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Rumen Fungi and Their Role in Ruminal Fermentation

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Introduction

There has been an evolution of the gastrointestinal tracts of herbivorous mammals to provide microorganisms with environments conducive to microbial fermentation of plant fibre. The ecosystem of a rumen is multiplex where nutrients ingested by ruminants are assimilated by fermentation process. Such alimentary systems are synergic, with the host providing inputs of heat, moisture and food while the microorganisms contribute protein as microbial biomass and by-products of digestion such as volatile fatty acids for utilization by the animal. The microbial ecosystems in the gut of herbivores are invariably very complex both in terms of types of microorganisms present and their interactions with each other and the host. Normal value of fungal count in animals fed on 60% roughage and 40% concentrate based diet is 10^4 to 10^6 zoospore/ml rumen content.

Rumen fungi

There has been an evolution of the gastrointestinal tracts of herbivorous mammals to provide microorganisms with environments conducive to microbial fermentation of plant fibre. In 1975, Orpin recognized the motile zoospore stages (flagellate protozoa) of a new class of microorganisms, the anaerobic chytridiomycete fungi and the first named species *Neocallimastix frontalis*. They are anaerobic in nature. The cell wall of anaerobic fungi has chitin as the main structural component. Instead of mitochondria, ATP-generating organelles (hydrogenosomes) are found which produce H2. A common characteristic of rumen fungi related to ruminant nutrition is their ability to colonize extensively the lignin-containing plant cell walls of forages. Fungal biomass is 8-12% of total microbial biomass in rumen.

Life cycle - The biology of anaerobic fungi (AF) is characterized by a complex life cycle similar to that seen with aerobic chytrid fungi. The most commonly observed growth cycle alternates between a motile zoospore stage and an immobilized thallus bearing one or more sporangia. Depending on the fungal genus, the zoospores have either a single flagellum or a bundle of about fifteen flagella (range: 7-30) beating in synchrony.

The zoospores are attracted to pieces of freshly ingested plant material by chemotaxis

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After attaching to the feed particle, they encyst and germinate, eventually to form a larger vegetative structure (the fungal thallus) composed of the sporangium and the rhizoid.

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A mature sporangium contains one or two to as many as 88 mononucleate zoospores formed by repeated division of the single fungal nucleus contained in the original zoospore body.

↓

Zoospores are then released

The rhizoid is the structure which attaches to the growth substratum and penetrates into it. When these fungi are cultured, their life cycle varies between 24 and 32 h, though zoosporogenesis has been reported to occur as little as 8 h after germination. The time span of a typical fungal growth cycle in the rumen is likely to be similar to the mean retention time of digesta particles in the rumen (about 18-24 h).

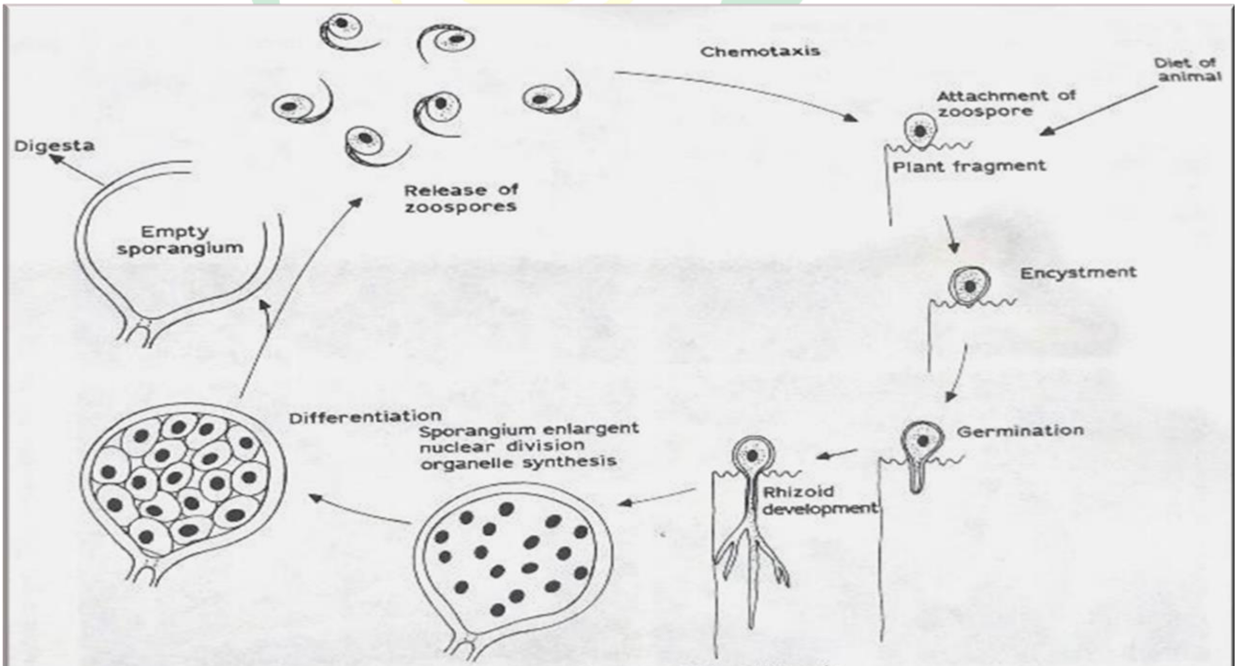

Fig. 2. Life cycle of *Neocallimastix*.

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Distribution

Anaerobic fungi colonize the alimentary tracts of herbivorous animals that consume a fibrous diet and have a digestive retention time sufficient for a complete fungal life cycle. They are present in the more important species of domesticated ruminants (sheep, goats, cattle and water buffalo), as well as occurring widely among many different species of herbivorous mammals, both ruminant (such as antelopes and deer), ruminant-like (such as camelids) and other foregut fermenting animals (such as kangaroos) as well as large hindgut fermenters (such as horses and elephants).

Colonization- Initial transfer of fungi would occur between juveniles and their dam. Some important species of fungi isolated from rumen of domestic and wild animals are given in Table 2.

Table 2. Source of isolation of different species of fungi.

Sr. No.	Fungus	Source of isolation
1.	Neocallimastix frontalis	Cow
2.	N. patriciarum	Sheep
3.	N. hurleyensis	Cattle
4.	Sphaeromonascommunis (Caecomycescommunis)	Cattle
5.	Caecomycesequi	Horse
6.	Orpinomycesbovis	Cattle
7.	Anaeromycesmucronatus (Ruminomycesmucronatus)	Cattle
8.	Ruminomyceselegans	Cattle
9.	Piromycescommunis,Piromycesmae, Piromycesdumbonica	Horse, elephant

Enzymes

The anaerobic fungi produce a wide range of polysaccharide degrading enzymes and broad range of excellent hydrolases including cellulases, xylanases, mannases, estrases, glucosidases and gluconases, which can be organized in cellusomes.

Fungi secreted group of enzyme.

1. Polysachharidases: consisted of endoglucanase, xylanase, cellodextrinase and amylase.

2. Glycosidases: consisted of α and β-glycosidases, β-frucosidase, β-xylosidase and α,1-arabinofuranosidase.
3. Esterases: consisted of acetyl xylan esterse, β-coumaryl esterase and ferulolyl esterase.

The ability to produce high concentrations of cellulases and xylanases and to produce enzymes active against "crystalline" cellulose states that fungi are potentially active fiber degraders. Enzymes have been found associated with the rhizo-mycelium and many were also secreted into the surrounding environment.

Interaction

Protozoa - The interaction of fungi with ciliate protozoa would predominantly occur in the fluid phase of digesta and on the surface of plant particles where ciliate protozoa are often observed. Removal of protozoa from the rumen leads to an increase in the numbers of fungal zoospores. Protozoa digest fungal biomass.

Bacteria – Rumen bacteria may decrease fibre digestion by fungi. Colonization of forages by fungi was substantially greater when antibacterial antibiotics were included in rumen fluid media.

Contribution of fungi to digestion in ruminants

A. **Feed Intake** - AF exert their major effect in the rumen by facilitating the physical disruption during rumination of the fibrous particles of poor quality feed which leads to a more rapid clearance of these particles from the rumen. They solublise lignin complexes.
B. **Fibre Digestion and Fermentation in the Rumen-** AF contribute significantly to ruminal fiber degradation by attacking plant cell walls in two ways, i.e., enzymatically, and physically.Fungi are considered to have an ability to modify particle size or other fiber characteristics that relate to intake or passage of fiber through the intestinal tract. Acetate is produced by anaerobic fungi as a major product during carbohydrate fermentation without the production of any propionate or butyrate.
C. **Protein Digestion** - AF have the potential of contributing to the protein supply of the host animal, both through the production of proteolytic enzymes in the rumen and as a

proportion of the microbial protein synthesized in the rumen which passes to the abomasum and intestines for digestion and absorption.

D. **Nutrient Source** - The large majority of crude protein absorbed in the duodenum originates from rumen microbes and anaerobic fungi can represent up to 20% of this microbial biomass. Rumen AF possess a highly favorableamino acid (AA) profile and fungal AA were highly digestible for sheep, i.e., showing 90–98% true AA digestibility. AF such as Orpinomyces sp. are also substantially involved in the ruminal biohydrogenation of linoleic acid thus producing conjugated linoleic acids that are absorbed by the host animal.

E. **Feed Additive** - AF strain Piromyces sp. FNG5 improved ruminal degradation of fiber fractions and organic matter, as well as a higher N retention and increased total tract digestibilities of organic matter and fiber fractions in AF-treated ruminants, which was likely caused by higher activities of fungal cell wall-degrading enzymes. Also enhanced growth and milk performance of calves and lactating buffaloes, respectively, as well as higher ruminal fiber degradability in response to administration of different AF strains.

F. **Silage Additive** – The enzymatic array of AF can be deployed as silage additives. Fungal enzymes are widely expressed extracellularly and highly effective in degrading cell wall structures over a wide pH range (4–8). Also these enzymes have high affinity for recalcitrant fiber components i.e. insufficiently degraded in the forestomach system.

Conclusion

Rumen fungi are anaerobic in nature and fungi colonize the alimentary tracts of herbivorous animals that consume a fibrous diet. They exert their major effect in the rumen by facilitating the physical disruption during rumination of the fibrous particles by secreting different carbohydrate digesting enzymes. They can be used as additive to improve fibre degradation.