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Perspective Article

On Rumen Microbial Evolution: Food Security Prospects

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Abstract

This article elaborates on discovering circadian rhythmicity of rumen microbial characteristics including pH, osmolarity, volatile fatty acids production and absorption capacity, lactate utilization capability, rumen liquid and solids volume and pool, microbial protein synthesis and efficiency, and microbial population diversity and variations. The evolution of ruminants on nature and during modernization has shaped such circadian properties of the rumen microbial ecology. Insights into such evolutionary microbial exclusivities can greatly help develop innovative pragmatic strategies to minimize risks of metabolic disorders and improve farm economics, human food security, and environmental quality measures.

Keywords: Evolution; Rumen; Microbial Ecology; Circadian Rhythm; Environment

Introduction

The rhythmic harmony in grazing and, thus, in nutrient delivery to rumen has significantly contributed to the circadian nature of microbial ecology. As a result, rumen microorganisms have developed specialized mechanisms to effectively cope with the changing and fluctuating environment including grazing and drinking time and rate, ruminating timing and frequency, and measures of the modern farming such as milking [1]. The objective of this article was to establish an evolutionary principle in rumen microbial fermentation and develop innovative strategies to optimize microbial metabolism, host ruminant productivity and health, and environmental attributes of the rumen ecology.

Discoveries and Discussion

Dependent on a circadian nature, ruminants have evolved to graze during day with few major peaks around dawn and dusk [1,2]. Modernization, however, has in ways compromised optimal natural rumen fermentation. This is in part due to altered dietary properties and increased dependence on feeds (e.g., starches and fats) that are not physically effective enough to maintain adequate rumination, chewing, insalivation, and rumen buffering capacity. In addition, alterations in grazing/feeding frequency, sequence and intensity which have occurred in modern farming may have in turn challenged the natural rhythms of rumen fermentation. Such challenges have demanded new adaptations in microbial population diversity as well as fermentation capacity and efficiency [3].

Establishing synchronies between the internal rumen microbial circadian properties and the external modern management strategies can help optimize microbial efficiency [4,5]. Ruminants have evolved to eat mostly during day and ruminate predominantly overnight. This is simply because natural rumination must and can only occur when the ruminant is not grazing, is relaxed, and is not threatened by the wild life. Recent discoveries indicated that in-house dairy cows and beef cattle fed once daily in morning vs. evening had improved productivity and sometimes increased feed efficiency [6-9]. Moreover, eating rate specially within 3-hour post-feeding was considerably higher in evening vs. morning fed cows [10,11]. This implies that shifted timing of eating alters circadian and, more importantly, the postprandial nutrient intake rhythms. As a result, postprandial patterns of rumen substrate availability, microbial fermentation properties (e.g., pH, osmolarity, volatile fatty acids production and absorption capacity, lactate utilization capability, rumen liquid and solids volume and pool, microbial protein synthesis and efficiency, and microbial population diversity and variations), and hepato-portal drained visceral supply of energy-generating, milk-secreting and tissue-depositing substrates were dramatically altered by shifting the eating time [10-12].

Nocturnal instead of diurnal eating was shown to increase rumen volume and concentrations of volatile fatty acids shortly post-feeding [12]. In light of the increased milk energy and fat density and production in evening vs. morning fed cows, the discovery suggests that the increased feed intake shortly post-feeding by evening eating did not compromise rumen microbial metabolism and health despite increasing acidity and the risk of subacute rumen acidosis (SARA), which would otherwise reduce milk fat production. A possible mechanism for the increased milk production in parallel with increased eating rate and rumen acidity is the increased rumen volume in evening fed cows. A greater rumen volume would provide greater sites of organic acids absorption and reduced likelihood of prolonged acids accumulation and microbial damages. These findings imply that the evolutionary patterns of the rumen microbial ecology offer perspectives to develop modern feasible strategies (e.g., manipulating circadian feeding/eating timing, frequency and sequence) to help optimize rumen physiology and ruminant efficiency and health.

Rumen microbes related metabolic disorders and abnormalities such as SARA, bloat, uncontrolled rumen endotoxins release from gram-negative bacteria, induced systemic proinflammatory responses, weakened immunity, and hepatic steatosis all cause major losses to global modern ruminant enterprises. Should the rumen microbes and the ruminant tolerate high-risk feed components (e.g., rapidly degradable starches) more at certain circadian times, pragmatic chances are to optimize feeding management to not be shocked by overly disturbed rumen microbial metabolism [13,14]. However, extensive complementary future research is required before uncomplicated feasible global prevention approaches can be formulated to minimize risks from the above metabolic complexities and the resulting health issues. This is a significant path into sustainable human food security.

Implications

In view of the rumen microbial evolution on a circadian basis, opportunities exist to develop modern management strategies to reduce microbial shocks and occurrence of metabolic disorders. Optimizing circadian feeding and eating timing and frequency is among feasible global approaches to maximize synchronies between the internal rumen microbial physiology and the external animal and feed management practices. The result will include improved microbial energetic and mass production, increased ruminant feed efficiency, improved animal health and human food production, and reduced output of undesirable products per unit of food input from the modern ruminant farming.

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