A Comparative Analysis of Silver Leaf Desmodium and Mexican Sunflower as Economically Viable Protein Sources for Ruminant Animals

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Abstract

With the rapidly growth in global population and rising demand for animal-based foods, the livestock sector faces increasing pressure to provide adequate and sustainable sources of high-quality nutrients particularly with high-quality protein sources. Conventional protein-rich feedstuffs often remain costly and inaccessible to many smallholder livestock producers necessitating the exploration of alternative locally available and economically viable options. This study aimed to assess and compare the nutritional content of two promising plant species; Mexican Sunflower (*Tithonia diversifolia*) and Silver Leaf Desmodium (*Desmodium uncinatum*) as potential and readily available protein sources for livestock. Comparative research was employed involving sampling of the plant materials and subsequent laboratory analyses to determine their protein, fiber, ash and moisture content. The findings revealed significant differences between the two plants regarding their nutritional compositions. Mexican Sunflower exhibited a higher crude protein content of 28.05% surpassing some conventional protein sources like corn distillers' grains and cottonseed meal. This high protein level suggests its potential as a valuable concentrate or protein supplement in ruminant diets. In contrast, Silver Leaf Desmodium had a lower crude protein content of 18.54% comparable to alfalfa hay a common high-protein forage. Interestingly, Silver Leaf Desmodium displayed a remarkably high crude fiber content of 24.28% exceeding typical levels for legumes and making it a suitable fiber source for ruminants. On the other hand, Mexican Sunflower had a lower fiber content of 6.56% indicating the need for supplementation with other high-fiber ingredients to achieve balanced rations. Regarding ash content, an indicator of mineral composition, Mexican Sunflower exhibited higher levels ranging from 12.66% to 14.7% suggesting potentially higher mineral concentrations than Silver Leaf Desmodium (6.9-7% ash). However, a detailed analysis of specific mineral profiles and bioavailability is recommended for accurate assessment. The plants studied had high moisture content (82.30% to 83.1%) challenging storage and preservation. The study also noted the economic and environmental benefits of using these plants as ruminant feed potentially reducing costs for farmers and aiding nitrogen fixation.

INTRODUCTION

In the rapidly growing world population, food security has become a significant concern for most countries especially the developing nations. The population has been increasing steadily for the past two centuries and is expected to continue with this trend (Gu et al., 2021). There are estimations that the world's population is projected to reach 9.7 billion by 2050 (UN, 2022) with continued growth expected throughout the century. The factors contributing to this include increased life expectancy, reduced infant mortality rates and advanced health care. Population increase poses a significant challenge to food production and distribution to meet the growing demand.

One of the essential outcomes of this challenge is the increasing demand for animal products such as meat, milk, fish and eggs. Livestock is said to contribute up to 40% and 20% of the total agricultural output in developed and developing countries respectively supporting the livelihood of 1.3 billion people (FAO, 2009). The current economic growth and rise in living standards in developing countries have led to a shift in dietary preferences towards more animal-based diets as protein sources (Henchion & Zimmermann, 2021). This preference for animal products as protein in diet sources has put pressure on agriculture to produce more animal products.

The demand for animal products has led to restructuring animal production systems from the conventional ways. This has resulted in more focus on health, nutrition and farm animal management (FAO, 2019). Animal nutrition and feeding contribute approximately 50–70% of livestock's overall performance and productivity. This encompasses various outputs, including meat, milk, and other animal products. Effective and balanced nutrition is crucial for ensuring the health and growth of animals, thereby significantly influencing the overall success of animal production (Peter and Bern, 2013). One of the most challenging aspects of nutrition for animals and humans is obtaining sufficient quantities of high-quality protein at an affordable price.

Regarding animal nutrition especially for ruminants (as previously mentioned), ensuring their meals include a sufficient and high-quality supply of protein is essential for their general well-being, development and production. The availability and affordability of protein-rich fodder alternatives become crucial for livestock producers. However, comparable issues come up when discussing human nutrition. Meeting nutritional requirements requires having access to reasonably priced, high-quality protein sources especially in areas where conventional protein sources may be scarce or expensive. The statement may be relevant in conversations about sustainable agriculture, food security and animal and human nutrition choices. This poses a challenge for alternative, cost-effective and readily available protein sources bringing about the aspect of researching conventional plants such as the Mexican Sunflower and the freely growing silver leaf desmodium.

MATERIALS AND METHODS

Sampling Methods for Silver Leaf Desmodium and Mexican Sunflower

A random sampling approach was utilized to select representative samples of Silver Leaf Desmodium and Mexican Sunflower. This method ensured unbiased samples that accurately reflected the overall population of these plant species in the study area.

Laboratory Analysis Procedures for Assessing Protein, Fiber, Ash Content and Moisture Content

Determination of Moisture Content

Determining moisture content or dry matter content in animal feeds was conducted using an oven-drying method. Firstly, porcelain crucibles were dried in an air-circulation oven at 105°C for an hour, cooled in a desiccator and then weighed accurately then the feed samples were homogenized, ground and weighed into the dried crucibles. The crucibles with samples were then placed in the oven at 105°C for 5–8 hours until a constant weight was achieved. After drying, the crucibles were cooled in a desiccator and weighed again to calculate the moisture content (%MC) and dry matter (%DM) using the weight difference before and after drying.

The Determination of Crude Ash Content

Determining crude ash content in animal feeds involved heating clean porcelain crucibles in a muffle furnace at 550°C – 600°C for an hour to achieve constant weight. The crucibles were cooled and weighed accurately. Test samples were ground, weighed and placed in the crucibles then heated to 550°C – 600°C for 2–5 hours in the muffle furnace for ash content. The crucibles were cooled and weighed again and the percentage of crude ash was calculated using the weight difference before and after washing.

Determination of Crude Fiber

The determination of crude fiber using the muslin cloth method began with weighing 2 grams of the feed sample and placing it in a Berzelius beaker. A solution of 0.255 N sulfuric acid was prepared and heated in the beaker with the sample for digestion. After acid digestion, the residue was filtered using a muslin cloth followed by alkali digestion using 0.313 N sodium hydroxide solution. The residue was washed, dried and incinerated in a muffle furnace. The difference in weight before and after determining ash content was used to calculate the crude fiber content.

Determination of Protein Content

Determining crude protein in animal feeds using the Kjeldahl method involved several key steps. Firstly, 1g of the feed sample was weighed and placed in digestion tubes with catalysts and concentrated sulfuric acid. The mixture was then heated at 350–380°C to break nitrogen bonds and convert them to ammonium ions. After digestion, the sample was diluted, transferred to a distillation unit and distilled to release ammonia which was trapped in a boric acid solution. The captured ammonia was then titrated using standardized hydrochloric acid. The percentage of nitrogen (%N) was calculated using the titration results and the sample weight employing a conversion factor (1.4007). The nitrogen percentage was then multiplied by a factor (F) to determine the crude protein content where F varied depending on the type of forage or feed being analyzed. This method required various equipment such as an analytical balance, fume hood, digestion block heater, distillation unit, digestion tubes and various reagents such as sulfuric acid, sodium hydroxide, boric acid and hydrochloric acid. Additionally, a blank reagent tube was used as a control to account for any background or impurities in the reagents or equipment ensuring accurate results. Overall, the Kjeldahl method provided a reliable way to determine the crude protein content in animal feeds.

RESULTS

Crude Fibre Determination

The amount of crude fibres in the two forages varied significantly. Silvery desmodium was significantly higher in crude fibre content of 24.28 and comparatively Mexican sunflower at 6.56. The results for Mexican sunflower (*Tithonia diversifolia*) and Silvery desmodium (*Desmodium uncinatum*) are presented in Fig. 1 below.

Crude Protein Determination

The comparison of the results showed that the two forages had significant differences in the content of crude protein. Mexican sunflower contained more nitrogen percentage (4.49) hence had a greater crude protein value of 28.05. Silvery desmodium on the other hand reported a nitrogen percentage of 2.97 which corresponds to a lower crude protein composition of 18.54 as shown in Fig. 2 below.

Moisture Content Determination

The findings in Fig. 3 indicate clear differences between the two forage species in terms of dry matter and moisture content. Silvery desmodium had relatively higher dry matter content, ranging from 22.30% to 25.38%, with corresponding moisture levels of 77.70% to 74.62%. Mexican sunflower, on the other hand, exhibited lower dry matter content (16.90% to 17.70%) and consequently higher moisture content (82.30% to 83.10%).

Ash Determination

The results showed (Fig. 4) notable variation in ash content between the two forage types. Silver leaf desmodium recorded lower ash content values of 6.9% (R1) and 7.0% (R2) while Mexican sunflower had considerably higher ash content with 14.7% (R1) and 12.66% (R2). This indicated that Mexican sunflower contains nearly double the mineral content of Silver leaf desmodium.

DISCUSSION

Comparison of Protein Content

The results of this study reveal significant differences in the protein content between Silver Leaf Desmodium and Mexican Sunflower. The Mexican Sunflower exhibited a higher crude protein content of 28.05% while Silver Leaf Desmodium had a lower crude protein content of 18.54%. These findings align with the specific objective of comparing the protein composition of the two plants and provide valuable insights into their potential as protein sources for ruminants. When comparing these results to the existing literature on ruminant protein requirements, it becomes evident that both plants possess considerable potential as supplementary protein sources. According to Schwab (2022), ruminants' metabolizable protein (MP) requirements vary based on species, age and production purpose, with lactating dairy cows having higher protein needs than dry beef cows. Haenlein (2001) emphasizes the importance of protein in supporting various physiological processes in ruminants including muscle development, milk production, reproduction and immune function.

The Mexican Sunflower's crude protein content of 28.05% is comparable to some conventional protein sources used in ruminant diets. For instance, soybean meal a widely used protein supplement typically contains 44–49% crude protein (Maxwell et al., 2015). While not matching the protein density of soybean meal, the Mexican Sunflower's protein content is substantial and could contribute significantly to meeting the protein requirements of ruminants particularly when combined with other protein-rich feedstuffs or supplements (Nurdianti et al., 2024; Simoni et al., 2024).

On the other hand, Silver Leaf Desmodium's crude protein content of 18.54% is lower than that of the Mexican Sunflower but still within the range of protein levels found in various forage crops. Legume forages such as alfalfa and clover are known for their higher protein density than grasses with a protein content of 15–25% (Haenlein, 2001). Silver Leaf Desmodium's protein content falls within this range making it a potentially valuable forage option for ruminants particularly when included in a well-balanced ration. Evaluating the potential of these plants as viable protein sources for ruminants requires considering not only their protein content but also other factors such as palatability, digestibility and overall nutrient composition. While protein is a crucial component of ruminant diets, a balanced ration should also provide adequate energy, fiber, minerals and vitamins to support optimal animal health and productivity (Godoi et al., 2024).

Fiber Content Analysis

The results of this study reveal a significant difference in the crude fiber content between Silver Leaf Desmodium and Mexican Sunflower. Silver Leaf Desmodium exhibited a considerably higher crude fiber content of 24.28% while Mexican Sunflower had a lower crude fiber content of 6.56%. These findings have important implications for the potential use of these plants as ruminant feed, as fiber plays a crucial role in ruminant diets and digestibility. Fiber, particularly structural carbohydrates such as cellulose and hemicellulose is essential to ruminant diets. Ruminants possess a unique digestive system that allows them to break down and utilize fibrous plant materials through microbial fermentation in the rumen (Van Soest, 1994). The fiber content of feedstuffs influences the rumen environment, microbial activity and overall diet digestibility.

According to Haenlein (2001), forages with higher fiber content such as legumes and grasses form the foundation of ruminant diets providing fermentable fiber and promoting rumen health. The high fiber content of Silver Leaf Desmodium (24.28%) aligns with its classification as a legume forage making it a potentially valuable source of fiber for ruminants. This high fiber content can contribute to maintaining a healthy rumen environment and promoting efficient feed digestion.

On the other hand, the lower fiber content of Mexican Sunflower (6.56%) suggests that it may not be as effective in providing the necessary fiber for optimal rumen function when used as a sole source of feed. However, when combined with other high-fiber feedstuffs or forages, Mexican sunflowers could contribute to balancing the overall fiber content of the ration (Lourençon et al., 2024). It is important to note that the digestibility of fiber can vary depending on its composition and the presence of other factors such as lignin, which can inhibit fiber degradation by rumen microbes (Van Soest, 1994). Therefore, while the crude fiber content provides valuable information, further analysis of fiber fractions and digestibility may be necessary to fully assess the suitability of these plants as ruminant feed sources. In terms of implications for using these plants as ruminant feed, the high fiber content of Silver Leaf Desmodium makes it a promising forage option particularly for ruminants with higher fiber requirements such as beef cattle and dairy cows in later stages of lactation (Haenlein, 2001). Its inclusion in ruminant rations could help maintain rumen health and support efficient diet digestion. It is crucial to consider the fiber content and composition of feedstuffs when formulating ruminant rations as fiber plays a vital role in rumen function, digestibility and overall animal health and productivity (Godoi et al., 2024). Further research into these plants' specific fiber fractions and digestibility would provide additional insights into their potential as ruminant feed sources.

Ash and Mineral Composition

The ash content results obtained in this study provide insights into the mineral composition of Silver Leaf Desmodium and Mexican Sunflower. The ash content represents the inorganic matter in the plant material, primarily consisting of minerals essential for ruminant nutrition (Van Soest, 1994; Mtengeti et al., 2021). Evaluating the mineral content is crucial as minerals play vital roles in various physiological processes such as bone development, enzyme function and reproduction (McDowell et al., 2020). The results indicate that Mexican Sunflower has a higher ash content ranging from 12.66% to 14.7%, compared to Silver Leaf Desmodium, which had an ash content ranging from 6.9% to 7%. While the specific mineral composition was not analyzed in this study, the higher ash content in Mexican Sunflower suggests a potentially higher mineral concentration than Silver Leaf Desmodium. According to the existing literature, ruminants have varying mineral requirements depending on their physiological state, production level and growth stage (Suttle, 2010; Moraes et al., 2022). Lactating dairy cows, for instance, have higher mineral requirements than dry cows or growing cattle (McDowell et al., 2020). Some essential minerals for ruminants include calcium, phosphorus, sodium, magnesium, potassium and trace minerals like zinc, copper and selenium (Gonçalves et al., 2021).

The higher ash content in Mexican sunflowers suggests that it could potentially contribute to meeting the mineral requirements of ruminants particularly when included as part of a balanced ration. However, it is important to note that these minerals' specific mineral composition and bioavailability would need further evaluation to determine their suitability for ruminant nutrition. On the other hand, the lower ash content in Silver Leaf Desmodium may indicate a lower mineral concentration. While legumes are generally known for their ability to fix atmospheric nitrogen and contribute to soil fertility (Haenlein, 2001; Kariuki et al., 2022), their mineral content can vary depending on factors such as soil type, climate and growth stage (McDowell et al., 2020). It is worth noting that excessive or deficient levels of certain minerals can have adverse effects on ruminant health and productivity. For example, high levels of potassium or oxalates can interfere with calcium absorption leading to metabolic disorders (Suttle, 2010; Moraes et al., 2022). Therefore, a balanced mineral profile is essential for optimal ruminant nutrition. Further analysis of the specific mineral composition would be necessary to fully evaluate the potential benefits or limitations of the mineral content in Silver Leaf Desmodium and Mexican Sunflower. This could involve determining the levels of essential minerals such as calcium, phosphorus, potassium and trace minerals and comparing them to the established requirements for different ruminant species and production stages. Additionally, assessing the bioavailability of these minerals, which can be influenced by factors such as mineral interactions, fiber content and anti-nutritional factors would provide valuable information for formulating balanced rations (Gonçalves et al., 2021; Moraes et al., 2022). Overall, while the ash content indicates the mineral composition, a comprehensive mineral analysis and bioavailability evaluation would be necessary to fully understand the potential benefits or limitations of using Silver Leaf Desmodium and Mexican Sunflower as ruminant feed sources from a mineral nutrition perspective.

Moisture Content Considerations

The results of this study reveal significant differences in moisture content between Silver Leaf Desmodium and Mexican Sunflower. Silver Leaf Desmodium exhibited a high moisture content ranging from 74.62% to 77.70% while Mexican sunflowers had an even higher moisture content ranging from 89.32% to 95.59%. These findings have important implications for the practical use of these plants as ruminant feed sources as moisture content plays a crucial role in storage, handling and feed formulation. High moisture content in feedstuffs can lead to spoilage and the growth of undesirable microorganisms during storage as moisture provides an environment conducive to microbial growth (McDonald et al., 2011). This can result in the degradation of nutrients and the production of mycotoxins which can be harmful to ruminants (Fink-Gremmels, 2008). As such, the high moisture content observed in Silver Leaf Desmodium and Mexican Sunflower may pose long-term storage and preservation challenges. To address this issue, appropriate drying or ensiling techniques may be necessary to reduce the moisture content to levels suitable for safe storage and handling. According to McDonald et al. (2011), silage production can effectively preserve high-moisture forages as the anaerobic fermentation process prevents spoilage and maintains nutrient quality. However, proper ensiling techniques and adherence to appropriate moisture levels are crucial for successful silage production.

In addition to storage considerations, moisture content plays a role in feed formulation and ration balancing. Ruminant diets are typically formulated on a dry matter basis and the moisture content of individual feedstuffs affects their contribution to the overall dry matter intake and nutrient composition of the ration (Van Soest, 1994). Feedstuffs with high moisture content may need to be adjusted or combined with drier ingredients to achieve the desired dry matter content and nutrient balance in the ration. For practical use as ruminant feed, the high moisture content of Silver Leaf Desmodium and Mexican Sunflower may necessitate additional processing steps such as drying or ensiling to ensure proper storage and preservation. This can have implications for the overall cost and feasibility of using these plants as feed sources as additional processing and handling may be required. Furthermore, the moisture content can influence the ruminants' palatability and intake of the feed. While high moisture content can sometimes improve palatability, excessive moisture levels can lead to feed spoilage and reduced intake (McDonald et al., 2011). Therefore, balancing moisture content and palatability is essential to ensure optimal feed intake and ruminant utilization.

In conclusion, the high moisture content observed in Silver Leaf Desmodium and Mexican Sunflowers presents challenges for their practical use as ruminant feed sources. Appropriate storage, handling and processing methods may be required to ensure proper preservation and maintain nutrient quality. Additionally, moisture content must be considered during feed formulation to achieve the desired dry matter intake and nutrient balance in ruminant rations. Further research into the optimal moisture levels and preservation techniques for these plants would be beneficial in maximizing their potential as sustainable and practical ruminant feed sources.

Economic Viability and Sustainability

Exploring alternative and cost-effective protein sources for ruminants, such as Silver Leaf Desmodium and Mexican Sunflower holds significant implications for economic viability and sustainability for livestock production systems. These plants present promising opportunities to address the growing demand for affordable and environmentally friendly feed solutions aligning with the research objectives and the broader context of sustainable agriculture. Regarding economic benefits utilizing locally available and naturally growing plant species like Silver Leaf Desmodium and Mexican Sunflower can reduce reliance on costly commercial protein supplements and concentrate feeds. Conventional protein sources, such as soybean meal and fishmeal are often subject to price fluctuations and market volatility making them less economically viable for small-scale livestock producers (Ayantunde et al., 2005). Farmers may reduce feed costs by incorporating these alternative protein sources into ruminant rations while maintaining the necessary protein levels for optimal animal growth and productivity.

Moreover, the cultivation of these plants can be integrated into existing agricultural systems reducing the need for additional land and resources. Silver Leaf Desmodium and Mexican sunflowers are known for their adaptability to diverse climatic conditions and soil types making them suitable for cultivation in various regions (Gualberto et al., 2011; Hueze et al., 2017). This versatility can contribute to the economic viability of livestock production by reducing the costs associated with specialized cultivation practices or expensive inputs. From a sustainability perspective, using these plants as ruminant feed sources aligns with the principles of environmental conservation and resource efficiency. Legumes such as silver leaf desmodium, can fix atmospheric nitrogen, reduce the need for synthetic nitrogen fertilizers and contribute to soil fertility (Haenlein, 2001). This can lead to lower environmental impacts and improved soil health supporting sustainable agricultural practices. Cultivating these plants can contribute to biodiversity conservation by providing habitats for various species and promoting diverse ecosystems (Ayantunde et al., 2005). This aligns with the broader objectives of sustainable livestock production, which emphasize the importance of maintaining ecological balance and minimizing negative environmental impacts. It is worth noting that the economic viability and sustainability of using these plants as ruminant feed sources may also depend on factors such as the efficiency of cultivation practices, processing methods and the overall productivity of the plants in different regions. Optimizing these factors through research and development can further enhance the potential benefits of these alternative protein sources.

Relating these findings to the research objectives, the comparative analysis of Silver Leaf Desmodium and Mexican Sunflower provides valuable insights into their potential as economically viable and sustainable protein sources for ruminants. By identifying their nutritional composition, particularly in terms of protein, fiber and mineral content, this study contributes to understanding their suitability as feed alternatives addressing the broad objective of assessing their nutritional value. Furthermore, evaluating economic and sustainability aspects aligns with the broader context of sustainable livestock production. As the demand for animal products continues to rise, there is an increasing need for environmentally friendly and cost-effective feed solutions that can support the growth of the livestock sector while minimizing its environmental footprint (Henchion & Zimmermann, 2021).

Limitations and Future Research

While the findings of this study provide valuable insights into the potential of Silver Leaf Desmodium and Mexican Sunflower as protein sources for ruminants, it is essential to acknowledge the limitations and identify areas for future research to address remaining knowledge gaps. One of the limitations of the current study is the sample size. The analysis was conducted on a limited number of samples which may not fully capture the variability within these plant species due to factors such as environmental conditions, soil composition and maturity stage at harvest. A larger sample size, spanning different geographical locations and growing conditions could provide a more comprehensive understanding of the nutritional profiles and potential variations. Additionally, the study focused primarily on the plants' protein, fiber, ash and moisture content. While these are crucial parameters for evaluating their suitability as ruminant feed sources, other factors such as digestibility, palatability and anti-nutritional factors were not extensively explored. These aspects can significantly influence the overall nutritional value and acceptance of the feed by ruminants and their investigation is essential for a comprehensive assessment. Furthermore, the study did not investigate these minerals' specific mineral composition or bioavailability. As discussed in the literature review, minerals play vital roles in ruminant nutrition, and a detailed analysis of the mineral profiles of Silver Leaf Desmodium and Mexican Sunflower would provide valuable insights into their potential to meet the mineral requirements of different ruminant species and production stages.

To address the limitations and delve deeper into the potential of Silver Leaf Desmodium and Mexican Sunflower as ruminant feed sources, several avenues for future research emerge. Firstly, conducting field trials and on-farm studies would provide valuable real-world insights into the performance and productivity of ruminants fed with these plants including aspects like feed intake, weight gain, milk production and overall animal health. Secondly, exploring digestibility and nutrient utilization through in vitro and in vivo studies would shed light on how effectively ruminants can absorb and utilize nutrients from these plants while also considering the impact of anti-nutritional factors on nutrient bioavailability. Thirdly, analyzing the mineral composition and bioavailability and assessing different processing and preservation methods like drying or ensiling could enhance storage stability, palatability and overall nutritional quality. Furthermore, conducting comprehensive economic and environmental impact assessments is crucial to evaluate the economic viability, resource utilization and sustainability of integrating these plants into ruminant diets considering production costs and potential environmental implications.

By addressing these limitations and undertaking further research in the areas mentioned above, a more comprehensive understanding of the potential of Silver Leaf Desmodium and Mexican Sunflower as alternative protein sources for ruminants can be achieved. This knowledge can contribute to developing sustainable and economically viable livestock production systems aligning with the broader goals of food security and environmental conservation.

CONCLUSION

The comparative analysis of Silver Leaf Desmodium and Mexican Sunflower in this study has provided valuable insights into their potential as alternative protein sources for ruminant animals. The findings highlight the significant differences in protein, fiber, ash and moisture content between these two plants indicating their varying nutritional profiles and suitability for specific applications in ruminant diets. Mexican Sunflower exhibited a higher crude protein content of 28.05% making it a promising concentrate or protein supplement that could contribute substantially to meeting the protein requirements of ruminants. On the other hand, Silver Leaf Desmodium with its lower crude protein content of 18.54% but higher fiber content of 24.28%, could serve as a valuable forage option, providing protein and essential fiber for rumen health and function. Furthermore, the ash content results suggest that Mexican sunflowers may have a higher mineral concentration potentially contributing to meeting the mineral requirements of ruminants when incorporated into balanced rations. However, a comprehensive analysis of the specific mineral composition and bioavailability is recommended to fully understand these plants' potential benefits or limitations from a mineral nutrition perspective. The moisture content findings highlight the need for appropriate storage, handling and processing methods to ensure proper preservation and maintain nutrient quality when using these plants as ruminant feed sources. Techniques such as drying or ensiling may be necessary to reduce the high moisture content observed in both plants.

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Figures

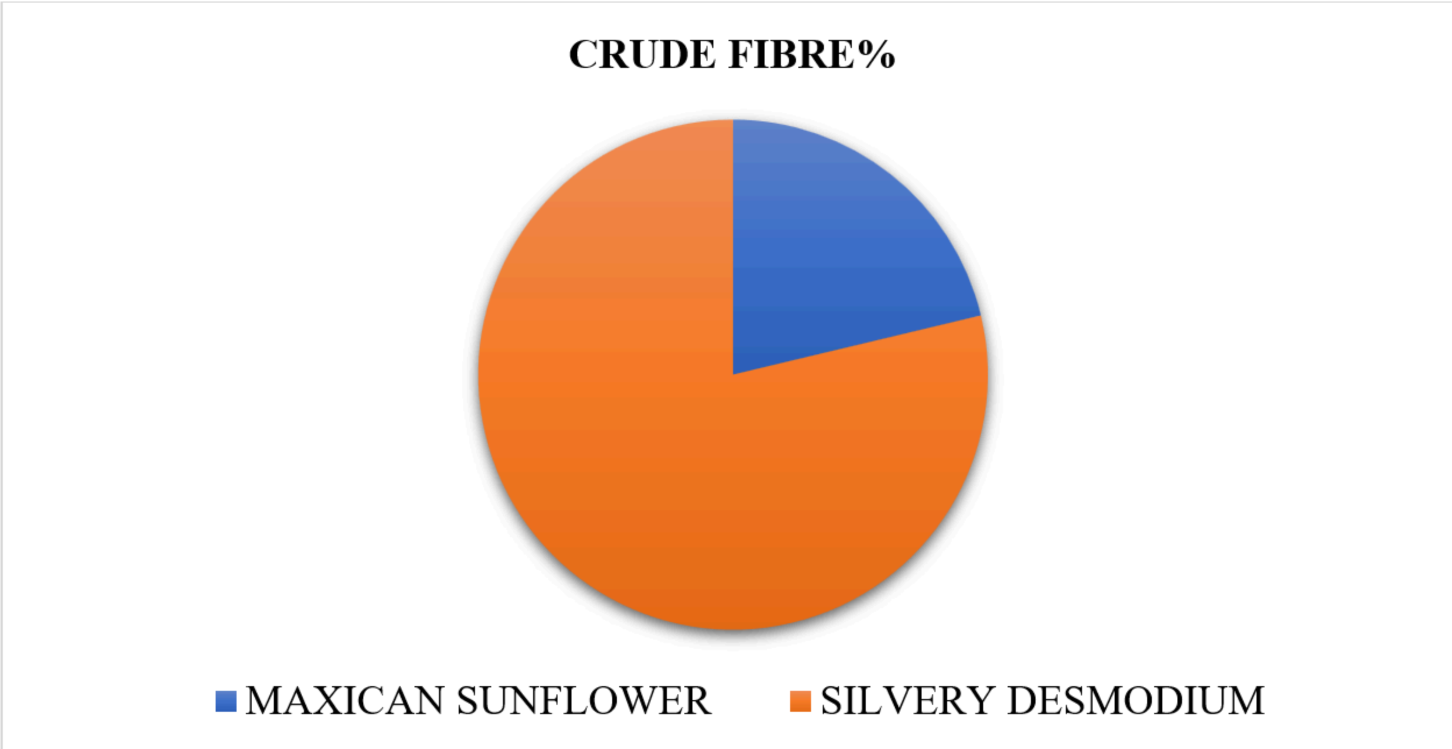

Figure 1

Crude Fibre Content Percentages

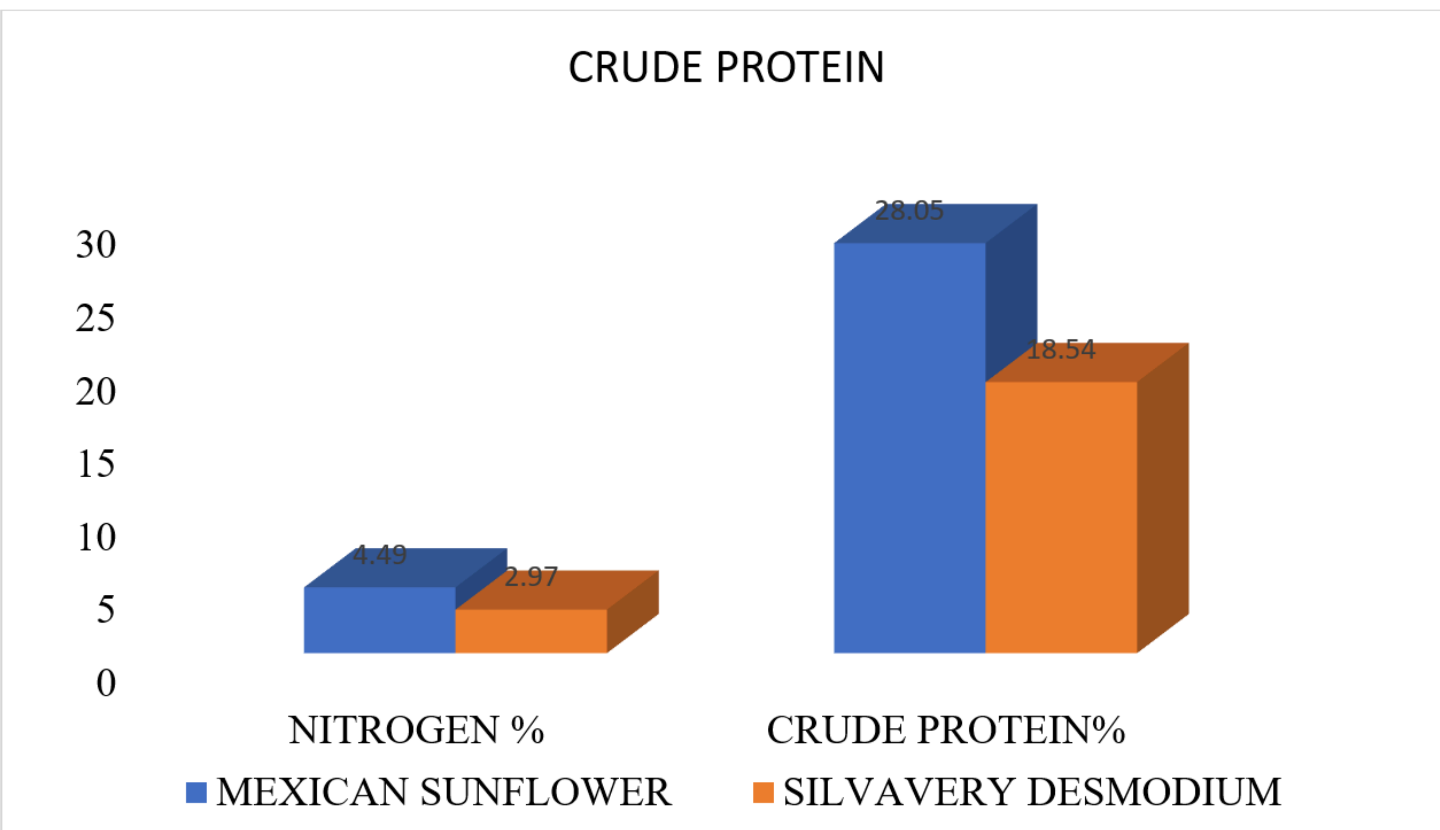

Figure 2

Crude Protein Content Percentages

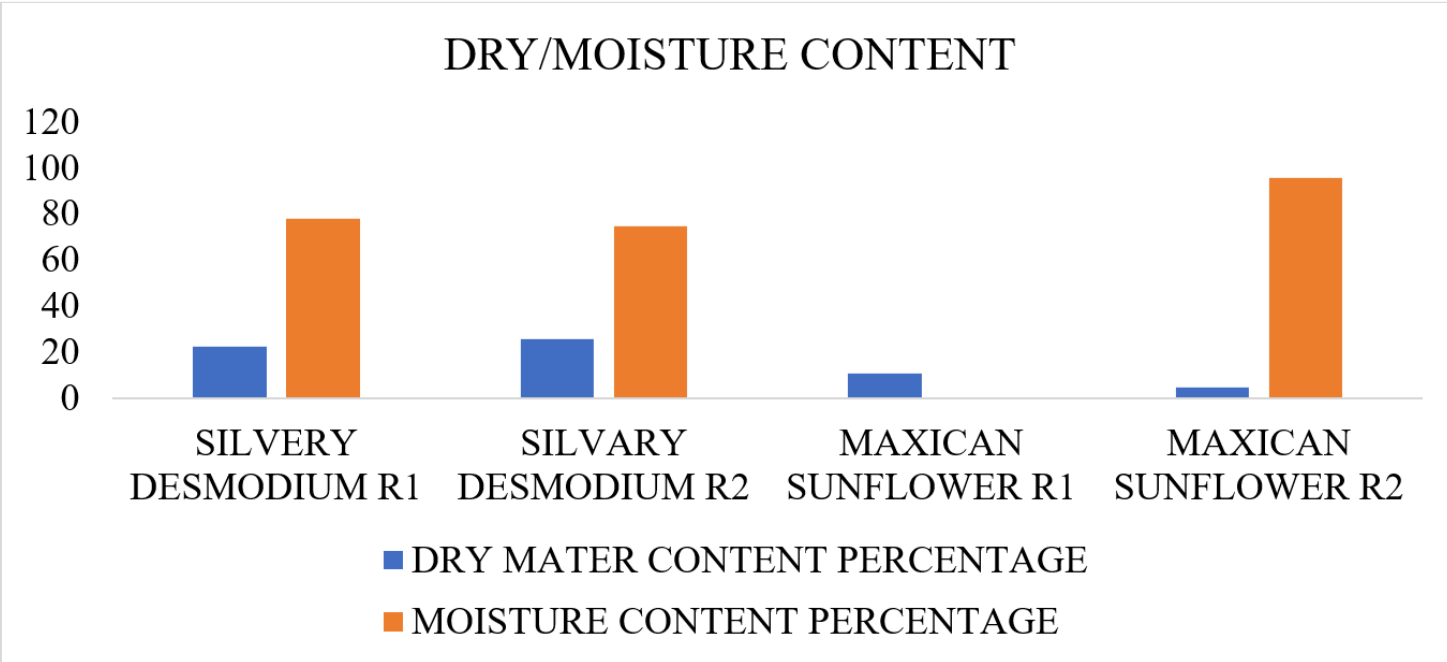

Figure 3

Moisture Content Percentages

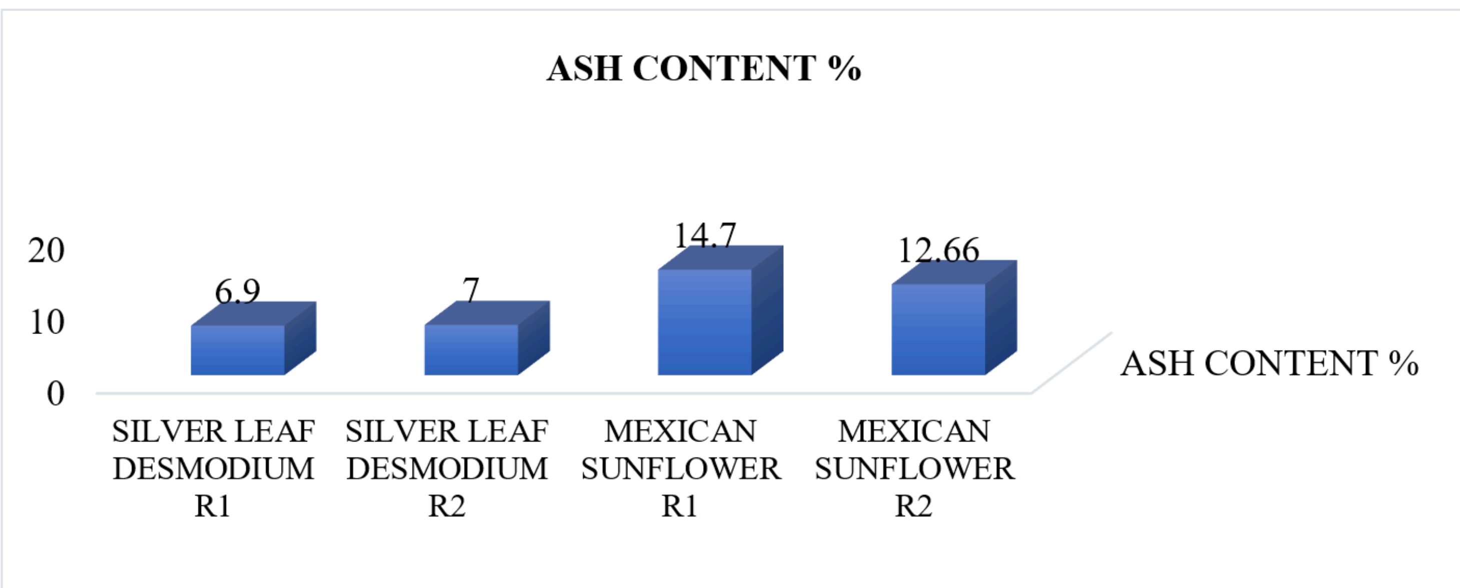

Figure 4

Ash Content Percentages

Supplementary Files

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- APPENDICES.docx