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RUMEN PARAMETERS OF WEST AFRICAN DWARF GOATS FED SELECTED FORAGE SPECIES AS SUPPLEMENT TO ELEPHANT GRASS

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ABSTRACT

The nutritive qualities of five selected forages (*Spondias mombin*, *Ageratum conyzoides*, *Calopogonium mucunoides*, *Terminalia catappa* and *Dialium guineense*) were investigated. Twenty-four West African Dwarf (WAD) goats were subjected to six dietary treatments with four animals per treatment in a completely randomized design in an *in vivo* experiment that lasted 84 days. All the forages were used to supplement *Pennisetum purpureum*. Animals fed *P. purpureum* + *T. catappa* had the highest rumen pH value (6.85) while the least value (6.67) was obtained in animals fed *P. purpureum* + *C. mucunoides*. Goats fed *P. purpureum* + *T. catappa* had significantly ($P<0.05$) higher total volatile fatty acids (84.67 Mm/100 mL) compared to 65.62 Mm/100mL observed in goats fed *P. purpureum* + *C. mucunoides*. Goats fed *P. purpureum* + *D. guineense* had the highest significant ($P<0.05$) values of glacial ethanoic acid (40.33 Mm/100ml) and propionic acid (24.67 Mm/100mL) and those fed *P. purpureum* + *A. conyzoides* had the highest butyric acid (18.67 Mm/mL). Goats fed *P. purpureum* + *A. conyzoides* had the highest significant ($p<0.05$) total bacteria count value (8.82 x 10^9 cfu/ml). The study concluded that goats fed *D. guineense* supplemented with *P. purpureum* gave the best volatile fatty acids production. While, *S. mombin* could be fed to ruminants due to its high tannin content.

Keywords: *Forages, Rumen fluid, Microbial counts, West African Dwarf goats*

INTRODUCTION

A major constraint to small ruminants production in Nigeria is the scarcity and fluctuating quantity and quality of the year-round feed supply (Fajemisin *et al*., 2013). This has been the basic reason for poor performance of livestock. Tropical grass fodder and crop by-products available during dry season in tropics have a low nutritive value due to their low protein and fermentable energy though they grow rapidly during the period of heavy rainfall and high temperature and this leads to grass maturing early and so contains high level of lignin. Forage quality and availability vary greatly from season to season which however, affect the output of the animals.

One possible way to mitigate this challenge and maintain production in the tropics is to introduce unconventional feeds which cannot be consumed by man but can be converted by ruminants into desirable human food. This will go a long way in reducing the cost of production without a decrease in productivity (Odeyinka, 2001). Multipurpose trees which are part of the natural vegetation and are accessible to farmers have always been useful protein supplement (Osakwe *et al*., 2000).

Current approaches to the evaluation of digestibility and nutritive value of feed resources using conventional *in vitro* feed evaluation and animal studies have resulted in a large body of information about nutrient composition and digestibility (Babayemi and

Bamikole, 2006). However, these techniques are unable to describe the microbial mechanisms involved in ruminal digestion and are unlikely to result in the development of rational feeding strategies. Rumen microbial ecology has been extensively researched into over half a century and many outstanding results have systemically described and characterized the predominant species of bacteria, protozoa and fungi in breeds of livestock that are not indigenous to Nigeria. Ruminal digestion relies upon a ruminal microbial community composed of protozoa, fungi, bacteria and archaea (Dehority, 2003), with the bulk of cellulose hydrolysis thought to be performed by bacteria (Wilson, 2011).

Despite the advancements made, though, more work is needed to better characterize the impact of diets on these populations of microbes, how they interact together synergistically and antagonistically, and how they are influenced by host factors. The objective of this study therefore was to evaluate rumen parameters and microbial profile of WAD goats fed different browse plants with *Pennisetum purpureum* as basal diet.

MATERIALS AND METHODS

Location of the experiment

The feeding trial was carried out at the School of Agriculture, Odoragunshin Epe Campus, Yaba College of Technology, Lagos State, Nigeria. The study site is located within longitude 6.47^0N and latitude 3.58^0E.

Experimental feed materials and sources

Five forage plants were harvested around the premises of the campus (Yaba College of Technology, School of Agriculture, Odoragunshin Epe Campus, Lagos State) and fed fresh to the animals as supplement to grass at 5% body weight (40kg browse plants and 60kg grass) as shown below:

Diet I (Control) – *Pennisetum purpureum* only (100%)

Diet II – *Spondias mombin* (40%) *and Pennisetum purpureum* (60%)

Diet III – *Ageratum conyzoides* (40%) and *Pennisetum purpureum* (60%)

Diet IV – *Calopogonium mucunoides* (40%) and *Pennisetum purpureum* (60%)

Diet V - *Terminalia catappa* (40%) and *Pennisetum purpureum* (60%)

Diet VI - *Dialium guineense* (40%) and *Pennisetum purpureum* (60%)

According to Omoniyi (2014)

Feeding and management of animals

Twenty-four male growing West African Dwarf bucks weighing between 11.10 – 14.20 kg were randomly assigned to six dietary treatments having four replicates per diet in a completely randomized design. The pens were thoroughly washed and disinfected. Animals were de-wormed with Albendazole® 2.5% oral suspension (Anthelmintic) at 1ml/10kg body weight and treated against ectoparasites with Cypermethrin® Pour-on at 1ml/10 kg body weight before allotting them to individual pens. Weights of the animals were taken before the commencement of the experiment and thereafter weekly to monitor weight changes during the trial. A known quantity (40%) of selected forage plants with (60%) *Pennisetum purpureum* were offered to the animals while (100%) *Pennisetum purpureum* only was served to the control animals. Clean water was offered daily *ad libitum.* After two weeks adaptation period had been observed, leftover feed was weighed and discarded every morning. Voluntary feed intake was determined as the difference between feed offered and feed refused. The period of the experiment was 84 days (12 weeks).

Collection of rumen fluid

Rumen fluid was collected from each animal at the end of the experiment prior to morning feeding for fermentative and microbial analysis. About 100 ml of rumen fluid was taken via the oesophagus with the aid of suction tube; the pH and the temperature of the rumen fluid were measured immediately using a pH meter

designed to measure both pH and temperature together. Rumen fluid was collected in the bottle already rinsed with about 1ml of 5% (v/v) orthophosphoric acid solution and stored frozen at -20^0C in an air tight bottle container for determination of volatile fatty acid concentration, ammonia nitrogen etc.

Determination of volatile fatty acids and ammonia nitrogen

Total volatile fatty acid production was determined by steam distillation process using Markham micro distillation apparatus (Markham, 1942). Individual volatile fatty acid (acetic, propionic and butyric acids) was determined using Gas chromatography as described by Mebrahtu (1992). Ammonia concentration, microbial load as well as identification were determined as described by Lanyansunya *et al.,* (2007) using standard methods.

Statistical Analysis

All data collected were subjected to one-way analysis of variance (ANOVA) while significant differences among means were compared using Duncan's Multiple Range Test (SAS, 1995).

Statistical model

$Y_{ijk} = \mu + T_i + _{ij +} \varepsilon_{ijk}$

Where,

Y_{ijk}= observation from animal j receiving diet i

μ= population mean

T_i= mean effect of selected browse plants

ε_{ijk}=Residual error

RESULTS

Effects of the selected plants on total volatile fatty acid, acetic acid, propionic acid, butyric Acid, rumen ammonia nitrogen and rumen pH and temperature of the experimental goats

The effect of the selected forages on the ruminal volatile fatty acids production is shown on Table 1. Diets had a significant influence (P<0.05) on the total volatile fatty acid and butyric acid production. Animals on *P. Purpureum + C. mucunoides* recorded the least value (65.62Mm/100mL) of total volatile fatty acids (TVFA) while the highest (P < 0.05) value (84.67Mm/100mL) was observed in the animals fed *P. Purpureum + T. Catappa* at the end of the experiment. Acetic acid values ranged between 32.33 - 40.33 Mm/100mL in animals fed *A. conyzoides + P. purpureum* and *P. purpureum + D. guineense* at the end of the experiment. There was no significant (P>0.05) variation in the values of acetic and propionic acids. Goats fed *P. purpureum + A. conyzoides* recorded the highest (P<0.05) value (18.67 Mm/mL) of butyric acid while goats fed with the control diet had the least value (7.67 Mm/mL). Ruminal ammonia nitrogen concentration ranged between 6.80 – 9.72 mg/L in animals fed *P. purpureum + D. guineense* and *P. purpureum + C. mucunoides* respectively. Addition of plant forages had no significant (P>0.05) effect on the pH of the rumen liquor of goats at the end of the study. Significant reduction in rumen temperature at the end of the study was observed in goats fed the selected forages. However, goats fed *P. purpureum + A. conyzoides* had the highest value (34.87^0C) while the least value of 32.90^oC was observed for goats fed *P. purpureum + T. catappa*.

Effects of selected plants on the rumen microbial count of the goats

The experimental diets significantly (P< 0.05) increased total viable bacteria count of the animals as shown in Table 2. The diets significantly increased the values for all the treatments. The least value of total viable bacteria count of 5.47 x 10^9 cfu/mL was recorded in animals fed *P. purpureum + T. catappa* followed by animals fed *P. purpureum* only while the significant highest (P < 0.05) value of 8.82 x 10^9 cfu/ml was observed in animals fed *P. purpureum + A. conyzoides*. The total fungi count ranged between 2.63 and 4.11 x 10^9 cfu/mL in animals fed *P. purpureum + A.*

conyzoides and *P. purpureum + S. mombin*. The least protozoa value (4.12) was observed in animals fed *P. purpureum* only whereas the significant highest value of 6.93 was observed in animal fed *P. purpureum + D. guineense*.

DISCUSSION

Supplementation of *P. purpureum* with browse forages reduced the pH of the rumen content though no significant variation was noticed among the goats. All the values recorded during the study were higher than the reported values of 6.44 – 6.63 observed in WAD sheep fed *D. guineense* after 5 hours of feeding by Osakwe and Steingass (2013) and these values fell within the range of 6.00 – 7.00 suitable for the growth and activities of bacteria reported by Aduku 1993 as well as the optimum pH for cellulolysis (Mould *et al.,* 1983). The range of values obtained also compared favourably to the range of 6.57 – 6.97 reported by Omoniyi (2014) when WAD sheep were fed selected forages. Temperature values recorded in the rumen during the study was lower compared to the optimum temperature of 39ºC for the growth of rumen bacteria as reported by Kamra (2005) and these values were similar to the values obtained by Omoniyi (2014). The improvement observed in the TVFA, acetic acid, propionic acid and reduction in the butyric acid concentration of the rumen liquor of goats fed the control diet and those supplemented with *S. mombin* was in line with the finding of Omoniyi (2014) and Adebayo (2022) when WAD sheep were fed selected plants.

The least value of TVFA observed in goats fed with *P. purpureum+ C. mucunoides* contradicts the report of Osakwe and Steingass, (2013) who attributed the reduction in the TVFA to the inhibitory effects of tannin content on VFA as this plant recorded almost the least value of tannin concentration. Getachew *et al*. (1994) also reported lower VFA production by adding CT in batch culture of mixed rumen microorganisms, a report which this study is not in line with. Significant improvement observed in the TVFA at the end of the study disagreed with the report by Hosoda *et al.* (2006) that supplementation of lemongrass leaf at 5% of the diet did not alter ruminal VFA concentration of dairy steers. The values reported in the molar proportions, i.e. acetic acid, butyric acid and propionic acids revealed that acetic acid had higher values than others and these values were in agreement with the fact that acetic acid has the highest proportion when animals were on forage diet and the values fell within the reported values by Khotsakdeen *et al.* (2010) in goats fed a tallow-rich ration fortified with yeast. No significant effects of selected forages were observed in the rumen ammonia nitrogen of the goats in this study only that some numerical variation was recorded.

The range of the rumen ammonia nitrogen values was higher than the reported range in WAD goats fed with *P. maximum* supplemented with browse forages (Isah *et al*., 2013). The improvement observed in the rumen ammonia nitrogen in this study when compared to the one reported by the cited author could be ascribed to the CP level of the forages, this agrees with the report of Nguyen (2009) that rumen ammonia nitrogen concentration reflected the CP levels in the diets and was associated with higher number of when the author fed maize as supplement to rice straw and grass to growing cattle. Rumen ammonia nitrogen is an important indicator of proteolytic activities during the fermentation process and it is a major source of nitrogen for microbial protein synthesis (Omoniyi *et al*., 2013 and Erdman *et al.,* 1986). Increase in rumen ammonia nitrogen with browse supplementation has been found by Adebayo (2022), Getachew *et al.* (1994), Manyuchi *et al.* (1994) and Kimambo and Muya (1991) to be a function of the degradability of the nitrogen in the forage legumes. The ruminal ammonia nitrogen concentration had a good profile with values between a minimum of 2 mg/100mL

(Satter and Slyter, 1974) and a maximum of 30 mg/100mL (Srinivas and Gupta, 1997) suggested for maximum microbial growth in the rumen but these values were lower than the minimum of 20 mg/100mL which is required for sufficient voluntary intake of low -quality roughage (Krebs and Leng, 1984).

Increase in the values of rumen total viable bacteria count of the goats fed with the selected forages might have been responsible for the observed high total volatile fatty acid as discussed. Addition of browse forages to *P. purpureum* improved digestibility of the diet by releasing more nutrients hence; provide more VFAs which enhanced microbial growth. Microbial yield is essential because it is an index of the amount of microbial protein made available to the animals each day (Brackett *et al.*, 1982). Increase in the TVC, Bacteria, fungi and protozoa counts at the end of the study might be attributed to the availability of nutrient in the rumen which triggered microbial proliferation (Isah *et al*., 2013). Makkar *et al*. (1995) reported lower protozoa numbers by *L. leucocephala* and leucaena hybrid KX2 tannins were fed at the levels of 7.3 and 11.6% to WAD goats. According to McSweeney *et al*. (2001) rumen protozoa, fungi and some of the bacteria are more resistant to condensed tannin as compared to other microbial populations, but Monforte *et al*. (2005) reported that with some condensed tannins rich plants protozoa numbers were negatively correlated.

Table 1: Effects of the selected forages on the rumen volatile fatty acids (Mn/100L) production and ammonia nitrogen (mg/L) of WAD goats

Parameters	*P. purpurem* only	*P. purpureum +D. guineense*	*P .purpureum+C. mucunoides*	*P.purpureum + S. mombin*	*P.purpureum + A. conyzoides*	*P.purpureum +T. catappa*	SEM	P value
TVFA (Mm/100ml)	69.33^{b}	75.00^{ab}	65.62^{b}	77.00^{ab}	75.33^{ab}	84.67^{a}	2.03	0.0857
Acetic acid (Mm/100ml)	33.67	40.33	33.33	33.00	32.33	34.67	1.13	0.3682
Propionic acid (Mm/100ml)	20.67	24.67	16.67	22.33	24.33	21.67	1.22	0.4962
Butyric acid (Mm/100ml)	7.67^{c}	17.00^{ab}	12.27^{bc}	13.00^{abc}	18.67^{a}	15.33^{ab}	1.07	0.0147
Rumen NH_3N (mg/l)	7.59	6.80	9.72	6.93	8.00	7.81	0.38	0.2675
Rumen pH	6.73	6.77	6.67	6.77	6.80	6.85	0.05	0.1665
Rumen temperature	33.37^{ab}	33.37^{ab}	34.37^{ab}	33.17^{ab}	34.87^{a}	32.90^{b}	0.25	0.0184

^{abc} Means along the same row with different superscripts are significantly different ($P<0.05$)
TVFA = Total volatile fatty acid; NH_3N = Ammonia Nitrogen
pH= Power of hydrogen concentration

Table 2: Effects of the selected forages on total viable count, bacteria count, fungi count, and protozoan of WAD goats

Parameters	*P.purpureum* only	*P.purpureum* +*D. guineense*	*P.purpureum* +*C. mucunoides*	*P.purpureum* + *S. mombin*	*P.purpureum*+ *A. conyzoides*	*P.purpureum* +*T. catappa*	SEM	P value
TVC (cfu/mL)	7.65	7.19	6.84	5.49	7.63	7.55	0.34	0.4618
Bacteria count (cfu/mL)	6.4^{ab}	7.58^{ab}	7.17^{ab}	7.76^{ab}	8.82^{a}	5.47^{b}	0.36	0.0886
Fungi count (cfu/mL)	3.45^{ab}	3.26^{ab}	1.81^{b}	4.11^{a}	2.63^{ab}	2.83^{ab}	0.24	0.0962
Protozoa (cfu/mL)	4.12^{b}	6.93^{a}	6.85^{a}	4.37^{b}	6.16^{ab}	5.09^{ab}	0.37	0.0564

^{abc} Means along the same row with different superscripts are significantly different (P<0.05)

TVC = Total viable count

CONCLUSION

Browse species are useful in providing animals with feed during the dry season. Supplementation of *P. purpureum* with the selected browse plants improved the total VFA, normalized the pH of the rumen environment with a resultant increase in the population of rumen microbial counts.

RECOMMENDATION

S. mombin could be fed to ruminants due to its high tannin content which prevents degradation of crude protein and thereby increase the rumen by-pass protein.

REFERENCES

Adebayo, B. J. (2022). Evaluation of the nutritive value of selected plants as potential feed resources for West African Dwarf sheep. Ph.D Thesis, Department of Animal Nutrition, Federal University of Agriculture, Abeokuta, Nigeria.

Aduku, A. O. (1993). Tropical feedstuffs analysis table. Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria Adv., 3(3): 169-173.

Babayemi, O. J. and Bamikole, M. A. (2006). Effects of *Tephrosia candida* DC leaf and its Mixtures with Guinea Grass on in vitro Fermentation Changes as Feed for Ruminants in Nigeria. *Pakistan Journal of Nutrition.* 5(1): 14-18

Brakettett, B. G., Bousquet, D., Boice, M. L., Donawich, W. J., Evans, J. F. and Dressel, M. A. (1982). Normal development following *in vitro* fertilization in the cow. *Bio, Reprod.* 27: 147-158.

Dehority, B. A. (2003). Rumen microbiology. Thrumpton, Nottingham University Press.

Erdman, R. A., Proctor, G. H., and Vandersall, J. H. (1986). Effect of rumen ammonia concentration on in situ rate and extent of digestion of feedstuffs. *Journal of Dairy Science.* 69: 2312-2320.

Fajemisin, A.N, Olomola, O.A., Fadiyimu, A.A., Alokan, J.A. (2013). Nutrient digestibility and nitrogen retention of WAD goats fed cassava peels, *Cajanas cajan* hay and concentrate supplements. In:

Getachew, G, Said, A.N and Sundstol, F. (1994). The effect of forage legume supplementation on digestibility and body weight gain by sheep fed a basal diet of maize stover. *Animal Feed Science and Technology,* 46: 97-108

Hosoda, K., Kuramoto, K. Eruden, B., Nishida, T. and Shioya, S. (2006). The effects of three herbs as feed supplements on blood metabolites, hormones, antioxidant activity, IgG concentration, and ruminal fermentation in Holstein steers. *Asian-Australian Journal of Animal Science*. 19:35–41. http://www.fao.org/ag/AGPC/doc/Publicat/

Isah, O. A., Omoniyi, L. A., Taiwo, O. O., Afolabi, A. D. and Fernandez, A. J. (2013). Dry matter and crude protein digestibility of WAD Sheep fed *Newbouldia laevis, Ficus thonnigii* and *Mangifera indica* as supplement to *Panicum maximum* during the dry season. *Proceedings of the British Society of Animal Science and the Association of Veterinary Teaching and Research Work includes papers from the Rare Breeds Survival Trust. 40th Anniversary Seminar and the*

Colloquium for Equine Reproduction. Nottingham, U.K. (16 – 17 April, 2013).

Kamra, D. N. (2005). Rumen microbial ecosystem. *Current Science*. 89 (1):124 - 135

Khotsakdeen, J, Vasupen, K, Wongsuthavas, S, Bureenok, S, Alhaidary,A, Mohamed,H.E, Beynen, A.C and Yuangklang, C. (2010). Rumen fermentation and Nutrient Digestibility in Goats Fed a Tallow – Rich Ration Fortified with Yeast. *Research Journal of Biological Sciences*. 5 (3): 246 – 250.

Kimambo, A. E and Muya, H. M. H. (1991). Rumen degradation of dry matter and organic matter of different parts of the banana plant. *Livestock Research and Rural Development*. 3 (3): 35-40 Scatter, L.D. and Slyter, L.L. 1974. Effect of ammonia concentration on rumen microbial protein production *invitro. The British Journal of Nutrition.* 32:199 – 208.

Krebs, G. and Leng, R. A. (1984). The effect of supplementation with molasses/urea blocks on ruminal digestion. In: *Animal production in Australia.* 15:704.

Lanyansunya, T. P., Wang, H., Kariuku, S., Mukisira, E., Abdulrasak, S., Kibitok, N. and Ondiek, J. (2007). The potential of *Commelina benghalensis* as forage for ruminant *Animals Feed Science Technology* 144: 185 – 195.

Makkar, H. P. S., Blummel, M. and Becker, K. (1995). Formation of complexes between Polyvinyl prolidones or polyethylene glycols and tannins, and their implication on gas production and true digestibility in *in vitro* techniques. *British Journal of Nutrition* 73: 897– 913.

Manyuchi, B., Mikayiri, S. and Smith, T. (1994). Effect of treating or supplementing maize stover with urea as feed for sheep and cattle. *Animal Feed Science and Technology*. 49: 11–23.

Markham, R., (1942). A steam distillation apparatus suitable for micro-Kjeldahl analysis. *Biochemistry Journal* 36: 790-790.

Mcsweeney C. S., Palmer B., Mcneill D. M. and Kraused. O. (2001). Microbial interactions with tannins: nutritionalconsequences for ruminants. *Animal Feed Science Technology* 91, 83-93.

Mebrahtu, T. (1992). Growth and photosynthesis of Black Locust. Proc. International Conference on Black Locust: Biology, Culture & Utilization. June 17-21. Michigan State University., East Lansing, MI.

Monforte-Briceno, G. E., Sandoval-Castro, C.A., Ramirez-Aviles and Capetillo-Leal, C.M. (2005). Defaunating capacity of tropical fodder trees: Effects of polyethylene glycol and its relationship to *in vitro* gas production. *Animal Feed Science Technol*ogy, 123-124 (1): 313-327.

Mould, F. L., Orskov, E. R. and Mann, S. O. (1983). Associative effects of mixed feeds. I. Effects of type and level of supplementation and the influence of the rumen fluid pH on cellulolysis in vivo and dry matter digestion of various roughages. *Animal Feed Science and Technology* 10: 15–30.

Nguyen, V. T. (2009). Feed intake, rumen fermentation, microbial protein synthesis and nitrogen retention in growing cattle given maize or molasses with two levels of crude protein as supplements. *Livestock Research Rural* vol 150, pp 200

Odeyinka, S. M. (2001). Effects of feeding varying levels of *Leuceana leucocephala* and *Gliricidia sepium* on the performance of West African dwarf goats. *Nigerian Journal of Animal Production*. 28:61-64

Omoniyi, L. A. (2014). Nutritional assessment of selected forages and their effects on ruminal bacteria and blood parameters of West African dwarf sheep. Ph.D Thesis, Department of Animal Nutrition, Federal University of Agriculture, Abeokuta Nigeria.

Omoniyi, L. A., Isah, O. A., Taiwo, O. O., Afolabi, A. D. and A. J. Fernandez. (2013). "Assessment of Nutritive Value of some Indigenous Plants Consumed by Ruminants in the Humid and Sub-Humid Region of Nigeria using *In Vitro* Technique". *Pacific Journal of Science and Technology*. 14(1):413-421.

Osakwe, I. I. and Steingass, H. (2013). Ruminal fermentation and nutrient digestion in West African Dwarf (WAD) sheep fed *Dialium guineense* supplemental diets. Conference of International Research on Food Security, Natural Resource Management and Rural Development held on 17-19, September by the University of Hohenheim, Germany.

Osakwe, I. I., Steingass, H. and Drochner, W. (2000). The chemical composition of *Phyllanthus discoidues* and its effect on ruminal ammonia and volatile fatty acid concentrations when fed to WAD sheep. *Archives Animal Nutrition* 53: 191-205.

SAS, (1995). Statistical analyses software package.

Satter, L. D. and Slyter, L. L. (1974). Effect of ammonia concentration of rumen microbial protein production *in vitro*. British Journal of Nutrition, 69, 2755-2766.http://dx.doi.org/10.1079/BJN19740022

Srinivas, B and Gupta, B. N. (1997) Rumen fermentation, bacterial and total volatile fatty acid (TVFA) production rates in cattle fed on urea-molasses-mineral-block licks supplement. *Anim Feed Sci Technol.* 65:275–286.

Wilson, D. B. (2011). Microbial diversity of cellulose hydrolysis. *Current Opinion Microbiology* 14, 259-263