Yeast supplementation to ruminant animals was found to change feed intake and digestibility, ruminal micro-organisms, profiles of volatile fatty acids, milk production and health (Kassab and Mohammed, 2013). Yeast supplementation to ruminant animals was found to stimulate lactate-utilizing and cellulolytic bacteria. It has been found that yeast supplementation modulates ruminal pH, particularly when given in combination with high concentrate diet due to it is growth stimulating of both lactate-utilizing bacteria and protozoa (Baker *et al.*, 2022).

β-Carotene

β-Carotene, a pro-vitamin A, acts as an antioxidant to prevent oxidative damage through scavenging free radicals. Aragona *et al.* (2021) investigated the effects of β-carotene supplementation to prepartum Holstein cows on colostrum quality and calf performance after parturition. The study

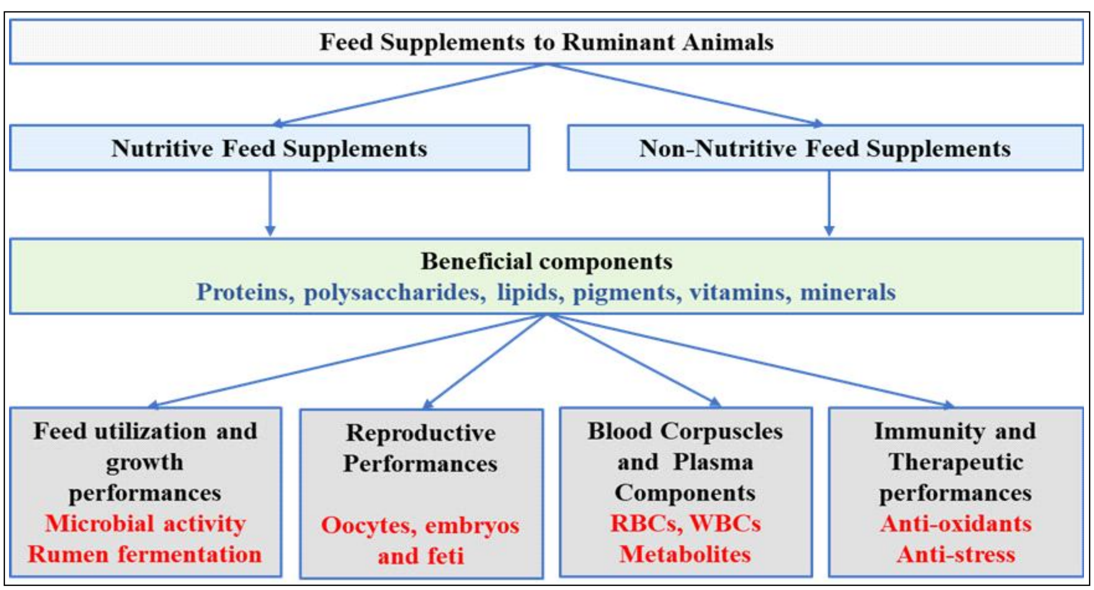

Fig 1: Effects of nutritive and non-nutritive feed supplements to ruminant animals.

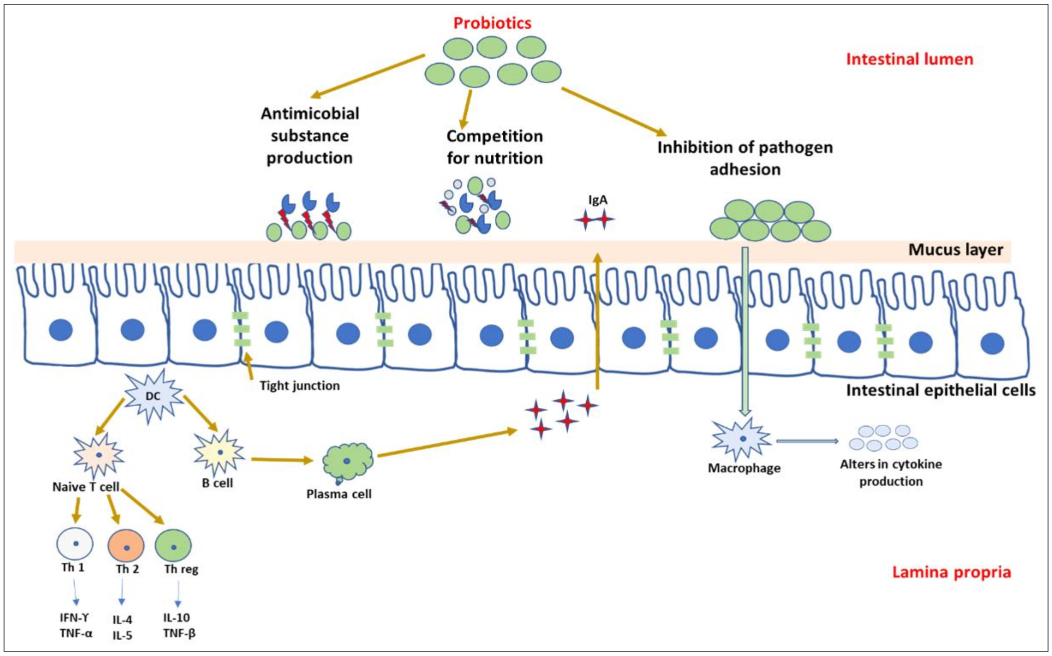

Fig 2: Improvement of epithelial barrier function by probiotics (modified from Das *et al.,* 2022).

indicated increased of fat and protein concentrations in colostrum upon β-carotene supplementation in addition to improved feed efficiency in calves. On the other hand, supplementing β-carotene negatively affects apparent efficiency of IgG absorption to cows in the prepartum period. Hye *et al.*, (2020) explored two intramuscular injection of β-carotene postpartum on fertility parameters. They found that two treatments with Carofertin postpartum increased β-carotene concentration in blood but had no effect on the fertility parameters.

Green algae (sources of β-carotene) are variable in size and shape and include thousands species; unicellular and colonial flagellates. Microalgae chlorella was supplemented to support oocyte and embryo production in goats (Silva *et al.*, 2023). The microalgae Chlorella did not enhance the quality of oocytes whereas it improved the quality of embryos and stimulated their mitochondrial function. Our work on Donallela saliena (Senosy *et al.*, 2017; Mohammed *et al.*, 2018; Ali *et al.*, 2021) resulted in improvement in reproductive hormones values, oocytes and embryo development and quality.

Ruminant animals are experienced oxidative stress during transitional period when it is difficult to meet energy demands. This occurs when free radical production exceeds antioxidant production (Goff and Horst, 1997), leading to production of reactive oxygen species (ROS). The ROS are oxygen-containing molecules created during metabolic processes that maintain homeostasis *via* lipid peroxidation, cell signaling, host defense and apoptosis. Within the body, the balance of ROS is a perpetual process that is affected during times of stress (Albera and Kankofer, 2010). Therefore, the β-carotene as an antioxidant is beneficial for such oxidative stress circumstances.

Protein supplementation

Non protein nitrogen (NPN) can be utilized efficiently by ruminant animals to microbial protein (Miller, 1979). The biological impacts of various protein sources on feed utilization, milk production and composition and reproduction performance of ruminant species were investigated in several species. Ruminant animals feed on poor quality roughages and crop residues in most of developing countries, which are deficient in essential nutrients. Protein deficiency is the major constraint is such feeds (Leng, 1990). Urea and nitrate supplementation to ruminant species were investigated in several studies (Ziyadah *et al.,* 2010; Mohammed *et al.,* 2012; Wang *et al.*, 2023) as dietary protein supply at lower concentrations (1.0 and 1.5%).

Supplementation of dietary urea was reported to elevate in blood urea nitrogen and decrease glucose values concentrations (Ziyadah *et al.*, 2010), resulting in negative effects on ovarian follicle growth and development, oocyte quality and progesterone values (Rhoads *et al.*, 2006; Mohammed and Attaai, 2011). In addition, nitrate supplementation resulted in reduction in dry matter intake and methane production in dairy cattle (Wang *et al.*, 2023).

Lipids supplementation

Ten per cent of discovered essential oils have economic and commercial relevance (Nehme *et al.,* 2021). When administered to animals, they may induce an effect alone, or have synergistic, additive or antagonistic effects (Braun *et al.*, 2019; Elcoso *et al.*, 2019). The effects of essential oils on ruminant species were investigated. Plants essential oils can give livestock species biological impacts. Several essential oils were investigated for improvement animal performance, rumen functions, milk production in addition to promoting animal health. Several commercial products were investigated to promote animal production and health (Wells, 2023). Essential oils were used as alternatives to antibiotics to modify ruminal fermentation, enhance feed utilization and production of ruminant animals (Al-Suwaiegh *et al*., 2020).

Many studies were explored essential oils as nutraceutical agent to replace conventional antimicrobial agents in ruminant species (Funston and Summers, 2013) due to their antibacterial, antifungal and antiviral properties (Kasaian *et al.,* 2016). Essential oils were investigated *in vivo* and *in vitro* as potential therapeutic agents against mastitis due to their ability to penetrate the lipid bilayer of the bacterial cell membrane (Tavares *et al*., 2020).

Mammalian species can synthesize all of the fatty acids with the exception of of omega-3 and omega-6 families, which should be supplied in the diets. The problems with supplementation of essential fatty acids (FAs) to ruminant animals are occurrence of lipolysis and bio-hydrogenation of FAs in the rumen. Very little unsaturated FAs are available for absorption and the toxic effect of unsaturated FAs to rumen microbes is indicated (Maia *et al*., 2007). The ruminal bio-hydrogenation resulted in 70-90% saturation of dietary unsaturated FAs (Chilliard, 1993). Therefore, pathway of rumen bio-hydrogenation requires fat manipulation to ensure reaching dietary unsaturated FAs to small intestine in the form of conjugated linoleic acid (CLA). This can be achieved through the ingredients of feed (Alshaheen, 2016; Abdel-Raheem *et al*., 2021), shifting the ability of rumen bypass (Khorasani *et al*., 1990) and changing the environment of rumen (Latham *et al.,* 1972).

Milk production was doubled per cow in the last 40 years due to improved systems of nutrition, genetic progression and dairy management (CIWF, 2021). Several studies have reported inconclusive and inconsistent findings of lipid supplementation to dairy cattle (Hristov *et al*., 2013; Tekippe *et al*., 2013; Hashemzadeh-Cigari *et al*., 2014) due to differences in experimental conditions, the supplemented doses and sources, age of animals. In addition to changes of milk yield, essential oils may play a role to enhance the transport of Ca^{2+}, which can aid in the prevention of hypocalcemia (Nilius and Szallasi, 2014).

There are different factors modified milk production and composition (Kholif *et al*., 2016, 2019; Hu *et al.,* 2019; Al Mufarji *et al*., 2022a,b). Feeding strategies can be used to modify milk production and composition as lipid supplementation (Hifzulrahman *et al.,* 2019; Wang *et al.,* 2019). Rumen-protected fats of different sources were utilized to improve the physiological responses, milk yield and composition in heat-stressed animals (Liu *et al.,* 2008; Al Mufarji *et al*., 2022a). Protecting the fat from ruminal biohydrogenation determines the efficiency of FAs transferred into milk and the percentage of n-3 FA improvement in milk (Alshaheen, 2016). Several studies were previously evaluated the effects of fat supplementation on milk production and composition (Bernal *et al*., 2010; Mohammed and Al-Suwaiegh, 2016). However, caution is taken of dietary fat supplementation because of the significant decreases of feed intake (Andersen *et al*., 2008). In addition, saturated free fatty acids (FFAs) seemed to make a state of insulin resistance, increase the amount of glucose for synthesis of lactose and consequently for milk production (Pires *et al*., 2007). Supplementing 200 g/d of fish oil resulted in a 26% reduction in milk fat yield compared to 200 g/d of olive oil (Mattos *et al.,* 2004). Therefore, the objective or purpose is to supply essential fatty acids without compromising rumen production.

Minerals supplementation

The major and trace minerals are important for body function resulting in optimal production, reproduction and immunity as calcium, magnesium, phosphorus, copper, iodine and selenium. Phosphorus (P) is the most important mineral in the body played multiple roles in body functions. Phosphorus supplementation to ruminant animals has received restored interest due to its potential effect on growth, development and reproduction in mammalian species (Kumar, 2003). Earlier studies studied the effects of phosphorus supplementation on reproductive performance in cattle and ewes (Phiri *et al*., 2007; Senosy *et al*., 2017). They found that animals supplemented with phosphorus had significantly shorter interval from calving to oestrous resumption compared to non-supplemented ones. Deficiency of phosphorus caused abnormalities in reproductive performances including ovarian sub-function and low conception rate (Call *et al.,* 1986; Read *et al.,* 1986). In addition, supplementation of organic phosphorus improved feed utilization, hematological and biochemical profiles in addition to reproductive performances of anestrous ewes (Senosy *et al*., 2017).

Phosphorus is a key function for the rumen micro-organism and body cells (Kumar, 2003). Body weight was higher due to organic P supplementation (Mosaad and Derar, 2009; Senosy *et al*., 2017). Plasma proteins was higher upon phosphorus supplementation as a result of increased nitrogen retained (Prados *et al*., 2017) indicating normal liver function, which confirmed through AST and ALT liver enzymes in normal values. In addition, phosphorus supplementation resulted in the decrease in creatinine and urea nitrogen reflecting a tendency of improved nitrogen feed utilization. Furthermore, the values of red and white blood cells were higher due to P supplementation indicating improved nutritional and metabolic status. Furthermore, anestrus ewes restored reproductive performance upon phosphorus administration (Senosy *et al*., 2017).

CONCLUSION

The feed supplements change rumen micro-organism, nutrient digestibility, body weight gain, blood and plasma profiles. Such improvements over feed supplement lead to enhancement in ovarian follicle structures and the resulting oocyte, embryos and newborns in addition to alleviation of dysfunctions. The continuous progress in nutritive and non-nutritive feed supplements or additives is necessitated for both animals and human as well. Therefore, the future prospective studies to find beneficial new feed additives is an emerging approach for improving productive and reproductive performances.

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Conflict of interest

There is no conflict of interest for authors to declare.

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