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REVEIW ARTICLE

Impact of Climatic, Nutritional, and Management Factors on Ruminant Reproductive Performance

Saif Ullah[1], Abdul Quddus[1&2], Abdul Baseer[1&3], Barishna Tareen[1], Abdul Ghafar[1]

1. Faculty of Veterinary and Animal Sciences, Lasbela Univeristy of Agriculture Water and Marine Sciences, Uthal 90150, Balochistan, Pakistan.
2. College of Animal Science and Technology, Nanjing Agricultural University, Nanjing 210095, China.
3. College of Animal Science and Technology, Northwest A&F University,Yangling,Shaanxi,China,712100.

Abstract

Reproductive performance in ruminants plays an important role in the sustainability of livestock industry. In addition, various climatic stresses, nutrient inadequacies, and poor management practices hinder reproductive performance. This review highlights the influences of climatic, nutritional, and management aspects on reproductive performance in ruminants. Firstly, climatic stress in terms of heat stress exerts adverse effects on reproduction by causing endocrine malfunction, estrus non-expression, failure of follicle maturation, deterioration of oocyte quality, and decline in semen characteristics of male ruminants. Secondly, various nutritional aspects, such as energy deficiency, inadequate protein intake, and insufficient minerals and antioxidants impact reproductive performance through modifications of physiological and hormonal processes. Lastly, efficient reproductive management practices, such as environmental manipulation, proper nutrition, reproductive technologies, and conservation of heat-resistant breeds are very crucial in order to reduce reproductive loss in ruminants. It is concluded that appropriate reproductive management through climate adaptation, precise nutrition, improved herd management, and genetic selection plays a major role in the preservation of reproductive performance.

Keywords: Reproductive performance, Climate change, Management, Heat stress, Nutrition, & Ruminants.

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***Corresponding author: Saif Ullah**

1. Introduction

The ruminant livestock serves as an important source of milk, meat, fiber, and financial benefits to millions of individuals around the world. Reproductive success of the ruminants is a determinant factor responsible for growth and development of herd, productivity, genetic improvement, and overall farm profitability. Reproduction success involves several biological processes regulated by interactions of endocrine, metabolic, genetic, environmental, and managemental factors. Disruption in these interactions can have adverse effects on fertility and reproduction.

Climate change has become a serious threat to livestock production systems. Increased temperatures, changes in rainfall distribution, droughts, and extreme climatic conditions have become the driving force of pressure on livestock production. The ruminants are faced with a double problem in that they serve not only as producers of greenhouse gases but also among the production systems that are highly prone to climatic impacts (1,2). It is estimated that by 2050, there will be an increase in demand of 70% for both meat and milk globally, despite the climatic challenges facing livestock production systems (1,3).

Amongst all physiological systems in the body, reproduction system is highly susceptible to stress from environmental elements. Environmental stress such as climatic stress, nutritional stress, and management stresses can affect reproductive performance at several levels. These can cause low conception rate, failed fertilization, embryo mortality, increased postpartum anestrus and longer calving interval (2,3,4). Heat stress, especially, is known to be one of the factors that negatively affect reproductive performance in male and female ruminants (13). Poor nutrition and improper management may also contribute to the adverse effect of reproduction because they can negatively influence hormonal regulations and metabolic performance.

Environmental factors, especially climatic factors, also indirectly influence reproductive performance. Inability to meet the increased energy requirements due to increased metabolic rates under heat stress, along with reduced quality of forage, will negatively affect the energy status of the body and reproductive performance (2,11). It is therefore, important to understand the interaction between these factors for the development of strategies to ensure reproductive performance and productivity of animals. Therefore, the purpose of this review is to investigate how climate, nutrition, and management factors affect the reproductive performance of ruminants.

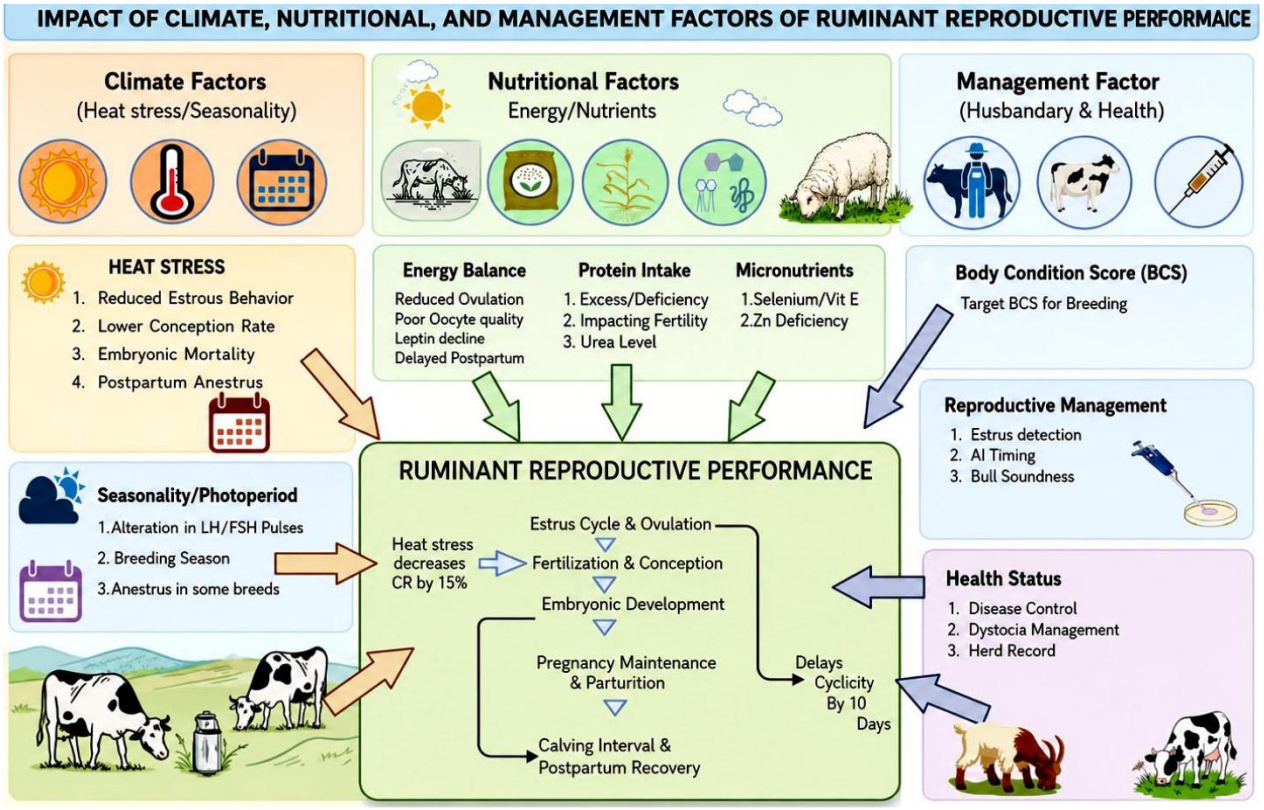

Figure 1. Diagram showing the main climate, nutrition, and management factors that impact reproductive efficiency of ruminants. Climate conditions, seasonality, energy, protein and mineral metabolism, body condition score, reproductive management, and herd health affect estrus cycle,

ovulation, fertilization, embryo development, gestation, and post-partum recovery and contribute to reproductive success. **Abbreviations:** BCS, Body Condition Score; AI, Artificial Insemination; LH, Luteinizing Hormone; FSH, Follicle-Stimulating Hormone; CR, Conception Rate.

2. Review of Literature

2.1. Climatic Factors and Reproductive Efficiency

Environmental factors greatly affect the ability of ruminants to reproduce. Heat stress has been found to be one of the most adverse climatic effects with serious implications for the reproductive capacity and efficiency of animals. THI can be used to assess the level of thermal stress experienced by livestock and associated impacts on reproductive success (3,5,6). In response to the elevation of temperatures above thermoneutral levels, changes in metabolism and physiology occur that negatively affect the reproductive processes.

2.1.1. Effects on Female Reproduction

Heat stress leads to impairment in the HPG axis function, thus decreasing the secretion of two key hormones involved in follicular growth and ovulation – GnRH and LH (5,7). The increase in body temperature lowers the intensity and duration of estrus expression and contributes to problems with heat detection and the prevalence of silent estrus cases (6,7).

Additionally, heat stress negatively impacts the process of ovulation due to impaired follicle development and low quality of the oocytes released from them (13). Hyperthermia affects the hormonal system of the organism, compromising the developmental ability of the oocytes. Hyperthermia of the uterus also limits uterine perfusion and raises its temperature, thus negatively impacting the chances of fertilization and embryogenesis (2,3,5,8,13).

2.1.2. Effect on Male Reproductive Functions

Heat stress can also have adverse effects on male reproduction. In order to be functional, the process of spermatogenesis requires temperatures below body temperature. Any alterations in this gradient affect spermatogenesis, increase germ cell death, and decrease semen quality (2,3,9,10, 14).

The effect of heat stress on sperm quantity, decreased motility, increased morphological defects, and decreased libido has been widely reported in heat-stressed bulls and rams (2,9,10). Of particular importance is the delayed impact of heat stress on spermatogenesis because of the long period needed for its completion. Poor semen quality can persist for up to four to six weeks following the end of heat stress, an event described as the "lag effect" (2,3,10).

2.2. Nutritional Factors and Metabolic Control

Nutrition is one of the key factors influencing the efficacy of reproduction in ruminants. Heat stress has indirect influences on reproduction through the reduction in nutritional resources caused by higher lignification and protein content and lower digestibility (2,11).

2.2.1. Negative Energy Balance

Negative Energy Balance (NEB) is characterized by the scenario where the energy expenditure of the body outweighs the energy taken through diet; this condition is common in high-yielding dairy cows during early lactation (4). During NEB, there is a reduction in the levels of the metabolic hormones – insulin, insulin-like growth factor-1 (IGF-1), and leptin (4,11,12).

Insulin, IGF-1, and leptin are metabolic hormones that act as messengers indicating the link between nutrition and reproduction. Low levels of leptin lead to a low activity of kisspeptin neurons responsible for regulating the release of gonadotropin-releasing hormone (GnRH) and the pre-ovulatory luteinizing hormone (LH) surge (4). As a result, the ovaries fail to mature properly causing irregular estrous cycles and hence reducing conception.

2.2.2. Micronutrients and Antioxidants

Minerals and vitamins must be present in appropriate amounts to ensure reproductive health. Selenium, copper, and zinc act as cofactors for enzymes involved in protecting the reproductive tissues from oxidation. Lack of these micronutrients increases oxidative stress causing retention of the placenta, infertility, embryo death, and weakened immune responses (4,11).

The antioxidants such as vitamins E and C protect the reproductive organs from free radicals thus preventing cellular membrane damage caused by lipid peroxidation (4,5,11).

2.2.3. Proteins and Fatty Acids

Nutrition with regard to proteins is very essential for enhancing reproduction. Excess supply of rumen degradable proteins will lead to high levels of Blood Urea Nitrogen (BUN), which will in turn lower the uterine pH to unfavorable values for the survival of embryos (4,11). High BUN has been associated with low conception rates and higher rates of embryonic losses.

On the other hand, dietary supplementation of poly unsaturated fatty acids especially the omega-3 fatty acids could be employed to enhance fertility through regulation of reproductive hormones and prevention of prostaglandin F2a production. Lower prostaglandin levels favor maintenance of corpus luteum and therefore facilitate pregnancy establishment (4,11).

2.3. Management and Reproductive Efficiency

Effective management is very vital since it is capable of making the ruminants to withstand both nutritional and environmental challenges. It involves proper shelter provision, use of advanced reproductive technologies and health care (2,3,5,6).

2.3.1. Environmental Manipulation

Installation of shade houses, cooling facilities, fans and sprinklers can greatly reduce the heat load on the animals. Environmental manipulation results in lowering of body temperature of animals thus increasing their feed intake and improving their reproductive performance. It has been proven that animals using cooling techniques tend to exhibit better fertility and conception compared to those in natural environmental conditions (2,3,5).

2.3.2. Advancements in Reproductive Techniques

Current reproductive technologies, which include Timed Artificial Insemination (TAI) and Embryo Transfer (ET), are very useful when aiming at improving animal fertility. With the use of these technologies, there is less reliance on estrus identification and heat-tolerant stages are avoided; thus enhancing conception rate (2,5,6).

2.3.3. Nutrition Management

Proper nutrition practices can aid in alleviating some of the negative impacts caused by heat stress. For instance, feeding high energy diets, ensuring proper nutrition balance, addition of antioxidants and changing times of food administration to cooler hours can assist in minimizing metabolic heat production (2,11).

2.4. Resilience through Indigenious Genetics

Preservation and use of indigenious cattle breeds are essential steps towards adaptation. Cattle from local breeds have evolved to adapt to the environment, which includes having traits such as resilience against heat stress, diseases and poor quality feed resources (1,2,3,10). Breeds like Sahiwal cows and Red Maasai sheep are better adapted to adverse climatic conditions than several highly productive exotic breeds. Genetic adaptation to climate may help ensure reproductive success in the future when the adverse effects of climate change manifest (1,2,10).

3. Conclusion.

Reproductive efficiency in ruminants is significantly affected by the cumulative influence of climatic, nutritional, and managerial factors. Heat stress affects the normal functioning of the endocrine system, decreases gamete quality, and negatively impacts fertility in both male and female animals. Inadequate nutrition, especially negative energy balance and deficiency of micronutrients, negatively influences reproduction processes through alterations to metabolic and hormonal pathways. Effective management, consisting of environmental changes, precise nutrition, and advanced reproduction technology, is a necessary intervention for overcoming these effects.

Conservation and use of local breeds provide additional avenues for improving resistance to climatic stress. As such, an effective strategy towards improving reproductive efficiency should include climate adaptation, proper nutrition, management, and conservation of genetic resources (2,4,5,1,14).

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