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# Impact of Ruminal Transfaunation on Performance and Health of Fattening Lambs – A Review

**Mohammed A*, Elrawy A, Mahmoud U and Darwish M**

Department of Animal, Poultry Behavior and Management, Faculty of Veterinary Medicine, Assiut University, Egypt

***Corresponding author:** Ahmed Mohammed, Department of Animal, Poultry Behavior and Management, Faculty of Veterinary Medicine, Assiut University, Egypt, Tel: +201006286326; Email: ahmed.abd_elhafez@aun.edu.eg

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## Abstract

Understanding the host impact on its symbiotic microbiota is crucial in redirecting the rumen microbiota and thus improving animal health and performance. Rumen fluid transplantation has been proposed as one of the promising methods for reshaping the symbiotic microbiota and enhancing host health and performance. The aim of this invited review is to summarize the impact of ruminal transfaunation on the health and performance of sheep especially fattening lambs. Rumen transfaunation using the ruminal fluid from a healthy donor animal to improve the rumen microbiota and treat a sick recipient animal was performed long before. The microbial populations and associated advantages of the rumen transfaunation have been explored in many studies before. Rumen fluid transplantation has been performed to confer benefits for animals by altering gastrointestinal tract microbiota. Ruminant scientists agree that restoring ruminal bacterial equilibrium of animals suffering from ruminal disorders like simple indigestion, acidosis, plant intoxication, and following surgical correction of a left-displaced abomasum, would aid rumen function recovery. In humans, the support of a healthy microbial community in the digestive tract is also recommended previously. In humans, digestive disorders have been treated with fecal microbiota transplantation. This review presents the impact of ruminal transfaunation on the gastrointestinal microbial ecology, production performance, antioxidant status and immune response of sheep especially fattening lambs.

**Keywords:** Ruminal Transfaunation; Fattening Lambs; Health; Production Performance; Ruminal Microbiota

**Abbreviations:** VFAs: Volatile Fatty Acids; GIT: Gastrointestinal Track; NDF: Neutral Detergent Fiber; TLRs: Toll-like Receptors; SCFAs: Short Chain Fatty Acids; ROS and RNS: Reactive Oxygen and Nitrogen Species; MDA: Malondialdehyde; TAC: Total Antioxidant Capacity; TOS: Total Oxidant Status.

## Introduction

Ruminants are mammals (Class – Mammalia) in the Order Arteriodactyla (toed mammals and hooved) Suborder Ruminantia. The word ruminant, came from the Latin word ruminare, means to chew over gain hence the nomenclature of cud chewing [1]. The ruminant can be considered to be a superorganism because it has a symbiotic relationship of life between the cells of the animal›s body and the rumen microbes. The host animal has been affected by factors influencing the viability of microorganisms in the reticulo-rumen as well as anywhere along the gastro-intestinal tract [1]. Ruminants have a four-chambered stomach, consisting of the reticulum, rumen, omasum and abomasum. Ruminants typically eat quickly with minimal chewing. After being swallowed, feed enters the reticulum, which is continuous with the rumen. The rumen is the largest of the four stomach chambers and serves as a large mixing vat that is the site of microbial fermentation and nutrient absorption. Combined, the rumen and reticulum of an adult dairy cow can hold around 50 gallons of partially digested feed. The omasum, with its many leaves or laminae, regulates flow of digesta to the abomasum. The abomasum is the gastric, glandular compartment similar to the stomach of nonruminants (simple stomach animals) with secretion of acid (HCl) and pepsinogen and a pyloric sphincter that controls flow of digesta from the abomasum to the duodenum [1].

Rumination involves the partially digested feed (cud) is regurgitated by bringing the cud up to the esophagus, and then re-chewed in the mouth. Chewing during rumination is slower and more consistent than during eating. The cud is eventually re-swallowed and the process continues with another bolus regurgitated for cud chewing (crushing and grinding of particles by the molars). The rumination process stimulates saliva production to help buffer the rumen pH and decrease feed particle size, allowing it to pass from the reticulum into the omasum. As partially digested feed passes through the omasum, water is absorbed, reducing the volume of material that arrives in the abomasum. The abomasum, often referred to as the true stomach, produces acid and digestive enzymes similar to the stomach of non-ruminant animals, further breaking down the feed before it passes into the lower gastrointestinal tract for further digestion, absorption and ultimately elimination. Cud chewing increases surface area of the feed particles, in particular fibrous material, to enhance microbial digestion [1].

Gastrointestinal microbiota has an important role in the health and feed utilization of animals [2]. The symbiotic microbiota in the rumen facilitates the digestion by decomposing the ingesta and degrading the plant materials into different volatile fatty acids (VFAs), ammonia, etc., to supply the host with nutrient and energy [3]. Therefore, the improvement of rumen microbial ecology can possibly affect the digestion capability resulting in enhanced lamb feed efficiency and then production performance. Various methods have been performed into previous studies to redirect rumen microbiota. For instance, changing rumen pH [4], minimizing the rumen protozoa [5], changing animal diets [6], dietary supplementation of feed additives like probiotics, prebiotics and synbiotics [7] have been investigated in different studies. On the contrary, no one of the previously mentioned methods has shown harmonic positive effects, indicating that the previously mentioned methods to improve animal health and production performance by reshaping the symbiotic microbiota have not been achieved yet.

A balance of symbiotic bacteria is necessary for a healthy intestinal microbiome and related physiological homeostasis [8,9]. In the case of ruminants, ruminal fluid transplantation has been known to transfer ruminal microbes from healthy donor animals to provide health benefits to the recipient ones [2]. Rumen fluid transplantation has been proposed as one of the promising methods for changing the symbiotic microbiota and improving host production performance [1]. Whether ruminal fluid transplantation can accelerate gastrointestinal transition, reshape gastrointestinal microbiota communities. In large ruminants, ruminal fluid transplantation has been developed to reduce the harmful effects of rumen acidosis [10], treat rumen function disorders [1], and improve health of cows with surgical correction of displaced abomasum [11]. In small ruminants, ruminal fluid transplantation has improved immunological and inflammatory reactivity while decreasing feed intake, nutrient digestibility, and growth performance [12]. However, ruminal fluid transplantation may not be appropriate for lambs during weaning, and research with calves suggests that fast changes in the gut microbiota during weaning may be hazardous [13]. These conflicting findings may be partially due to variations of the symbiotic bacteria (i.e., bacterial strains and types) as well as dosage.

Therefore, this review aimed at elucidating the impact of ruminal transfaunation on health and production performance of sheep especially fattening lambs. To prepare the review, we conducted a literature search with focus on the effect of ruminal transfaunation on health and performance of sheep using the following criteria: (1) peer-reviewed journal articles in English were included; (2) chapters in an edited book were selectively involved; (3) studies on cows and fattening calves were selectively included to verify and/or support the data on sheep. The key words used during literature search included ruminal transfaunation, health, production performance, sheep.

## Ruminal Transfauntion

Ruminal transfauntion is vital for animal health and feed consumption and also it has been established in the case of ruminants to transfer ruminal microorganisms from healthy donor animals to receivers to give health advantages [2]. Ruminal transfauntion has been presented as one of the potential approaches for changing the symbiotic microbiota and improving host performance [1]. Transfauntion of gastrointestinal microbiota improved gut barrier damage in pigs [14] and successfully treated sheep ruminal acidosis [10].

### Concept of Rumen Microbiome (Symbiotic Microbiota)

The rumen can be showed as an anaerobic and methanogenic fermentation chamber that involves microorganisms that have the ability to use, and improve the productivity of, cellulolytic feeds (i.e. straw, silage, hay, and grass) [15]. The rumen microbiome, i.e., the community of microorganisms that found in the rumen, is characterized by its extensive diversity (encompassing bacteria, archaea, protozoa and fungi), high population density and complexity of interactions [16]. The continuous fermentation carried out by these microorganisms leads to ingested compounds being broken down into their subcomponents. There are three intersecting micro-environments found in the rumen that contain these microbes; the solid phase making up 70% of the microbial mass, the liquid phase making up 25% of the microbial mass, and the rumen epithelial cells and protozoa, containing 5% of the microbial mass [17]. The ruminal microbiota is a diverse and complex ecology that is critical to animal health and performance.

Diet, environment, age, and the host's health state are all discovered to have a role in developing the rumen microbiota. Diet, in particular, can have a significant impact on rumen function by modifying microbial populations and fermentation activity [4,18-20]. Roughage influences rumen development and the expression of genes involved in VFA absorption in rumen epithelial cells. As a result, one of the most important aspects, diet, has been adjusted in big feeding operations of ruminants to enhance feed efficiency. According to a review of the available research [19], nutrition has the greatest impact on ruminal microbiota, however comparison studies across species are needed. Scientists would use modern omics technologies to quickly identify the microbial makeup, functions in the gastrointestinal track (GIT), host-microbe interactions, and variables influencing GIT microbiota.

Another element influencing rumen bacteria is the host's age. The main rumen bacteria, for example, differ between newborn, 2-month-old, 6-month-old, and 2-year-old cows [21]. Climate, temperature, humidity, topography, and herd management are all factors that influence the rumen microbiota-host relationship. When a host gets ill, its gut microorganisms and microbial activities may alter from those found in healthy animals [22].

## Physiological and Anatomical Properties of the Rumen

The rumen is a complex ecosystem in which nutrients absorbed by microbes like bacteria, protozoa, and fungus and then digested anaerobically. The major end products of fermentation are VFAs and microbial biomass, which are utilized by the host ruminant. The environment in the rumen promotes microorganisms in providing the enzymes needed to digest the nutrients [23]. The functional health of the reticle-rumen is a necessary condition for productive behaviour, which includes cattle health and animal welfare [24].

Ruminants have the ability to transform low-quality fibrous resources into human-useful goods like meat and milk. Ruminal microorganisms' capacity to manufacture the enzymes required for fermentation processes enables ruminants to acquire the energy contained in forages more effectively [23], in contrast the ruminal fermentation process is inefficient since it generates various byproducts such as methane gas (Kingston-Smith et al., 2012) and excess ammonia [25].

Ruminants' anatomical adaption allows them to utilize cellulose as an energy source without requiring external supplies of vitamin B complex or critical amino acids since ruminal bacteria may manufacture such products [25,26]. The ruminant host receives nutrients from the bacteria to produce energy [27]. The ruminant digestive system is made up of four parts: the reticulum, the rumen, the omasum, and the abomasum. The rumen is primarily where the fermentation activities take place [28]. Microorganisms create the enzymes found in the rumen, which are needed to digest and ferment the food consumed by ruminants; consequently, the rumen is seen as a fermentation vat [29].

## Types of Ruminal Bacteria (Table 1)

| Type of bacteria | Microorganism | Impact | Reference |
|---|---|---|---|
| Cellulose-degrading bacteria | *Butyrivibrio fibrisolvens, Ruminococci albus, and Fibrobacter succinogenes* | Essential for animal nutrition because they break down cellulose, this makes up the majority of these plants' cell walls. | [30-32] |
| Lipolytic bacteria | *Anaerovibrio lipolytica* | Hydrolyze the lipids in the rumen, and breaking the ester bonds and releasing fatty acids. | [33] |
| Lactate-degrading bacteria | *Selenomonas lactilytica and Megasphaera elsdenii* | Metabolize lactic acid and limit its buildup, which helps to keep the pH in the right range. | - |
| Pectin-degrading bacteria | *Lachnospira multiparus* | Create and release pectinolytic enzymes into the ruminal environment. | [34] |

| | | | |
|---|---|---|---|
| Amylolytic bacteria | *Bacteriodes ruminicola, Ruminobacter amylophilus , Selenomonas ruminantium, Succinomonas amylolítica and Streptococci bovis* | Produce other VFAs such as formate, acetate, propionate, and succinate, and ferments glucose to provide acetate, formate, and ethanol as a final product. | [35-37] |
| Lactic acid-utilizing bacteria | *Megasphaera elsdenii* | Is the main species responsible for lactic acid metabolization; thus, it has an important role in the prevention of acidosis during the adaptation period when ruminants are fed diets high in concentrate. | [38] |

**Table 1:** The most common ruminal bacteria.

The ruminal ecosystem is made up of a diverse group of microorganisms that live in a symbiotic interaction in an anaerobic environment [39]. Ruminal bacteria, protozoa, and fungus make up the microbiota and bacterial populations are particularly sensitive to the rumen's physicochemical features [36]. Bacteria, which make up the bulk of microorganisms that survive in anaerobic environments, are found in the rumen [40].

### Function and Importance of the Rumen

Because the host is unable to manufacture cellulolytic enzymes, the microbiota is primarily responsible for complicated polysaccharide breakdown. Many microorganisms interact to digest complex substrates such as cellulose, starch, and proteins, resulting in energy, protein, and vitamins accessible to the host [41]. The most prevalent microorganisms in the rumen are bacteria [42] and also the rumen microbiota is mostly composed of bacteria [43]. Manipulation of microbiota has been explored in order to increase energy harvesting, minimize methane emissions, and prevent and cure rumen disorders [44,45].

There are several methods for manipulating the ruminal microbiota, including probiotics, prebiotics, antibiotics, and microbiota transfaunation, which involves transferring rumen fluid from one animal (donor) to another. The ruminal microbiota is relatively stable in adult animals, owing to two factors: redundancy, which is the ability of numerous microbial species to perform the same job, and resilience, which is the ability to rebound from a disruption [46].

### Impact of Ruminal Juice Transfauntion

Rumen microbiota transfaunation has long been employed by veterinarians and is commonly advised to restore ruminal equilibrium [47,48]. Transfaunation has been demonstrated to aid cows suffering from abomasum displacement [11,49], abomasum impaction, gangrenous mastitis [50] and dysbiosis (abnormalities in the normal microbiota composition) induced by antibiotic therapy [51]. However, Tankersley, et al. [52] reported that, the technique did not improve blood metabolites, reproductive performance, or the incidence of illnesses following calving. Interspecies rumen microbiota transfaunation (from bovine to small ruminants) has been demonstrated to promote a faster recovery of protozoa populations as well as physical qualities such as color, flavor, and consistency in sheep and goats with experimentally produced acute ruminal lactic acidosis [53,54].

### Impact of Ruminal Fluid Transfaunation on Nutrient Metabolism

As a result, ruminal microbiota is tightly correlated to host feed digestion and metabolism. Numerous studies have found that one or more types of ruminal microbiotas influence feed efficiency, nitrogen digestibility, and methane emission in ruminants [55-57]. In comparison to the reticulum, omasum, and abomasum, the adult rumen plays the most important role in the breakdown of ingested organic materials due to the presence of diverse bacteria. Rumen microorganisms can convert dietary carbohydrates to VFA, which can account for up to 80% of ruminant energy requirements [58]. Some rumen microorganisms also produce their own proteins for growth (referred to as microbial crude protein, MCP) by consuming energy and nitrogen from the meal. The MCP are digested and absorbed by the host in the small intestine, contributing to the host's nutrition and wellbeing [27,59]. Furthermore, certain microorganisms may create vitamins such as B and K. Numerous enzymes necessary for the production of vitamin B12 are present in rumen microorganisms but not in the human GIT microbiome [60].

Methanogens in the rumen, on the other hand, generate methane through a series of redox processes, and methane is a potent greenhouse gas [61]. As a result, rumen microorganisms have a high potential for contribution to animal husbandry, and some of them can be used in animal production [45]. The bacteria that live in the rumen impact the host metabolism by degrading dietary components, despite the fact that these microbes are not regarded to be host specific tissues. This microbiota assists in the digestion of the meal by secreting enzymes. The rumen microbiota has been shown to have an important effect on feed efficiency, milk output, and dairy cow components [56]. The role of microbial enzyme activity, for example, can enhance monosaccharide content [62]. Nitrogen and fiber digestion contribute significantly to feed efficiency, and it is also associated with rumen microorganisms that generate MCP and VFA for the host [59]. According to one study, *Fibrobacter succinogenes, Butyrivibrio fibrisolvens, and Ruminococcus sp*. are the most important ruminal bacterial species in terms of nitrogen use by the host [63]. Toll-like receptors (TLRs) in the epithelium, for example, may detect lipopolysaccharide and lipoprotein breakdown products from bacteria [64]. When TLR4, TLR5, and TLR9 are activated by lipopolysaccharide, the host secretes bacterial flagellin and other bioactive molecules (such as cholecystokinin), which alter dietary nitrogen digestion and absorption.

A recent study discovered that some bacteria impeded the digestion of neutral detergent fiber (NDF) in goats [65]. Several bacterial phyla, including *Proteobacteria,* and *Tenericutes*, as well as a few bacterial species, including *Anaeroplasma, Campylobacter,* and *Clostridium*, are also associated with apparent crude fiber digestibility in pigs [66]. Cellulolytic microorganisms are among the most common bacteria in the rumen, they influence host fiber digestibility by secreting cellulose and controlling VFA production and profile. Furthermore, VFA can both give energy and regulate the host's intestinal barrier function. In its current form, transfaunation refers to the transfer of microorganisms such as bacteria, protozoa, fungus, and archaea from the rumen of a donor to the rumen of a recipient [67].

### Medicinal Functions of Ruminal Transfaunation

Rumen transfaunation was later utilized as a therapy to improve calf health. Rumen transfaunation enhanced calf health and survival in a field research with a herd experiencing bloody diarrhea and the loss of preweaned calves [68]. Transfaunation is the technique of transferring rumen fluid containing microorganisms and nutrients from healthy animals into animals with poor rumen digestion. This procedure is thought to enhance rumen function and has been used as a biotic therapy for ketosis, anorexia, and numerous causes of dyspepsia such as rumen acidosis. As indicated in the review by Depeters and George [1], this procedure is recommended in various text books and practical guides on bovine medicine.

## Simple Indigestion

Sudden changes in food contents can cause anorexia in ruminants [69], which is reflected in rumen pH alterations [70]. Anorexia (decrease in appetite) with ruminal hypo motility to atony (stasis) is a clinical indication of uncomplicated dyspepsia in dairy calves [70,71]. Sudden changes in dietary components can cause anorexia in ruminants [69], which is reflected in variations in rumen pH (Merck and Co, 2010). Ruminal fluid transfaunation from a healthy donor animal to an animal suffering from mild indigestion is a widely suggested technique for dairy cattle and other ruminants [72]. Rumen transfaunation was found to be advantageous for sheep employed in biomedical research that had minor indigestion [72].

In their biomedical research, sheep were administered pelleted diets, which contributed to the development of subclinical rumen acidity. Ruminal fluid transfaunation successfully treated uncomplicated indigestion in sheep [72], furthermore improves cow health after calving, milk output, and animal health in a well-managed herd [52]. Transfaunation or refaunation is a popular medical treatment in animal medicine to cure ruminant indigestion [73].

## Displaced Abomasum

Ruminal fluid transfaunation was employed as an adjuvant therapy after surgery, and cows were transfaunated following surgical correction of a left-displaced abomasum, treatments were administered immediately following surgery and again on the first postoperative day [11]. Ruminal fluid transfaunated cows showed greater dry matter intake and milk output compared to control cows on day 2 following surgery and for the next three days. Serum concentrations of B-hydroxybutyrate on days 3 and 5 post-surgery were considerably lower in transfaunated cows than control cows. Administration of rumen fluid to cows convalescing following surgical correction of left displaced abomasum showed favorable benefits [11].

## Plant Intoxicants

Mimosine (amino-B-(N-[3-hydroxy-4-pyridone]) propionic acid) is a poisonous amino acid found in plants of the genera *Leucaena* and *Mimosa* [74,75]. Mimosine inhibits protein synthesis and, when taken long-term by animals, results in decreased hair growth and loss with suspected antimitotic action. Mimosine was metabolized in the rumen to 3-hydroxy-4-pyridone [75]. The rumen microbiota in cattle and goats was capable of degrading mimosine but not its hazardous metabolite, 3, 4-dihydroxy pyridine. *Leucaena*, on the other hand, was not hazardous to ruminants because rumen microorganisms could breakdown both mimosine and 3, 4-dihydroxy pyridine [76]. Recently, rumen fluid from goats containing rumen bacteria capable of digesting sodium monofluoroacetate, a poisonous chemical found in *Amorimia spp.*, ruminal transfaunation was utilized in order to prevent animal poisoning [77].

Tannins are polyphenolic chemicals found in plants and also they are antibacterial to some microbes and have been demonstrated to lower methane generation in sheep and goats [78]. Tannin intake can also be detrimental to animal health [79]. Tannins bind proteins, and research is being conducted to harness this binding feature to minimize protein breakdown in the rumen in order to improve nitrogen consumption by ruminants [80] and to prevent bloat in cattle grazing alfalfa [78].

## Acidosis

It is generally recognized that ruminants' rumens serve as critical sites for digestion and metabolism, and that the ruminal bacteria play a crucial role in these processes [81]. Ruminant health is significantly impacted by changes in the structure and function of the ruminal microbiota [82]. Ruminal acidosis can be caused by intake of fine particle size (diameter smaller than 0.07 in.) or highly concentrated feeds containing quickly fermented carbohydrates [83]. Such diets necessitate less chewing, resulting in reduced saliva production, which reduces buffering capacity [84]. Consumption of quickly digested carbohydrates increases rumen VFA production, as a result, lactic acid production. As a result, ruminal pH drops and the ruminal fauna shifts from primarily gram-negative to gram-positive organisms [85].

This illness is characterized clinically by ruminal atony, in appetence, and lethargy [86]. Transfaunation is the process of introducing healthy protozoa, VFA, and gram-negative bacteria from a clinically normal ruminant into the rumen of an in appetent sheep in order to repopulate the ruminal fauna and correct the pH. Transfaunation is commonly used to treat ruminal atony and anorexia in ruminant animals [11,86]. Acute or clinical acidosis occurs when the ruminal pH goes below 5.0. Clinical symptoms may include decreased salivation, lethargy, decreased gastrointestinal motility, anorexia, and diarrhea [87]. Acute rumen acidosis represents an economically significant loss to the beef and milk production business. Ruminants have a complex stomach system, with the stomach being separated into four compartments, the biggest of which is the rumen. Clinical rumen acidosis is still the principal cause of illness and death in current ruminant production systems [71]. Reticulum-rumen function, which includes cattle health and animal welfare, is a necessary condition for productive behaviour [24].

Clinical ruminal acidosis occurs when the rumen's fluid pH falls below 5.2 as a result of an excessive buildup of organic acids [88,89]. The classic situation leading to clinical rumen acidosis is excessive feeding of quickly fermentable carbohydrates, sometimes known as "grain overload". Excess grain consumption is not required for the development of the syndrome because any rapidly fermentable carbohydrate (apples and other fruits, bakery waste products, incompletely fermented brewery products, and standing green corn) can provide the necessary substrate for clinical disease development [71]. When the rate of generation of VFA and lactate exceeds the rate of absorption, the pH of the rumen begins to fall. Volatile fatty acids and lactate accumulate in the rumen fluid and are absorbed into the systemic circulation [90].

Previous research showed that ruminal acidosis, a typical ruminal digestive problem in dairy or beef cattle given large levels of readily fermentable carbohydrates can disrupt ruminal microbial homeostasis and rumen epithelial function and, finally, result in noticeable decreases in animal performance, which results in significant financial losses and adversely impacts the sustainability of the ruminant sector [88]. Ruminant scientists agree that restoring ruminal bacterial equilibrium with rumen acidosis would aid rumen function recovery [91,92]. Ruminal transfaunation is a practical approach in production in which ruminal fluid containing healthy microbial flora and buffer systems is transferred from a healthy donor to receptors suffering from rumen disease [1]; it is also regarded a routine and successful treatment to rumen acidosis in bovine production systems.

A study looked at the benefits of ruminal transfaunation for sheep with ruminal acidosis and discovered that the sheep who received ruminal transfaunation recovered to normal health [72]. However, there is a scarcity of data on the dynamic changes in rumen fermentation and bacterial populations that occur after ruminal transfaunation in sheep with rumen acidosis, as well as its favorable effects on rumen epithelial shape and function [1].

## Effect of Ruminal Transfauntion on Fattening Lambs

Ruminal transfaunation improved the mean blood levels of IgA and IL-6 in weaned lambs compared to control animals, however, it has lowered growth performance, nutritional digestibility, and feed intake [12]. Contrasting to previous research, transfection of gastrointestinal microbiota prevented rumen acidosis in sheep and reduced gut barrier damage in young piglets [14,65]. Research with calves suggests that ruminal transfauntion may not be suitable for lambs during weaning and that fast changes in the gut flora during weaning may be hazardous [13].

### Effect of Ruminal Transfauntion on Gastrointestinal Microbiota of Fattening Lambs

In order to provide the host with nutrients and energy, the symbiotic bacteria in the rumen breaks down the food that is consumed and breaks down plant components into various VFAs and ammonia. This process improves digestion. Therefore, increased sheep feed efficiency and therefore production may result from improved rumen microbial digestive capabilities. Various methods have been used in the past to reroute the rumen microbiota, such as altering animal diets [6], lowering rumen pH [4], and reducing rumen protozoa numbers [5]. Microbial transplantation has been considered as one of the potential approaches for remodelling the symbiotic microbiota in small animals [93-96]. The recipient cows' fermentation characteristics recovered to their former state immediately after transplanting [97], and their bacterial profiles returned to their original state, demonstrating that the host has a major influence on rumen microbiota re-establishment. In cows with dysbiosis brought on by antibiotics, tranfaunations improved richness and diversity, and the donors' microbiota was able to invade the rumen [51]. In the same time, patients with dysbiosis brought on by antibiotic usage and *Clostridium difficile* infection can also greatly benefit from faecal microbiota transplantation in humans [98].

Compared to control animals receiving water, transfaunation given to lambs throughout their early lives improved the bacterial diversity [99]. After weaning, the gastrointestinal environment changes, creating opportunities for particular bacteria species to grow. This progressively alters the microbiota, and utilizing ruminal transfaunation to transfer a mature microbiome to the rumen just accelerates up this process [65,100,101].

There were no apparent changes in the pH of rumen fluid between control and transfaunated cows at any point of time, although the two groups' pHs were more suited to rumen digestion during the course of the experiment than those of the non-transfaunated group [102]. The fermentation of the ingested food by the ruminant is entirely dependent on the microbial community [103,104]. Most of the energy and protein required by the host are supplied by the fermentation process, mostly in the form of short chain fatty acids (SCFAs) and microbial proteins [46]. Microbial colonization may be influenced by a number of parameters, including nutrition and the environment [105]. When the microbiota is less stable and more basic, these adjustments can be more noticeable in subsequent colonization cycles [106]. A diversified and established microbial community in the rumen is more durable and resistant to disturbances as compared to less developed ecosystems.

When the disturbance is removed, the microbiota's composition and function tend to recover to pre-treatment levels [107,108]. However, in juvenile ruminants, the impact of modifications may last for some time after the modification is completed. Saro, et al. [106] showed that a long-term early life treatment may influence the composition of the rumen microbial community and that this effect can last for weeks after the intervention. Abecia, et al. [109] demonstrated that the treatment effect lasted after the alteration was removed in the early life of baby goats. Currently, numerous methods for influencing rumen fermentation through early life microbiota have been investigated, including diet types [110], weaning technique [111], rumen fluid inoculation [112], and different additives [106,113].

## Effect of Ruminal Transfauntion on Production Performance of Fattening Lambs

**Effect of Ruminal Transfauntion on Body Weight and Body Weight Gain:** Microbial transplantation has been considered as one of the potential approaches for modifying host performance and remodelling the symbiotic microbiota in small animals [93-96]. Rumen fluid transplantation in fattening lambs decreased average daily gain in live weight and apparent digestibility of ether extract in 3 month old fattening lambs, and it decreased apparent digestibility of NDF and ADF in one year old lambs [12]. Yin, et al. [12] reported that the initial and final live weights were similar in the 3 month and one year fattening lambs exposed to ruminal fluid transfaunation in comparison with controls.

**Effect of ruminal transfauntion on feed intake and feed conversion ratio:** The feed intakes of transfaunated cows were higher than those of the non transfaunated ones; appetite differences may have contributed to the variability of rumen protozoa, pH values. Cows that received rumen fluid had significantly greater feed intakes, significantly greater daily milk yields, and significantly lower rumen fluid acidity. Because non-transfaunated animals subjected to indigestion after consuming concentrate may have rumen fluid pH that is low for several weeks [102]. However, rumen fluid transplantation in fattening lambs decreased average feed intake in 3 month old fattening lambs compared to control lambs [12]. On the other hand, cows that received rumen fluid had much higher feed intakes, higher daily milk outputs, and significantly lower rumen fluid acidity; furthermore, transfaunated cows also had significantly higher feed intakes than non-transfaunated cows [11].

Furthermore, rumen transfaunation enhanced the dry matter intake of treated bulls above deionized water-treated bulls [114]. Ruminant scientists agree that recovering the microbiota in the rumens of stressed and travelled cattle quickly results in enhanced animal health and performance following transportation [92]. After transportation, the bulls given 10 kg of rumen fluid consumed more feed than the control group [114]. Also, according to Galbat and Keshta [102], cows in the transfaunated group consumed much more feed on a daily and cumulative basis and produced significantly more milk than cows in the non-transfaunated group. In cattle, the feed intake improved as a result of the rumen fluid treatment. When compared to the control group, animals that received 1 liter of rumen fluid consumed considerably more feed on days 1 and 4 after ruminal transfusion [115]. Compared to the transfaunated cows, cows in the non-transfaunated group showed a lower protozoal counts and activity as well as reduced milk output [102].

### Effect of Ruminal Transfauntion on Antioxidant Activity of Fattening Lambs

Free radicals, including reactive oxygen and nitrogen species (ROS and RNS), are chemically reactive substances that may destroy macromolecules including lipids, carbohydrates, proteins, and nucleic acids by oxidative damage [116]. Antioxidants help prevent cell deterioration by lowering free radicals [117]. In healthy animals, there is a balance between free oxygen radicals and the protective antioxidant system. Oxidative stress is the term used to describe the shift in the antioxidant system's favoring of oxidants over free radicals. In many diseases, oxidative stress contributes to cellular and molecular tissue damage [116]. Malondialdehyde (MDA), the final product of lipid peroxidation, enzymatic antioxidants such as superoxide dismutase, glutathione peroxidase, and catalase, non-enzymatic antioxidants such as reduced glutathione, vitamins C and E, total antioxidant capacity (TAC), and total oxidant status (TOS) are all commonly used markers in determining oxidative stress in sheep [118].

The determination of oxidative stress has recently become significant in clinical practice as a complementing component [119]. Shearing has been shown to cause a considerable rise in blood MDA values, indicating the presence of oxidative stress in sheep [120]. The antioxidant indicators' blood levels were unaffected by ruminal transfaunation, however, among the intestinal permeability indicators, the mean serum level of D-lactate dehydrogenase was greater in both ruminal transfaunation groups than in the control group [12].

### Effect of Ruminal Tansfauntion on Immune Response of Fattening Lambs

When it comes to immunoglobulins in the weaned lambs, the ruminal transfaunation group's mean blood levels of IgA and IL-6 were greater than those of the control groups in comparison [12]. Researchers found that the activation or inhibition of Toll-like receptor (TLR) by microbial signals in humans might influence the modulation of immune responses [121]. As a result, it was hypothesized that rumen microorganisms are critical for the development and control of the neonatal immune system, and that rumen microbes play an important role in sustaining long-term health and production. Malmuthuge, et al. [122] discovered that the gut microbiota and mucosal immune activities of lambs fed MR (milk replacer) or MR+S (milk replacer + starter) changed throughout the weaning transition. For ruminants, the earliest microbial sources and profiles may be essential in determining the microbe-immune system interaction and its implications for adult health in the early postnatal period. For weaned lambs, ruminal transfaunation has improved immunological and inflammatory reactivity [12].

### Effect of Ruminal Transfauntion on Mortality of Fattening Lambs

Stresses such as decreased food digestibility, leaky gut epithelia, or immunological dysfunction can all cause an increase in morbidity and mortality during the weaning phase [123]. Post-weaning care of lambs is a prevalent problem, as evidenced by a 4.6 percent post weaning death rate for sheep [124]. As the animals adjust to solid diet during weaning, the gut microbiota progressively changes. This reconfiguration of the microbiota may increase the stress associated with weaning [125]. According to several studies like Blanton, et al. [126], Charbonneau, et al. [127], and Ahern and Maloy, [128], it involved a variety of interactions between bacteria that affect feed digestion, gastrointestinal integrity, and immunological reactivity [129]. Ruminal transfaunation may not be appropriate for lambs during weaning, and research with calves suggests that fast changes in the gut microbiota during weaning may be hazardous [125-136].

## Conclusion

Finally, it is important to mention that intervention strategies to improve the production performance and health of fattening lambs have been the focus of many published studies, which apply different approaches, including nutritional manipulation (i.e., pelleting of the total mixed ratio and diet formulation according to the metabolic condition of the lambs), as well as dietary supplementation of feed additives in the diet (e.g., prebiotics, synbiotics, probiotics, vitamins, minerals, etc.), improving of genetic traits of sheep by different methods such as selection, presenting fresh sires, inbreeding, crossbreeding and formation of new breed. Nevertheless, effectiveness of most of the interventions has been variable or inconsistent. More recently, innovative approaches have been explored, including reshaping the ruminal microbiome by ruminal transfaunation. However, no one of the previously mentioned methods has shown harmonic positive effects, indicating that the previously mentioned methods to improve animal health and production performance by reshaping the symbiotic microbiota have not been achieved yet and still need further research and study.

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