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Study on Differences in Forage Protein Utilization and Optimization Paths for Ruminants and Non-Ruminants

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Abstract: Nutritional intake affects animal growth, and foraging is one of the ways in which animals take in nutrients. A good understanding of the digestive mechanisms of animals can improve the nutritional composition of feeds for the target group being fed. This paper compares and contrasts the digestive mechanisms of ruminants and non-ruminants, with an in-depth discussion of specific structures and functions as well as optimized pathways for different animal forage digestion pathways. Findings suggest that ruminants rely on their unique four-chambered stomach, while non-ruminants rely on enzymes in the small intestine. Forage nutrient composition has been improved in various ways by researchers focusing on different parts of the digestive mechanism pathway, such as absorption in the small intestine and microorganisms in the rumen, which can be seen in the differences in the digestive system and the digestive pathway. In addition, this paper discusses substances that favor animal growth, and will provide new perspectives on feeding techniques that will improve the nutritional balance and growth of animals.

Keywords: Ruminant, non-ruminant, forage, digestion.

1. Introduction

Nutrition plays a crucial role in animal physiology. By influencing the ability of animals to absorb nutrients and their reproductive ability, nutrition can affect the animal's health status and productivity. For instance, a study measured the pressure in ruminants' reticulum to determine various behaviors made by cows [1]. This means that by deep study of the way animals digest nutrition, the improvement of feeding forage can be made and thus it can promote the development of agriculture. s Ruminants and non-ruminants differ in the absorption and utilization of proteins and these differences are caused by the different metabolic pathways and digestive system. Ruminants like cattle and sheep have the complex four-compartment stomach which can allow them to better digest cellulose. Even if cellulose is hard to converted into available energy, microbes in ruminants help them for fully use of it. Non-ruminants have only one stomach, hence the name monogastric, and rely more on enzymes in the small intestine for their digestive system.

The food needs for both ruminants and non-ruminants are being noticed by people. For growing yak, the study mentioned how the diverse level of dietary protein will influence their growth by affecting the fermentation in the rumen [2]. For single-stomach animals, a study found that some green biomass can be used to provide sustainable protein [3]. All these studies are based on the metabolic pathways and digestive systems of animals. Besides the studies for improving the main forage, there are also studies focusing on the additives that can be used, such as essential oil and

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aromatic plants [4]. However, there are not as many articles discussing the waste caused by animals during their digestion process. Animals will secrete nitrogen into the environment and may cause related problems such as climate change [5]. More studies can be motivated by focusing on improving the forage to reduce the potential harm that may be brought by the waste produced by animals. Even if ruminants and non-ruminants are studied separately, their digestive systems still have some similarities in their small intestines and large intestines. Future studies can also pay attention to forage that can have a beneficial influence on ruminants and non-ruminants at the same time.

Based on current studies, this paper proposes differences in forage protein digestion and optimization of feeding forage for ruminants and single-stomach animals. Firstly, the difference in protein digestion will be discussed by explaining the structure and function of digestive systems and metabolic pathways in digestion for both types of animals separately. Then, the differences are considered and appropriate improvement programs are sought for specific animals to increase their digestibility. Increased digestion rate and productivity are important for agriculture to improve the economic benefit. This paper aims to provide an overview of current studies on animal foraging and provide some new perspectives for improving the feeding forage.

2. Differences in Protein Digestion for Ruminants and Non-Ruminants

2.1. Digestive System of Ruminants

2.1.1. The Structure and Function of Ruminants' Digestive System

When ruminants like goats take in food, the food follows the digestive pathway of first entering the mouth, sliding into a four-compartmented stomach through the esophagus, then going through the small intestine, cecum, and finally the large intestine. The four-compartmented stomach is the most complex system for ruminants, which includes rumen, reticulum, omasum and abomasum. These four stomach chambers display different specific digestive functions.

The rumen is the largest and most important stomach compartment in ruminants, which digests about 70% of the protein. The rest 30% would be sent into the abomasum and small intestine. There are a lot of microbes in the rumen to help it digest food. Rumen is related to various microbe reactions. Rumen microbes are nearly all anaerobic and rumen provides the non-oxygen condition for its fermentation. Microbes would utilize fermentation to decompose cellulose and other implicated botanic ingredients. The combination of the rumen and reticulum is called the reticulum, a structure that mixes and breaks down methane gas and is also where plant fiber is digested [1]. The reticulum acts as a sifter, filtering out indigestible material. The third compartment of the ruminant stomach is the omasum, whose main function is to reabsorb fluids, facilitating the sorting of particles and the harvesting of microorganisms. By the above means digested material can be diluted less so that it can be better digested by enzymes in the lower digestive tract [6]. The abomasum is the last and final gastric compartment which digests proteins by producing gastric juice. The function of gastric juice is similar to that of the monogastric stomach in non-ruminants and is also important for the denaturation of macromolecules such as hemicellulose in sheep species [7].

Other organisms such as small intestine and large intestine also play a great role in ruminant digestion. Duodenum, with the help of the product produced in other organs like the liver and pancreas, is responsible for emulsifying the lipids by breaking large fat into small droplets for better absorption. The small intestine takes care of the war absorption as well. War reabsorption will occur in the large intestine to fully uptake the water.

DOI: 10.54254/2753-8818/93/2025.22374

2.1.2. The Digestion of Protein in Ruminants

The most crucial characteristic of ruminants is that they use microbes to translate protein into amino acids which ruminants could easily absorb. CH2O gained from the food would first be digested to glucose and then pyruvic acid by the digestive tract. After that, pyruvic acid would be translated into volatile fatty acid (VFA), relying on the effect of microbes in the rumen. VFA, a primary energy source for ruminants, was once estimated to contribute as much as 75% of the total metabolic energy [8].

The digestion of protein starts from the entry of true protein and non-protein nitrogen (NPN) into the rumen. NPN metabolism is a very complex process. Dietary NPN will be degraded, microbes will uptake ammonia, mycoprotein (MCP) will be synthesized, ammonia will be absorbed through the rumen wall, and then enter the omasum [9]. The lysis of protein would result in polypeptides and become amino acids. With the reaction among NPN, amino acids, and microbes in rumen, MCP would be produced. Then, MCP would be transported into abomasum to be digested.

When cattle ingest a bunch of grass, the food will first go through its esophagus to enter its stomach. The food first enters the rumen, where the grass is stored if the cow does not need energy immediately. The food will have some reaction with the microbe in rumen to provide some energy source while waiting. When the cattle want to digest, the food will flow into the reticulum and return to the salivary gland through the esophagus. During the process of chewing, the salivary gland will provide chemical digestion by producing saliva amylase. Saliva amylase can convert starch into maltose, and the salivary gland can provide mechanical digestion by the chewing of teeth as well. After the digestion in the mouth, the food will go to the third compartment in stomach- omasum, where the gastric mucosa can absorb water from the food, and the rest will enter the abdominal cavity to digest proteins. After the entire digestive process in the stomach, the nutrients will enter the small and large intestines, where the water that is not absorbed in the colon will be reabsorbed.

2.2. Digestive System of Non-Ruminants

2.2.1. The Structure and Function of Non-Ruminants Digestive System

In non-ruminants, which are also known as single stomach animals, the digestive system is made up of five parts: ingestion, digestion, absorption, assimilation and egestion. The main organisms involved would be stomach, small intestine, and large intestine. The stomach in non-ruminant animals has a similar function of the abomasum in ruminants. The stomach provides an acidic environment for killing pathogens and the condition that favors enzyme reactions. The enzymes, such as pepsin, in the stomach, can digest protein into amino acids. The structure and function of small intestine and large intestine are nearly the same in single stomach animals as ruminants. Despite water absorption, the enzymes, which were secreted by pancreas and the intestine, allow the degradation of protein. The small intestine also has cellular receptors that are specific in the small intestine on the surface of its epithelium to provide conditions for the uptake of digested nutrients. The rest of the non-digested dietary fiber will be digested in the large intestine. The microbiota in the large intestine will help the digestion process by facilitating the fermentation of dietary fibers.

2.2.2. The Digestion of Protein in Non-Ruminants

The digestion of protein mainly happens in stomach and small intestine. Stomach provides an acidic environment and secretes pepsin to break down protein into amino acids and peptides. In duodenum of small intestine, enzymes such as lipase, amylase, and protease can transform fats into nutrients. In small intestine, the absorption of water takes place.

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The combination of functions of pancreas, liver, gall bladder and small intestine enhances protein digestion in single stomach animals. Pancreatic juice is produced in pancreas. Bile is produced in liver and stored in the gall bladder. It will emulsify the lipids by breaking large fat into small droplets in the gall bladder to favor the following reactions. Lipids that have already been emulsified will be absorbed by small intestine with the help of the specific receptors on its epithelium surface. Some microbiota in small intestine will also take part. Cholecystokinin (CCK) hormone regulation will include the microbiota by regulating the production of bile and pancreatic lipase to influence the digestion of lipids [10]. Compared with ruminants, single-stomach animals' protein digestion will rely more on small intestine instead of the stomach. So, the microbe in small intestine is important for their nutrient uptake.

When a non-ruminant animal like a cock takes in a worm, it will go through the following processes. Worms will be chewed in the salivary gland and sent to the stomach by esophagus. Different from the rumination in cattle, food eaten by a cock will directly be started to digest the first time it enters the stomach. Various enzymes in the stomach will degrade protein into amino acids for further absorption. Then, the nutrient will come to small intestine. Water will be absorbed and digested nutrients will be uptake by the receptors on the surface of small intestine. Finally, the chyme will be sent to large intestine. There occurs the final absorption of water. The dietary fibers which are not digested in the small intestine will be digested here by the microbiota in large intestine [10].

2.3. Comparison and Contrast between Digestion of Ruminant and Non-Ruminant

The digestion of ruminant and non-ruminant both go through the same process is the convert of carbohydrate and cellulose into short-chain fatty acid, the break down of protein into amino acid and ammonia and the hydrolysis of lipids [11]. The cooperation between bile, pancreatic juice and enzymes in small intestine allows the digestion happen in small intestine. The difference will be the diverse focuses of the digestion spot. Rumen plays the most important role in ruminant digestion while small intestine would be more important for non-ruminants. In rumen, ruminants will more rely on the help of microbe to degrade, and thus creates a mutualism relationship. Single stomach animals rely more on the enzyme in small intestine and stomach.

3. The Importance of Forage to Animals

The process of organisms digesting food to absorb and utilize the ingredients in the food to stabilize vital movement, growth and reproduction, is called nutrition. Nutrition has a large impact on the animals' health status. Taking advantage of the feeding forage to improve animals is the main purpose. The history of forage started a long time ago. Feeding with hay for young calves was evaluated by 1897. These foraging plans were considered to decrease the rate of abnormal behavior and improve the development of rumen [12]. The digestion rate of starch and protein can have a large impact on feed conversion rate (FCR) in broiler chickens [13]. Different plans have focused on different phases of animal development and different uses of the animal. For instance, the nutrition plan for beef cattle will focus on increasing the secretions for gastrointestinal hormones and the plan for growing yak will focus on higher nitrogen utilization [2, 14]. However, there are still many questions of whether these forage's safe and efficient. The release of nitrogen when ruminants digest food will cause some burden on the environment as it leads to issues of acid deposition and climate change [5]. Further studies can also focus on improving the waste caused by the process of digestion.

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3.1. Improvement of Ruminant Foraging Technique

3.1.1. Improvement Focusing on Small Intestine

Fermentation in ruminant's forestomach requires a lot of starch and protein. Various enzymes are needed in the small intestine, such as pancreatic α-amylase and sucrase-isomaltase [15]. This complex digestive mechanism of the small intestine is worth studying to reinforce the efficiency of digesting protein. One study determined the effect of RPL-T on soluble protein and starch digestion rate in cattle and found that administrating RPL-T at a certain rate orally can increase the pancreatic α-amylase, and thus accelerate the digestion rate in small intestine [14]. There is still a large number of different enzymes which help the breakdown into amin acids in small intestine, such as protease-trypsin and protease-peptidase. Studies can focus on specific substances that can speed up these enzymes' activity rates to help ruminants improve digestion.

3.1.2. Improvement Focusing on Microbes in the Rumen

Adjusting rumen, which is the most important compartment in ruminants' stomach, can expedite ruminants' digestion on a large scale. Allowing the epithelium of rumen to uptake more VFA, the addition of 0.9% postbiotics from L. plantarum RG14 can give the intake of nutrients a better way [16]. VFA improvement is not the only perspective, since sometimes the supplied substance may have no effect on VFA concentration, but on other proteins such as rumen degradable protein (RDP) [17]. Fermentation and certain microbes in rumen are also essential starting points for us to improve ruminants' feeding forage. When studying yaks which live in the cold season. By increasing the metabolism of arginine and proline, a high level of protein can promote the formation of protein for microbes in the rumen [2]. Ruminal microbes can utilize NPN to digest protein.

3.2. Improvement of Non-ruminant Foraging Technique

When looking into non-ruminants foraging techniques, studies can start with the important ingredients in their food: starch and nitrogen. The starch disappearance and nitrogen disappearance rate will influence the digestion rate in the lumen of the intestine. Through studies over many years, feed ingredients that can affect these two rates are studied. Sorghum, canola and soybean meal all have specific impacts [13]. To meet the increased requirement for available protein sources such as forage feed, studies seek alternatives such as grass and forage legumes. The high CP concentration allows lucerne, one type of legume, to fulfill the need for amino acids for single stomach animals to become a great raw material for sustainable protein sources [3]. Despite the improvement of main feeding forage, studies also focus on the additives that can be used to improve non-ruminants' health. Components such as herbs and essential oils can have a positive influence on animal production. Along with some other components, they can impact the activity of EOs to optimize EO products for single stomach animals' growth [4].

4. Conclusion

This paper discusses the differences between the digestive system and optimizing paths for feeding forage for ruminants and non-ruminants where the special four compartment stomach shapes its digestion pathway. Thus, more studies of forage improvement for ruminants have been made focus on ruminant's stomach compartments such as rumen. Non-ruminants are more dependent on enzymes in the small intestine for digestion as they do not have a unique stomach. This paper builds on existing research not only on integrating the characteristics of protein digestion in ruminants and non-ruminants and the corresponding technological improvement advances in forage, but also lays the

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foundation for future research and expands new perspectives on the topic. There are still some limitations in this paper, such as the lack of statistical data that limits the creation of a database of different forage components. Those involved in animal husbandry should unite to provide more benefits for future research in this field. However, the outlook for future animal foraging study is promising. Improvements on feeding forage will allow better future growth of the animals and will also provide benefits for human.

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