

Evaluation of Heavy Metals in fresh and partially digested cellulose in the abomasum of beef Cows fed on *Pennisetum purpureum* (Elephant grass)

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ABSTRACT

This study was carried out to evaluate the physicochemical characteristics of partially digested cellulose from abomasums of beef cows in two abattoirs in Bayelsa State. The pH and temperature of partially digested cellulose of a total of one hundred and twenty eight (128) cows was determined at biweekly interval for a period of 8 months (August 2024 to March 2025). Partially digested cellulose samples were also collected from a total of sixteen (16) cows at biweekly interval in the month of August 2024. The samples and raw/fresh undigested feed (*Pennisetum purpureum* - Elephant grass) of the cattle were analyzed for heavy metals such as Iron (Fe), Copper (Cu), Zinc (Zn), and Lead (Pb). The results showed that, the temperature of the partially digested cellulose samples after collection ranged from 29°C to 35°C and the pH ranged from 5.5 to 6.0. Iron concentration values (mean ± SD) for *P. purpureum* before and after digestion at Swali abattoir was 3.14 ± 1.13 mg/kg and 2.54 ± 0.99 mg/kg respectively. While Iron concentration value at Bayelsa Palm abattoir was 3.48 ± 0.53 and 2.85 ± 0.54 respectively. Lead concentration values at Swali abattoir was 0.02 ± 0.00 mg/kg and 0.015 ± 0.006 mg/kg respectively. While Lead concentration at Bayelsa Palm abattoir was 0.04 ± 0.02 and 0.034 ± 0.020 respectively. Results of this study revealed that, heavy metal concentrations of *P. purpureum* before and after digestion were generally higher at Bayelsa Palm abattoir than in Swali abattoir. The decreasing order of the heavy metal concentration was; Zinc > Iron > Copper > Lead. There was also a general reduction in the heavy metal content of *P. purpureum* after digestion. The values of Iron, copper, zinc and lead in the feed of the cows were generally higher than their values in the partially digested cellulose. This indicates that the abomasums of beef cows provides a relatively stable physicochemical environment for microbial digestion, hydrolysis and fermentation of the high quality cellulose feed as characterized by the mildly acidic pH levels and physiological temperature range of partially digested cellulose.

Keywords: Abattoir, *Pennisetum purpureum* (Elephant grass), Heavy Metals, Beef Cow, Digested Cellulose, Abomasum.

Introduction

Cenchrus purpureus, synonym *Pennisetum purpureum*, (Paudel et al., 2018) also known as Napier grass, or elephant grass is a species of perennial tropical grass native to African grasslands (Farrell et al., 2002). It has low water and nutrient requirements, and therefore can make use of otherwise uncultivated lands (Strezov et al., 2008). Historically, this wild species has been used primarily for grazing (Khan et al., 2007). Recently, however, it has been used as part of a push-pull agricultural pest management strategy. Napier grasses improve soil fertility, and protect arid land from soil erosion.

It is also utilized for firebreaks, windbreaks, in paper pulp production and most recently to produce bio-oil, biogas and charcoal (Strezov et al., 2008). It also helps feed animals such as goat, rabbit, even pig, and cow.

The push-pull pest management technique involves the desired crop being planted alongside a 'push' plant, which repels pests, in combination with a 'pull' crop around the perimeter of the plot, which draw insects out of the plot (Khan et al., 2007). Napier grass has shown potential at attracting stemborer moths (a main cause of yield loss in Africa) away from maize (Khan et al., 2007) and hence is the "pull" crop.

This strategy is much more sustainable, serves more purposes and is more affordable for farmers than insecticide use. Stem borers (*Busseola fusca* and *Chilo partellus*) are the cause of 10% of total yield loss in Southern and Eastern Africa and on average 14-15% in sub-Saharan Africa (Farrel et al., 2002). The larvae cause immense damage to maize and sorghum by burrowing into their stems and eating from within. This not only makes them difficult to detect and remove but also damages the vascular tissue necessary for plant growth (Khan et al., 2007). Insecticide effectiveness is low against stem borers, as larvae are protected by protective cell wall layers around the stem (Aminah et al., 1997). Insecticides are also expensive for poor farmers and can build chemical resistance by the pests (Miller and Cowles, 1990). In addition, chemicals are carried into final food products (Miller and Cowles, 1990). Instead of trying to prevent the occurrence of pests, the push-pull strategy (also known as stimuli-deterrent) aims to guide their inevitable biological evolution to prevent damage to valued crops (Miller and Cowles, 1990). With an estimated 83% increase in soil fertility, and 52% effectiveness in stem borer control, the implementation of this technique could significantly reduce food insecurity.

Ruminants are defined by their mode of plant digestion, and have evolved a fore stomach, the rumen, that allows partial microbial digestion of feed before it enters the true stomach (Cassio et al., 2014). Ruminants have adapted to a variety of ecological niches because of diverse ruminal microbial populations, which consist primarily of bacteria, protozoa and fungi. Ruminant animals have the ability to convert low quality feeds into high quality protein and to utilize feeds from land not suitable to grow crops for human consumption. This is made possible by the ruminal microorganisms that synthesize and secrete the β 1-4 cellulase enzyme complex, thereby allowing hydrolysis of plant cell walls.

Cellulose digestion typically occurs optimally near neutral pH values around 6.5 to 6.8. At this pH range, digestion proceeds actively, but as the pH drops below about 6.0, the rate of digestion declines significantly. For example, cellulose digestion rate constants showed a relative decrease of approximately 7% for every 0.1 unit decrease in pH from an initial pH near 6.8. When the pH falls below roughly 5.4 to 5.3, cellulose digestion is substantially inhibited or ceases entirely.

This is partly because acidic conditions can cause lysis or detachment of cellulolytic microbial cells from the cellulose substrate, reducing microbial activity and cellulose breakdown. Different cellulolytic bacteria differ in pH tolerance; for instance, some species stop growth or digestion below pH 5.2 to 5.6, with corresponding decreases in their ability to ferment cellulose. Under conditions with added soluble carbohydrates that ferment rapidly to acids, the pH can decrease, which also lowers cellulose digestion efficiency.

Partially digested cellulose environments tend to become more acidic due to microbial fermentation end products, and when pH drops below about 5.4, cellulose digestion by many microbes is inhibited or stopped due to cell detachment and reduced microbial activity. These observations come mainly from in vitro ruminal microbial fermentation studies that mimic digestion conditions in the ruminant stomach.

The temperature of partially digested cellulose, such as that collected from the digestive system of ruminants, is typically close to the internal body temperature of the animal. For example, cellulose collected immediately after partial digestion in the abomasum of ruminants was measured at approximately $35.9 \pm 0.58^{\circ}\text{C}$, reflecting the warm biological environment where digestion occurs.

Regarding the enzymatic digestion of cellulose, the optimal temperatures for cellulase enzymes that degrade cellulose vary depending on the organism and the enzyme sub-type. Studies on wood-eating termites show optimal endo- β -1,4-glucanase activity at around 65°C , with enzyme stability up to 55°C for 30 minutes, indicating that enzymatic cellulose digestion can be efficient at elevated temperatures relative to ambient biological temperatures (Raut et al., 2019).

In comparison, other cellulolytic enzymes such as cellulase and cellobiase from termites have optimum temperatures around 30°C and 38°C respectively, reflecting variation in enzyme thermostability within organisms. In bioprocessing contexts, the combination of partially digested cellulose and elevated temperatures (such as in thermophilic fermentation conditions) has shown synergistic effects, enhancing biogas production rates, indicating that temperature plays a key role in the further biochemical breakdown of cellulose after partial digestion.

Temperature has significant effects on cellulose digestion, influencing both the chemical structure of cellulose and the activity of microbes and enzymes that break it down. At elevated temperatures (above ~120°C), cellulose undergoes dehydration and thermal degradation reactions. Hydroxyl groups and some chemical bonds on cellulose molecules break down first, especially in the amorphous regions. Between 140°C and 160°C, the key β -(1,4)-glycosidic bonds that link glucose units begin to break, leading to cellulose depolymerization and the formation of smaller compounds like furans.

Heavy metal pollution from abattoir effluents is a significant environmental and public health concern due to the presence of toxic, persistent metals like lead (Pb), cadmium (Cd), iron (Fe), manganese (Mn), and zinc (Zn). These metals enter abattoir wastewater through contaminated animal feed, veterinary drugs, and slaughtering processes. They accumulate in the environment, bioaccumulate in aquatic organisms, and biomagnify along food chains, posing risks such as neurological disorders, kidney damage, and carcinogenic effects in humans.

Previous Studies in Nigeria show that abattoir wastewater often contains Pb and Zn concentrations exceeding regulatory limits for surface water discharge, while tap water near abattoirs may have Cd, Fe, Mn, and Pb levels above WHO drinking water standards. Furthermore, soils receiving abattoir effluents also show elevated heavy metal levels, with increased concentrations of Cu, Cd, Zn, Pb, and Fe compared to uncontaminated sites. This contamination not only changes soil properties but also leads to the accumulation of heavy metals in vegetables grown nearby, amplifying health risks for consumers. There is therefore, the urgent need for strategies to monitor and control heavy metal levels, and regulations to mitigate the detrimental ecological and human health consequences of such pollution (Usman et al., 2022).

Materials and Methods

Study Area and Sampling Locations

The study areas were Swali Market Abattoir, and Bayelsa palm Abattoir both located in Yenagoa metropolis. The Swali Market Abattoir is located at one end of Yenagoa town between latitude 4°91'639"N and longitude 6°26'548"E extending to

Swali river while the Bayelsa Palm Abattoir is located between Latitude 4°88'608"N and longitude 6°32'394"E in Yenagoa, Bayelsa State. The coordinates of sample locations worked were determined, using a GPS (Global Positioning System).

Sample Collection

Partially digested cellulose from the abomasum of beef cows were collected in sterilized containers according to the method of Obire *et al.*, 2010, after collection of the samples, the pH and temperature were checked *in-situ* and kept in sampling coolers and immediately transported to the Microbiology laboratory of Federal University Otuoke for analysis where other physicochemical and microbiological analyses were carried out (Adesoji *et al.*, 2016).

Sampling Duration

Partially digested cellulose from the abomasum of beef cow samples were collected bi-weekly for the month of August 2024. During each sampling, the collection of the samples was done in the morning hours when the activities in the abattoir were at their peak. Four samples were collected from four different abomasums in each of the abattoirs making a total of eight (8) samples during each sampling visit. The bi-weekly collection of partially digested cellulose samples for one month resulted in a total of sixteen (16) [(2 × 4 × 2)] samples collected. Partially digested cellulose samples were also collected from a total of sixteen (16) cows at biweekly interval in the month of August 2024. The samples and raw/fresh undigested feed (*Pennisetum purpureum* - Elephant grass) of the cattle were analyzed for heavy metals such as Iron (Fe), Copper (Cu), Zinc (Zn), and Lead (Pb). On the other hand, a total of one hundred and twenty eight (128) partially digested cellulose from abomasums of beef cows were collected at biweekly interval for a period of 8 months (August 2024 to March 2025) for determination of pH and temperature.

Physicochemical Analyses

The physicochemical parameters of the partially digested cellulose samples were determined according to the method described by the American Public Health Association (APHA, 2017). The temperature was determined using glass rod mercury thermometer and the pH by using HANNA Model HI98107 pHep[®].

The measurement of quantity of heavy metals such as (Lead (Pb), Zinc (Zn), Copper (Cu), and Iron (Fe) were analysed using an Atomic Absorption Spectrophotometer (Varian Spectrophotometer AA 220, Australia) according to (APHA, 2017).

Results

Table 1 presents the pH values (mean and standard deviation) of the partially digested cellulose in abomasums of cows in Swali and Bayelsa Palm abattoirs from August 2024 to March, 2025. Values ranged from 5.76 ± 0.01 in October 2024 to 5.96 ± 0.05 in February 2025 in Swali samples and from 5.77 ± 0.06 in August 2024 to 6.06 ± 0.01 in October 2024 in the Bayelsa Palm abattoir samples.

Table 2 presents the Temperature values (mean and standard deviation) of the partially digested cellulose in abomasums of cows in Swali and Bayelsa Palm abattoirs from August 2024 to March, 2025. Values ranged from 32.50 ± 2.50°C in February 2025 to 37.50 ± 0.50°C in January 2025 in Swali samples and from 33.19 ± 1.31°C in December 2024 to 35.56 ± 0.19°C in February 2025 in the Bayelsa Palm abattoir samples.

Table 3 presents the concentration values of heavy metals Iron (Fe), Copper (Cu), Zinc (Zn), and Lead (Pb) of Fresh/Raw *Pennisetum purpureum* (Elephant grass) before and of Partially Digested Cellulose (after Consumption). The values are given as mean ± standard deviation (SD), and statistical analyses include *p*-values to assess the significance of changes observed.

Table 1: The pH values (mean ± SD) of partially digested cellulose in abomsum of Cows in Swali and Bayelsa Palm Abattoirs

| pH values in Mean ± SD of partially digested cellulose | | | |
|--|---------------------|----------------------------|-----------------|
| Sampling Months | Swali Abattoir Cows | Bayelsa Palm Abattoir Cows | <i>p</i> -value |
| August 2024 | 5.90 ± 0.00 | 5.77 ± 0.06 | 0.89 |
| September | 5.89 ± 0.10 | 5.86 ± 0.13 | 0.89 |
| October | 5.76 ± 0.01 | 6.06 ± 0.01 | 0.89 |
| November | 5.89 ± 0.01 | 5.93 ± 0.12 | 0.89 |
| December | 5.89 ± 0.11 | 5.90 ± 0.11 | 0.89 |
| January 2025 | 5.94 ± 0.07 | 5.93 ± 0.14 | 0.89 |
| February | 5.96 ± 0.05 | 5.86 ± 0.06 | 0.89 |
| March | 5.93 ± 0.09 | 5.80 ± 0.13 | 0.89 |

Note: Results are reported as Mean±SD; *p*-values were determined by paired Ttest (*p* ≤0.05 was considered significant); *p*-values were determined by paired T-test (*p* ≥0.05 was considered not significant).

Table 2: Total Temperature (°C) of partially digested cellulose of Swali and Bayelsa Palm Cows

| Temperature (°C) values in Mean ± SD of partially digested cellulose | | | |
|--|--------------|-------------------|-----------------|
| Sampling Month | Swali Cows | Bayelsa Palm Cows | <i>p</i> -value |
| August 2024 | 34.25 ± 0.25 | 34.25 ± 0.25 | 0.89 |
| September | 33.50 ± 0.50 | 34.94 ± 0.44 | 0.89 |
| October | 33.50 ± 1.00 | 33.31 ± 0.31 | 0.89 |
| November | 36.75 ± 1.25 | 34.31 ± 0.56 | 0.89 |
| December | 33.25 ± 0.25 | 33.19 ± 1.31 | 0.89 |
| January 2025 | 37.50 ± 0.50 | 34.19 ± 1.19 | 0.89 |
| February | 32.50 ± 2.50 | 35.56 ± 0.19 | 0.89 |
| March | 32.50 ± 1.00 | 33.19 ± 0.56 | 0.89 |

Note: Results are reported as Mean±SD; *p*-values were determined by paired T test (*p* ≤0.05 was considered significant) *p*-values were determined by paired T-test (*p* ≥0.05 was considered not significant)

Table 3: Total Heavy metal Concentration of Fresh/Raw *Pennisetum purpureum* (Elephant grass) before and Partially Digested Cellulose (after Consumption)

| Heavy Metal | Sample Locations | Heavy metal concentration of <i>Pennisetum purpureum</i> (Elephant grass) before and after consumption | | | |
|-------------|-----------------------|--|-----------------|----------------|---------------|
| | | Mean ± SD Before | Mean ± SD After | p-value Before | p-value After |
| Fe (mg/kg) | Swali Abattoir | 3.14 ± 1.13 | 2.54 ± 0.99 | 0.64 | 0.56 |
| | Bayelsa Palm Abattoir | 3.48 ± 0.53 | 2.85 ± 0.54 | | |
| Cu (mg/kg) | Swali Abattoir | 0.57 ± 0.24 | 0.44 ± 0.19 | 0.53 | 0.40 |
| | Bayelsa Palm Abattoir | 0.67 ± 0.11 | 0.52 ± 0.11 | | |
| Zn (mg/kg) | Swali Abattoir | 4.27 ± 1.07 | 3.40 ± 0.91 | 0.82 | 0.79 |
| | Bayelsa Palm Abattoir | 4.48 ± 1.26 | 3.59 ± 1.15 | | |
| Pb (mg/kg) | Swali Abattoir | 0.02 ± 0.00 | 0.015 ± 0.006 | 0.14 | 0.06 |
| | Bayelsa Palm Abattoir | 0.04 ± 0.02 | 0.034 ± 0.020 | | |

Note: Results are reported as Mean±SD; p-values were determined by paired T-test ($p \leq 0.05$ was considered significant); p-values were determined by paired T-test ($p \geq 0.05$ was considered not significant).

Discussion

This study has revealed the physicochemical constituents including heavy metals in fresh and partially digested cellulose in the abomasum of beef cows fed on *Pennisetum purpureum* (Elephant grass). In the month of August the cows from Swali abattoir cows had the highest pH range of 5.90 while that of Bayelsa Palm was 5.77, samples collected in the month of September also revealed a high pH value from swali abattoir cows with pH value of 5.89, in the months of October, November and December Bayelsa palm cows had the highest pH values ranging from 6.06 to 5.93, while in the months of January, February, and March Swali abattoir cows recorded high values that ranged from 5.93 to 5.94. The pH values for Swali cows ranged between approximately 5.76 to 5.96 across the study period while the pH values for Bayelsa palm cows ranged between approximately 5.77 to 6.06.

The p-values for each month are all 0.89, indicating that there is no statistically significant difference in pH values between Swali and Bayelsa palm cows for any month as it is above the standard threshold of 0.05 for statistical difference. The pH values for both types of cows fall within a relatively narrow range around approximately 5.8 to 6.0. This suggests a stable rumen environment or gastrointestinal pH in both populations during this period.

The high p-values (0.89 in all cases) indicate that any observed difference in pH between Swali cows and Bayelsa palm cows is not statistically significant. This points to similar physiological or dietary influences on pH across the two locations during the sampling months. Rumen pH plays a critical role in digestion and fermentation processes in cattle. Normal rumen pH typically ranges between 5.5 and 7.0. Values below 5.5 can indicate acidosis, which can impact feed efficiency and cow health (Mao and Wang, 2025). The results obtained from this study are similar to results recorded by Khafipour et al., 2020, indicating that the cows are healthy cows. A paired-sample t-test was conducted to compare pH levels between partially digested cellulose from the abomasum of beef cows from Swali abattoir and partially digested cellulose from the abomasum of beef cows from Bayelsa Palm abattoir across the sampling months. The test assumed a hypothesized mean difference of 0.

There was no statistically significant difference in the pH values between the two sampling locations, $t(7) = 0.14$, $p = 0.89$. The pH data (Table 1) showed values ranging from 5.76 to 5.96 for both Swali and Bayelsa Palm cows across the study period, with no statistically significant differences ($p = 0.89$).

These mildly acidic readings contrast with the strongly acidic environment (pH 2–4) typically reported for fresh abomasal chyme in cattle.

The elevated pH observed in the present study likely reflects post-excretion pH buffering, a phenomenon in which exposure of digesta to air promotes microbial ammonia production and bicarbonate release, thereby neutralising the acidic chyme (Cherdthong et al., 2020; Wang et al., 2022). Such pH increases may also result from the residual buffering effect of ruminal saliva and the activity of environmental microorganisms that proliferate rapidly once digesta is exposed. Similar post-abomasal pH changes have been reported in tropical cattle husbandry systems, where ambient conditions accelerate biochemical transformations in gastrointestinal contents (Mishra et al., 2021). These findings indicate that pH levels were consistent between the two sampling locations during the study period.

Temperature is the degree of coldness or hotness of a body. Temperature influences the growth of microbes in the rumen digestive system; also change in temperature determines the increase or decrease of chemical reactions in the gut. Similarly the rate of biochemical reactions usually doubles for every rise in temperature. Table 2 represents the comparison of temperature values of partially digested cellulose from abomasum of beef cows during the study period. Temperature values from both Swali abattoir cows and Bayelsa Palm cows groups show similar temperature ranges, from roughly 32°C to 36.75°C across the sampling months. The temperature peaks in November for both abattoir cows. All *p*-values are above 0.05, with most being exactly 0.89 which indicates that there is no statistical significant difference in temperature of the partially digested cellulose between Swali cows and Bayelsa Palm cows throughout the sampling months. The standard deviations are comparable between both abattoir cows, suggesting similar variability in body temperature. Research on cattle physiology by Adewuyi et al. (2012) reported that temperature as a proxy for adaptation, health status, and environmental response.

Temperature readings (Table 2) ranged between 32.50 °C and 37.50 °C, with no significant differences detected between the two cattle groups. Peak values, such as the 37.50 °C recorded in January for Swali cows, are likely influenced by seasonal temperature fluctuations, feed composition, and metabolic heat production.

The recorded range falls within the physiological temperature range of bovine gastrointestinal contents, as reported in recent studies of ruminant digestive physiology (Bojkovski et al., 2021). Stable abomasal temperatures are critical for maintaining optimal enzymatic activity and microbial fermentation rates, with minor seasonal shifts reflecting adaptive responses to environmental and dietary conditions (Cheng et al., 2019). Previous studies in similar tropical climates by (Almeida et al. (2017); Ogunlade et al., (2019), revealed that body temperature differences among local cattle breeds in Nigeria were not statistically significant throughout dry and wet seasons, which is in line with values obtained during this study.

Heavy metals occur naturally as elements with high atomic weight and density which is at least 5 times greater than water, they can mostly be found in industrial, domestic effluents, agricultural, medical and technological applications and this led to their wide distribution in the environment, which poses a threat to human health and the environment. Their level of toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as status of exposed individuals and environment. Due to their high degree of toxicity, these metallic elements are of public health significance and considered as systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure Paul *et al.*, (2012).

Iron (Fe) concentration decreased slightly after consumption in both locations, but the changes were not statistically significant (*p*-values 0.64 and 0.56). Copper (Cu) Copper concentration in Swali Cows decreased from 0.57 ± 0.24 to 0.44 ± 0.19 mg/kg. While the values of Bayelsa Palm Cows, Copper concentration decreased from 0.67 ± 0.11 to 0.52 ± 0.11 mg/kg. Both changes did not reach statistical significance (*p* = 0.53 and 0.40). Zinc (Zn): Zn also showed a numerical decrease after consumption in SWC (4.27 ± 1.07 to 3.40 ± 0.91 mg/kg) and in BPC (4.48 ± 1.26 to 3.59 ± 1.15 mg/kg). These differences were not statistically significant (*p* = 0.82 and 0.79). Lead:(Pb) levels decreased after consumption in SWC from 0.02 ± 0.00 to 0.015 ± 0.006 mg/kg. In BPC, Pb decreased more markedly from 0.04 ± 0.02 to 0.034 ± 0.02 mg/kg.

The decrease approached or reached statistical significance ($p = 0.14$ and 0.06), with the latter closer to the threshold. The data suggest that heavy metal concentrations tend to decrease after partial digestion of cellulose, indicating potential metal bioavailability or reduction during digestion, which is similar to research reports by (Gao et al., 2020) stating that Heavy metal bioavailability in cow feed occurs as the metals bind to cellulose and other dietary fibers which impacts their absorption and excretion which supports that digestion of cellulose may reduce the concentration of certain heavy metals, particularly lead (Pb), leading to a potential detoxification mechanism or metal bioaccessibility. Also, The observed patterns align with previous research indicating that gastrointestinal transit causes only marginal alterations in trace element concentrations due to factors such as metal binding to dietary fibre, precipitation with sulphur compounds, or incorporation into microbial biomass (Rafique et al., 2020; Maguire et al., 2022). While the detected levels in the present study are well below toxic thresholds established for cattle (NRC, 2021), monitoring of Fe, Cu, and Zn remains important for both animal health and environmental risk assessment. Trace metals are essential cofactors for numerous metallo-enzymes, and imbalances whether by deficiency or excess can affect rumen microbial ecology, digestion efficiency, and host metabolism (Zhou et al., 2021). Establishing baseline concentrations in abomasal contents provides valuable reference points for detecting future contamination events, particularly in regions subject to agricultural runoff or industrial emissions.

Conclusion

Trace metals are essential cofactors for numerous metallo-enzymes, and imbalances whether by deficiency or excess can affect rumen microbial ecology, digestion efficiency, and host metabolism. Establishing baseline concentrations in abomasal contents provides valuable reference points for detecting future contamination events, particularly in regions subject to agricultural runoff or industrial emissions. There was also a general reduction in the heavy metal content of *Pennisetum purpureum* (Elephant grass) after digestion. The values of Iron, copper, zinc and lead in the feed of the cows were generally higher than their values in the partially digested cellulose.

This indicates that the abomasums of beef cows provides a relatively stable physicochemical environment for microbial digestion, hydrolysis and fermentation of the high quality cellulose feed as characterized by the mildly acidic pH levels and physiological temperature range of the partially digested cellulose.

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