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Utilization Of Rumen Boluses in Nutritional and Health Management of Ruminants

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Abstract. This review discusses the mechanisms of action, areas of application and effects on performance of rumen boluses used in different physiological periods of ruminants. Maximum productivity in farm animals, the protection of animal health and welfare and the sustainability of production are closely related to their adequate and balanced feeding in the different physiological periods as well as effective disease management. In recent years, the use of rumen boluses has become a practical method of supporting animal nutrition to achieve these goals. Rumen boluses are structures that are placed in the rumen and have a long-term release. They allow the controlled administration of mineral and vitamin supplements as well as pharmacological agents. Thanks to their sustained-release structures, they provide the necessary nutrients and medicines that animals need in a controlled manner during various physiological periods such as the transition period, pregnancy and lactation. Thus, they provide positive contribution to economic production by preventing metabolic diseases, improving reproductive performance, promoting immunity and the growth and development performance of the offspring. As a result, in light of the finding from the literature, it is suggested that rumen boluses can be used for both nutritional support and therapeutic purposes and can be evaluated as part of a total herd management strategy.

Keywords: Sheep, Goat, Rumen bolus, Prepartum, Postpartum.

1 Introduction

The transition period in ruminants, encompassing approximately prepartum three weeks and postpartum four weeks, is a critical period characterized by intense metabolic and hormonal changes (Drackley, 1999). During this period, increased energy and nutrient requirements, particularly when combined with the high metabolic demands of parturition and lactation, make animals more susceptible to metabolic disorders (Overton and Waldron, 2004). Inadequate nutrition or unbalanced rations can lead to metabolic disorders like hypocalcemia, ketosis and fatty liver. These diseases negatively impact not only animal health but also milk yield, fertility, and the immune system, leading to significant economic losses (Grummer, 1995). Various nutritional supplements are used in transition management to support metabolic balance and prevent nutrient deficiencies during these periods. Boluses, one of these, provide nutritional support when the animal needs it by releasing elements such as calcium, magnesium,

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phosphorus, selenium, and vitamins in a controlled manner (Mulligan et al., 2006). Bolus applications are particularly effective in preventing mineral imbalances such as hypocalcemia, which occurs after parturition, and also offer a protective effect against ketosis and other energy metabolism disorders (Martinez et al., 2016). Recent studies have shown that bolus applications have positive effects not only on metabolic health but also on performance criteria such as the immune system, milk yield, offspring growth, and fertility (Zhao et al., 2022). In this context, evaluating the effects of bolus applications in small ruminants during different physiological periods is becoming important for both animal health and productivity, as well as for breeder economics.

This review examines the effects of rumen bolus utilisation as a nutritional supplement and medication in ruminants on especially metabolic diseases in the transition period, milk yield, the immune system, the digestive system, fertility and offspring growth and development.

1.1 Effects of rumen bolus use on metabolic diseases

In ruminants, the increased nutritional requirements during parturition and lactation lead to the occurrence of various metabolic disorders. Metabolic problems such as fatty liver syndrome, ketosis, hypocalcemia, hypomagnesia and rumen acidosis, which are frequently encountered in livestock enterprises, can significantly affect animal health, product quality and business economy. The occurrence of these diseases is often due to an inadequate supply of energy, minerals and vitamins. In recent years, nutritional supplements in bolus form have become increasingly important in the prevention and treatment of these problems. Boluses, with their controlled-release ingredients, help to maintain metabolic balance and provide an effective solution for both disease prevention and treatment support. Studies on the use of boluses in metabolic disorders are presented below.

In the study conducted by Martinez et al. (2016), the effects of oral calcium bolus supplementation on the health status and milk yield of Holstein dairy cows during the early lactation period (transition period) after parturition were evaluated. A total of 450 cows were randomly assigned to three different treatment groups of 150 animals each, which received oral calcium bolus at different times after parturition. The treatment groups were as follows: a control group, a group that received two boluses of calcium immediately after calving and on the first postpartum day, and a group that received two oral boluses of calcium on the second and fourth postpartum days. It was reported that calcium supplementation had no effect on milk yield in the first month after calving. In multiparous cows,

calcium supplementation had a positive effect on milk production in the first 30 days of lactation in high-producing animals. However, in cows with lower milk yields, it did not bring any significant benefit and had a negative effect on economic results. Consequently, it was recommended that oral calcium supplementation after calving should only be used in high-producing cows with multiple births. However, the researchers explained that it should not be used in cows with only one birth, as it may have negative effects on reproduction and offer no benefits for reproductive performance.

Another study was conducted to evaluate the efficacy of bolus administration in the context of treatment protocols adapted to clinical signs in small ruminants diagnosed with rumen acidosis (26 sheep and 16 goats showing symptoms of acidosis) (Tufani et al., 2013). In the animals that received apples, cooked rice, beets and chapatti (Indian bread) along with their ration, a total of 42 animals were diagnosed with rumen acidosis. These animals were divided into three treatment groups according to clinical severity (Group I = mild, Group II = moderate, Group III = severe). The distribution of sheep and goats in each group was as follows: Group I = 18 small ruminants (11 sheep, 7 goats); Group II = 16 small ruminants (10 sheep, 6 goats); and Group III = 8 small ruminants (5 sheep, 3 goats). For the treatment of acidosis, the animals in group I received oral sodium bicarbonate in combination with a bolus preparation called “Rumentas". The animals in group II received oral sodium bicarbonate with the bolus preparation "Rumentas" plus parenteral fluid therapy and high-dose vitamin B1. The animals in group III received only parenteral fluid therapy and high-dose vitamin B1. In addition, all groups received antihistamines as supplementary therapy. The use of the bolus preparation was reported to contribute significantly to the control of clinical signs, especially in mild to moderate acidosis, by supporting rumen motility and stabilizing systemic parameters. After treatment, the vast majority of animals recovered completely, with only two cases of mortality reported, one animal each from groups II and III. The results suggest that bolus preparations can serve as an effective supportive treatment method for rumen acidosis. In the study by Aliarabi et al. (2017), 18 Markhoz goats were divided into two treatment groups. One group received a slow-release bolus containing selenium and zinc, while the other group served as a control and received no additional supplementation. In the goats receiving the bolus, significant improvements in immune system parameters were observed, plasma selenium levels increased and a reduction in markers of metabolic stress was reported.

Based on the studies presented above, it can be concluded that oral bolus administration can have significant effects on various clinical and production parameters in both cattle and small ruminants.

However, the effectiveness of these measures depends on the physiological condition of the animal, the severity of the disease, the stage of lactation and the individual production potential. In particular, the administration of calcium bolus has been shown to be beneficial in increasing milk yield in multiparous and high-yielding cows, while bolus preparations for the treatment of rumen acidosis have helped to maintain rumen function in mild to moderate cases. In addition, mineral-containing boluses have shown positive effects on the immune system and have played a role in stabilizing metabolic parameters such as rumen pH. However, it should be emphasized that indiscriminate or general application of boluses to all animals may not be economically or physiologically viable. Therefore, targeted and selective use based on the individual condition of the animal is crucial.

1.2 Effects of rumen bolus use on fertility

The reproductive performance of ruminants is one of the most important parameters that directly influence the economic structure and sustainability of livestock farms. Among the environmental factors that influence fertility, nutrition is the most important determinant. In small ruminants, there are three nutritionally critical periods: the pre-mating phase (flushing), early lactation (peak milk yield) and the last third of gestation, when fetal development is at its most intense. Deficiencies in trace elements such as zinc, selenium, copper, cobalt and iodine in this periods can lead to reproductive disorders such as irregular oestrus cycles, embryonic mortality, reduced pregnancy rates and dystocia (León-Cruz et al., 2020).

In a study conducted on high-producing Holstein cows exposed to heat stress, the effects of a bolus of trace elements and vitamins on reproductive and lactation performance were investigated (Khorsandi et al., 2016). In the group receiving the bolus, a reduction in the number of "open days" was observed, along with a significant increase in cumulative pregnancy rates up to the fifth insemination and improvements in the chemical composition of the milk. In addition, positive changes in milk quality indicators, such as a lower somatic cell count and a higher fat content of the milk, were also observed. In another study conducted in India on Kankrej cattle, the effects of an 80 g mineral bolus given immediately after calving on reproductive parameters were investigated up to 140 days after parturition (Naikoo et al., 2020). The results showed that only one cow in the bolus-treated group became pregnant at first insemination, and although plasma levels of progesterone, cholesterol and triglycerides fluctuated over time, no statistically significant differences were found between the bolus-treated group and the control group. In a study conducted on Kangal sheep, the effects of vitamin and mineral supplementation

on reproductive performance were compared between injectable and bolus forms (Takcı et al., 2023). The study found that the bolus administered 40–45 days prior to estrus synchronization had no significant effect on reproductive performance indicators such as estrus rate, pregnancy rate, lambing rate, embryonic mortality rate, and fertility. However, the dystocia rate was significantly lower in the group that received the bolus.

In another study by Kendall et al. (2000) conducted on eight-month-old male lambs, the effect of bolus supplementation on reproductive performance was investigated. In Ram breed lambs administered a bolus named Zincosel, which contains zinc, cobalt, and selenium, increases in sperm motility, percentage of live sperm, and membrane integrity were observed. Additionally, an increase in glutathione peroxidase (GSH-Px) enzyme activity and positive effects on sperm membrane health were reported. Similarly, in another study where Hampshire and Suffolk rams were given a bolus containing 500 mg of selenium, significant improvements were noted in sperm motility, volume, concentration, and viability, along with an increase in GSH-Px enzyme activity (Carrillo-Nieto et al., 2018). Mineral boluses are known to contribute not only to fertility but also to immune function and the control of parasitic infections. In a study conducted on Spanish goats, copper-containing boluses were found to be effective against Haemonchus contortus infection, significantly reducing parasite egg counts (Burke & Miller, 2006).

Studies investigating the general effects of nutrition on reproduction reported that inadequate mineral intake negatively affects the hypothalamic-pituitary-ovarian axis, disrupts GnRH secretion and suppresses the oestrus cycle (Assan et al., 2025). A common finding of all these studies is that intraruminal bolus administration is an effective method of correcting mineral deficiencies. However, numerous factors including animal species, age, breed, lactation status, bolus composition, timing of administration and environmental conditions can directly influence the results of such interventions. It is therefore crucial to develop targeted formulations rather than adopting a "one size fits all" approach. Controlled-release mineral boluses have the potential to improve both male and female fertility parameters in ruminants, either directly or indirectly. However, knowing the most appropriate bolus type, delivery method and timing for each species and breed will contribute to more economically efficient production.

1.3 Effects of rumen bolus use on the growth and developmental characteristics of the offspring

The growth and development of newborn offspring in animal production are closely linked to the timely and sufficient intake of essential nutrients. In this context, intraruminal bolus administration has significant effects on early growth rate, rumen development and immune system support in young animals.

In a study conducted on Mehraban sheep, the effects of a bolus of slow-release minerals (P, Mg, Zn, Co, I, Se) and a selenium injection administered approximately six weeks before parturition were evaluated in terms of biochemical parameters and offspring development (Aliarabi and Fadayifar, 2016). For this purpose, 105 sheep were divided into three treatment groups: The first group received a mineral-containing bolus, the second group received a selenium injection and the third group received no treatment and served as a control. Blood samples taken before and after birth were analyzed for GSH-Px, alkaline phosphatase (ALP) and vitamin B12 levels. In addition, the live weights of the lambs at birth and weaning were recorded. At the end of the study, it was found that GSH-Px activity increased in both the mineral bolus group and the selenium injection group before birth; however, this effect only persisted in the bolus group after birth. Administration of the mineral bolus significantly increased vitamin B12 and ALP levels in both periods. In addition, the lambs in the mineral bolus group showed significantly higher live weights and daily body weight gains, as well as a lower mortality rate and a lower incidence of white muscle disease. Similarly, the studies by Kendall et al. (1997) and Kendall et al. (2000) also reported that the administration of mineral boluses before birth had positive and lasting effects on the health of the ewes and the development of the lambs.

In a study examining the effects of slow-release selenium and sulfamethazine boluses in kids, a significant decrease in the incidence of parasite infections was found (Diaz-Sanchez et al., 2020). It was also found that bolus administration significantly improved growth performance for a certain period of time. This finding suggests that the effectiveness of mineral bolus applications in terms of performance outcomes may vary depending on the active ingredient, dosage and timing of administration. In a study conducted on Saanen goats, the in vitro release kinetics and field performance of continuous-release boluses were evaluated (Çomak et al., 2024). Field trials showed that the group receiving bolus treatment had a higher rate of multiple births and the offspring of goats that gave birth to twins and triplets had significantly higher body weight gain compared to the control group. The researchers concluded that

long-acting boluses can have positive effects on reproductive performance as well as on the growth and development of the kids. In Afshar sheep, boluses containing trace elements have been reported to improve plasma mineral concentrations, increase fertility rates and reduce infertility, all of which have a positive effect on the health of the offspring (Abdollahi et al., 2015).

In summary, rumen boluses containing various trace elements, vitamins and immune-supporting substances have a significant effect on the growth and development of the offspring. Especially in pregnant breeding animals, nutrient requirements increase in terms of both quantity and variety in the last three weeks of the prenatal period due to the rapid development of the fetus and the start of milk synthesis in the mammary glands. Therefore, the administration of bolus supplements in the rumen 3–4 weeks before weaning can provide significant benefits for the health of the maternal animal and newborn. Offspring that complete their prenatal development adequately and are born at a higher birth weight tend to have better postnatal growth and development. The controlled and sustained release of minerals helps to maintain the continuity of important metabolic processes, particularly those involving key elements such as copper, zinc and cobalt, thus supporting animal health and improving growth performance. In addition, the inclusion of antiparasitic agents in the bolus contributes to a reduction in the parasite load, which indirectly leads to better growth results. To optimize the positive effects of rumen bolus technology on offspring growth, improvements in formulation and physical design are required. This includes the development of dissolution profiles tailored to specific animal species and growth stages, as well as the adaptation of manufacturing processes to field conditions. Future research focusing on these areas will help to improve the efficiency of bolus applications and support the development of sustainable growth promotion strategies in animal husbandry.

1.4 Effects of rumen bolus use on lactation efficiency and composition

In small ruminants, milk yield and milk composition during lactation are influenced by various factors such as nutrition, metabolic balance and adequate micronutrient intake. In this context, mineral and nutrient supplements administered in bolus form are often used to support the overall health of the animals and improve both the quantity and quality of milk. Recent studies have shown that the administration of slow-release bolus supplements, particularly in late gestation, can have significant effects on milk production and milk components.

Rashnoo et al (2020) reported in their study on goats that the administration of slow-release boluses containing selenium (Se) and iodine (I) during the late gestation period resulted in a significant increase in milk yield, milk fat percentage and overall milk chemical composition. In addition, a significant increase in Se and I concentrations in the milk was observed. The kids of the selenium-fed goats also showed higher daily live weight gains and weaning weights compared to the control group. Another study investigated the effects of an oral calcium bolus administered during parturition on blood calcium, magnesium and phosphorus levels as well as milk yield and chemical composition during early lactation (Alhelo and Serbester, 2024). The study concluded that daily and total milk yield increased by 9.6% and 9.3% respectively during the first 28 days of lactation. However, no significant differences in milk composition or total lactation performance were found between the cows receiving the calcium bolus and those in the control group.

Similarly, a study conducted on 75 Italian Holstein cows investigated the effects of a bolus containing a herbal supplement. The bolus, which contained Echinacea purpurea, Silybum marianum, L-carnitine and vitamin E, was reported to positively influence energy metabolism, immune response and liver health factors that indirectly contributed to an increase in milk production (Esposito et al., 2024). The use of selenium (Se) bolus in small ruminants has also had a positive effect on milk yield and composition (Rashnoo et al., 2020). Selenium is a trace element involved in the synthesis of antioxidant enzymes such as glutathione peroxidase. Studies using organic, inorganic and nano-forms of selenium supplementation have reported an increase in milk yield as well as improvements in fat and protein content of milk (Amin et al., 2022). In particular, the use of Se yeast (organic selenium) was found to increase the fat and protein content of milk while reducing the number of somatic cells (Reczyńska et al., 2019). Rashnoo et al. (2020) also reported that the administration of a selenium-containing bolus during gestation in 40 dairy goats led to a significant increase in milk yield after birth as well as in the fat and protein content of the milk. In addition, selenium and iodine concentrations increased in the milk of the animals aplied bolus, which was associated with improved serum antioxidant levels in the offspring.

In a study conducted by Pirestani et al. (2011), the effects of slow-release mineral and vitamin boluses compared to feed supplements were investigated in relation to milk yield, composition and udder immune system in dairy cows. Sixty Holstein cows were used in the study and randomly divided into two treatment groups of 30 animals each: one group received a mineral-enriched bolus, while the other

group received daily minerals in their feed for six months. The results showed no significant differences in milk yield between the groups. However, remarkable improvements in milk composition were observed in the bolus-treated group. In addition, the somatic cell count (SCC) was lower in the bolus group, indicating a positive influence on udder health. From an immunological point of view, bolus administration increased the level of immunity-related proteins in the milk. Thus, although both treatment groups performed similarly in terms of milk yield, the bolus was shown to have positive effects on milk composition, udder health and immune function. In particular, the decrease in SCC indicates a lower risk of mastitis. In addition, the authors emphasized that long-acting sustained-release boluses can optimize mineral release and prevent daily fluctuations in mineral intake commonly observed with feed-based supplementation.

In a four-year study making in grazing cattle, the effects of long-acting boluses containing copper (Cu), selenium (Se) and cobalt (Co) on performance and reproductive traits were investigated (Sprinkle et al., 2021). In the study, two treatment groups that received bolus supplementation at different times were compared with a control group, with a total of 924 cows consisting of Hereford and crossbred cows being examined. At the end of the study, the use of boluses showed no significant effects on body condition scores or milk yield. However, positive effects on calf birth weight, weaning weight and calving interval were observed. It was also reported that bolus supplementation could compensate for mineral deficiencies in the pastures and possibly improve productivity. The researchers emphasized that long-acting mineral boluses have the potential to increase herd productivity, especially in areas where trace mineral deficiencies are prevalent. Kachuee et al (2019) investigated the effects of supplementation with organic, inorganic and selenium nanoparticles administered during late gestation in Khalkhali goats on selenium, zinc, copper and iron concentrations and on the transfer of these trace elements to the offspring via the placenta, colostrum and milk. The results showed that supplementing the diet of pregnant goats with various forms of selenium including sodium selenite (SS), selenomethionine (SM) and selenium nanoparticles (SN) resulted in increased Se levels in whole blood and serum compared to the control group. Differences were observed in the transplacental transfer capacity of the various Se forms. For example, the goats that received SM had higher whole blood and serum Se concentrations in their kids than those that received SS or SN. The researchers also found that supplementation with SN failed to increase Se concentrations in newborn kids. In addition, colostral Se concentrations were higher in the SM group than in the SS and SN groups, suggesting that selenomethionine passed into the milk at the fourth week of lactation at a higher rate than sodium selenite and Se nanoparticles.

The effects of plant-based boluses on milk yield have also been demonstrated in various studies. For example, the use of Galactin Vet Bolus, a plant-based product, resulted in a significant increase in milk production in Holstein × Jersey crossbred cows (Ravikumar and Bhagwat, 2008). This increase was particularly evident in cows in the later stages of lactation, with some animals showing an increase in milk yield of more than 20. In addition to milk yield, studies on the chemical composition of milk have shown that mineral boluses can affect calcium metabolism, which may indirectly affect milk composition. However, most studies have found only limited direct effects on milk composition. For example, calcium-containing boluses have been shown to increase serum calcium levels after birth, thereby reducing the risk of hypocalcemia. However, the direct effects of such interventions on milk yield and composition have not been clearly demonstrated (Jahani-Moghadam et al., 2018). In addition, a study by Baig and Bhagwat (2009) reported that the herbal bolus Galactin Vet has positive effects on milk yield and contributes to an improvement in milk composition, particularly in terms of fat and non-fat content (SNF). The preparation contains herbal substances such as Leptadenia reticulata, Asparagus racemosus and Withania somnifera, which are known to have galactopoietic properties. The researchers pointed out that these effects are mediated by the stimulation of prolactin secretion, which in turn promotes milk synthesis.

In general, slow-release boluses containing minerals or phytonutrients administered during late gestation or early lactation have been shown to increase milk production and positively influence the chemical composition of milk in ruminants. These effects can be attributed to the active ingredients in the boluses, which may influence the endocrine system, support metabolic balance and improve antioxidant defense mechanisms.

1.5 Effects of rumen bolus use on the immune system and digestion

Boluses used as feed additives for ruminants have been developed to meet physiological needs, maintain metabolic balance and support the immune system. These bolus applications, which contain vitamins, minerals, probiotics and other bioactive compounds, exert direct effects in the gastrointestinal system through controlled release. As a result, they improve digestive efficiency and contribute to the development of immune resistance against disease. Studies investigating the effects of rumen bolus on the immune and digestive systems are presented below.

In a study investigating the effects of boluses with trace elements containing zinc, cobalt and selenium on the immune system, 34 Suffolk cross lambs were used at three months of age (Kendall et al., 2012). Each bolus weighed approximately 33 g and contained 15.1% zinc, 0.52% cobalt and 0.15% selenium. During the trial period, the lambs grazed for 63 days without additional feed or mineral supplementation and were later moved to fresh pasture and slaughtered at either 86 or 121 days of age. Bolus administration resulted in a significant increase in erythrocyte glutathione peroxidase (eGSH-Px) activity and vitamin B12 levels. These results indicate a strengthening of the immune system, especially compared to the control group, which showed signs of cobalt and selenium deficiency. Although plasma zinc levels decreased over time in both groups, they remained higher in the bolus-treated group. No differences were found in the zinc concentrations in the liver. However, due to the suppressive effect of zinc on copper absorption, liver copper levels were lower in the bolus group. Regarding growth performance, daily live weight gains between day 42 and 63 were significantly higher in the lambs receiving the bolus than in the control group a result that can be attributed to the cobalt deficiency. In addition, increased IgG levels in the lambs treated with the bolus indicated an improved immune response. In conclusion, the administration of trace element bolus especially in grazing systems where mineral availability is limited supports immune function and improves growth performance in lambs.

In a study of 105 pregnant Mehraban ewes about six weeks before lambing, the efficacy of selenium and vitamin E injections was compared with that of slow-release boluses containing zinc, selenium and cobalt (Aliarabi & Fadayifar, 2013). At the end of the study, it was reported that the treatment with slow-release boluses resulted in significantly higher levels of antioxidant enzyme activity, plasma selenium and vitamin B12 in the pregnant ewes than the inorganic Se and vitamin E injections. In addition, the lambs of the bolus-treated ewes showed better growth performance and survival rate. In another study, 20 out of 100 Alpine goat kids naturally infected with Eimeria, weaned, showing signs of diarrhea and not previously treated prophylactically or therapeutically were selected to evaluate the effects of an intraruminal bolus containing sodium sulfametazine (SM) and selenium (Se) (Díaz-Sánchez et al., 2020). In conclusion, The bolus with 4 g SM and 90 mg Se led to a significantly lower load of Eimeria spp. in kids with an average body weight of 13.7 kg. Rose et al (2012) conducted a study with 38 Holstein–Friesian cows and administered a bolus of iodine, selenium and cobalt in the rumen approximately 57 days before calving. The results showed no significant effect of bolus administration on colostral IgG uptake in calves. However, a positive correlation was found between plasma T_3 concentration at 24 hours of age and IgG absorption and a negative correlation between plasma T_4

concentration at one hour of age and IgG transfer. These results suggest that complex interactions between thyroid hormones particularly T_3 and T_4 may play a role in modulating IgG uptake in neonates.

In a study conducted by Chaleshtori et al. (2021) using 80 Lori-Bakhtiari ewes, the effects of slow-release copper boluses administered during the late gestation period on lamb development were evaluated. Despite maternal serum copper levels remaining within physiological norms, lambs born to the bolus-treated ewes exhibited significantly higher weaning weights, daily body weight gains, serum copper, ceruloplasmin levels, and hematological parameters (hematocrit, hemoglobin concentration, and red blood cell count) compared to those in the control group. These findings indicate that intraruminal slow-release copper boluses given in late pregnancy can positively impact growth performance and specific hematological measures in lambs. Mineral deficiencies particularly of trace elements such as copper, selenium, and cobalt can adversely affect immune, growth, and reproductive performance in ruminants. To investigate whether soluble glass-form boluses could support these element levels, two field trials were conducted in grazing yaks (Tibetan cattle) (Liu Zongping, 2007). In these studies, 100 yaks were involved, with half of the animals receiving commercial boluses containing copper, cobalt, and selenium. Biochemical analyses of blood samples showed that yaks applied bolus had significantly higher serum ceruloplasmin, vitamin B_{12}, and erythrocyte glutathione peroxidase activities. Additionally, their serum selenium and copper concentrations were significantly elevated compared to controls, although zinc and cobalt concentrations were similar between the treatment groups. In another investigation, slow-release boluses containing Se, Cu, Zn, Co, and Mn were administered approximately 60 days before parturition to Naemi ewes and their offspring (Abdelrahman et al., 2017). Significant increases were observed in mineral levels in both blood and colostrum. Specifically, bolus-treated ewes exhibited higher blood levels of calcium, zinc, cobalt, and selenium, along with increased inorganic matter in colostrum. In their lambs, phosphorus, cobalt, and selenium concentrations were elevated. Moreover, bolus-treated ewes demonstrated higher total protein and cholesterol levels, while their lambs had reduced levels of glucose, urea, and triglycerides. The offspring of ewes applied bolus also displayed markedly higher live weights at 30 and 60 days post-birth compared to control group. In addition, the researchers noted that trace mineral supplementation via bolus contributed positively to both milk composition and colostrum quality.

A review of previous studies shows that slow-release boluses containing trace elements, vitamins and bioactive compounds administered to ruminants have significant and multifaceted positive effects on

animal health, immune function, metabolic balance and growth performance. Bolus applications in particular are seen to be an effective way to correct mineral deficiencies, improve antioxidant defenses and support digestive health in grazing animals, pregnant females or young ruminants. Boluses containing selenium, zinc, copper, cobalt and vitamin B_{12} have been reported to increase concentrations of minerals in plasma and liver, boost immune defenses and improve various hematological parameters. In addition, these applications have been shown to have a positive effect on offspring development, colostrum quality and postnatal growth performance. Overall, bolus supplementation in the rumen is recommended as a strategic approach to support healthy growth, immune strength and productivity in ruminants, especially in populations at risk of trace element deficiencies.

1.6 Effects of rumen bolus use as a medicine on animal health

In recent years, the increasing use of bolus-form drug applications for improving animal health and achieving optimal productivity has emerged as an effective strategy. These pharmaceutical boluses are typically administered orally and are formulated as dense tablets designed to remain in the rumen for extended periods, offering controlled release of active ingredients. Their use reduces the need for frequent or repeated drug administration, thereby minimizing animal stress and labor costs. In small ruminants such as sheep and goats, boluses containing minerals, vitamins, or drugs are widely used for nutritional supplementation, immune support, and control of parasitic diseases. Thanks to the anatomical structure of the ruminoreticular system, these high-density boluses can remain in the gastrointestinal tract for long durations and maintain prolonged efficacy (Ramteke et al., 2014).

The use of slow-release boluses containing zinc, selenium, and cobalt has been reported to improve growth performance and blood biochemical parameters in Markhoz goat kids (Aliarabi et al., 2017). The same study found significant increases in daily live weight gain, blood concentrations of vitamin B12 and zinc, alkaline phosphatase activity, and glutathione peroxidase levels in the bolus-treated group. Furthermore, an increase in the thyroid hormone T3 was observed, indicating the bolus's supportive role in metabolic activities. In grazing-based small ruminant systems, where mineral deficiencies are common, administering such mineral supplements in bolus form strengthens the immune system, enhances disease resistance, and positively impacts reproductive and growth performance. Gutiérrez-Blanco (2006) evaluated the effects of a slow-release intraruminal sulfamethazine bolus on parasite excretion in feces and live weight gain in Pelibuey lambs naturally infected with Eimeria spp. The study concluded that the parasite count in feces significantly decreased in bolus-treated lambs and that growth

performance improved, particularly under grazing conditions. Thus, the controlled-release properties of the bolus enabled long-lasting antiparasitic activity from a single dose. However, in lambs reared only under entansive conditions, performance parameters did not show significant improvement, highlighting the importance of evaluating bolus efficacy in the context of environmental factors.

From a pharmaceutical perspective, bolus formulations are designed to remain in the ruminoreticular compartment for extended periods due to their high density, during which they continuously release active ingredients to maintain therapeutic effects. However, there are technical challenges associated with bolus manufacturing. The requirement to include high concentrations of active compounds limits the use of binders, diluents, and excipients, potentially affecting bolus stability and release profiles. Additionally, the application equipment (bolus gun) and techniques must be appropriate for the species and administered with care. When evaluated based on existing scientific data, the use of boluses in ruminants offers significant advantages for both animal health and farm productivity. Boluses used for correcting nutritional deficiencies or for disease prevention and treatment contribute to animal welfare and enhance production profitability due to their prolonged effects. However, achieving these benefits requires careful consideration of factors such as bolus formulation, method of administration, dosage, and target species. Studies in the literature have demonstrated that bolus applications improve metabolic health indicators and are effective in combating parasitic infections. In this context, bolus technology can be regarded as a strategic tool for sustainable production and effective herd health management in ruminant livestock (Gutiérrez et al., 2006; Ramteke et al., 2014; Aliarabi et al., 2016).

2 Conclusion

Based on the studies, it can be said that rumen boluses are an innovative and effective tools for optimizing nutrition and health management in ruminants. In particular, boluses, which ensure a sustained and controlled release of minerals and vitamins, allow the continuous coverage of the physiological needs of ruminants. In addition, the use of boluses containing antiparasitic and probiotic agents offers significant benefits in maintaining animal health. Studies have shown that rumen boluses can have positive effects on live weight gain, milk yield, immune status and overall animal performance. However, it should be noted that the effectiveness of bolus administration may depend on factors such as bolus composition, method of administration and the age and species of the animal. Therefore, the following recommendations are suggested:

Bolus formulations should be specific to the animal species (cattle, sheep, goats), age and physiological status (gestation, lactation, growth period) and boluses with appropriate content and release profiles should be selected.

Rumen boluses containing antiparasitic agents can be considered as an alternative strategy for parasite control, especially in large herds, as they are easy to use and accurately dosed. Especially in regions with high seasonal parasite infestations, long-acting antiparasitic bolus formulations can be an alternative to the widespread use of medication.

There is a need for more controlled studies on the long-term effects of boluses on rumen microflora, variations in animal response due to genetic differences and interactions with different feed rations. Therefore, further field studies are needed to evaluate the effects and performance of rumen boluses under different environmental conditions and in different ruminant species.

Finally, a detailed analysis of the economic impact of bolus applications in animal production will provide decision makers with concrete data to support the wider adoption of this technology in practice.

3 References

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