International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 24, No. 3, p. 187-194, 2024

INNSPUB

RESEARCH PAPER OPEN ACCESS

Assessment of nutrient content in grain, hydroponic and conventional fodder with focus on maize, wheat and Sudan grass

Md. Baharul Islam[1], Md. Giush Uddin Ahmed*[1], Md. Akhtarul Islam[2], Md. Shakil Khan[1], Ferdous Akter[1]

[1]*Department of Agronomy and Agricultural Extension, University of Rajshahi, Rajshahi, Bangladesh*

[2]*Department of Veterinary and Animal Sciences, University of Rajshahi, Rajshahi, Bangladesh*

Key words: Green fodder, Nutrient content, Hydroponic, Maize, Wheat, Sudan grass

http://dx.doi.org/10.12692/ijb/24.3.187-194 Article published on March 16, 2024

Abstract

Livestock nutrition plays a crucial role in ensuring animal health and productivity. However, the nutritional quality of fodder can vary significantly depending on cultivation methods, posing challenges for livestock farmers in providing balanced diets for their animals. This study aimed to compare the chemical composition of fodder produced using three different cultivation methods: grain, hydroponic, and conventional. Specific objectives included assessing the levels of crude protein, fiber, ether extract, and ashes in maize, wheat, and Sudan grass fodder types. Fodder samples were collected from representative farms and subjected to laboratory analysis to determine their chemical composition. Standard methods were employed to assess crude protein, crude fiber, acid detergent fiber, neutral detergent fiber, ether extract, and ash content. Statistical analysis was conducted to compare the results among different fodder types. Hydroponically cultivated fodder consistently exhibited higher levels of crude protein and ether extract compared to conventionally grown fodder. Additionally, conventional fodder types tended to have higher fiber and ash content. However, all fodder types showed variations in nutritional composition depending on the crop species. Hydroponic cultivation methods resulted in higher protein and lipid content in maize, wheat, and Sudan grass fodder. Conventional fodder types had higher levels of fiber and ash, potentially impacting digestibility and nutrient availability. The findings suggest that hydroponic cultivation methods hold promise for enhancing the nutritional quality of fodder, thereby improving livestock health and productivity. Farmers should consider integrating hydroponic systems into their fodder production practices to optimize animal nutrition and achieve better economic outcomes.

* **Corresponding Author:** Md. Giush Uddin Ahmed ✉ ahmedmgu@ru.ac.bd

Introduction

Quality forage plays a pivotal role in ensuring the health and productivity of livestock. It encompasses various factors such as nutritional content, palatability, and digestibility. High-quality forage provides essential nutrients like protein, carbohydrates, vitamins, and minerals necessary for optimal animal growth, reproduction, and overall well-being (Allen, 2014; Van Soest, 1994). It supports efficient rumen function and helps prevent metabolic disorders in ruminants (Huntington, 1997). Additionally, quality forage enhances feed intake, promoting healthy weight gain and milk production in dairy animals. Its palatable nature encourages animals to consume adequate amounts, contributing to balanced diets and reducing the need for costly supplements (Wilkinson, 2011). Overall, quality forage is fundamental for sustainable livestock production.

Determining forage quality involves assessing various parameters such as nutrient composition, digestibility, palatability, and absence of contaminants. Methods include laboratory analysis of dry matter, protein, fiber, and mineral content (Undersander *et al.*, 2005). Digestibility is evaluated through techniques like in vitro or in vivo trials. Palatability is often determined by animal preference tests. Assessing for contaminants involves screening for molds, toxins, and harmful bacteria. Additionally, sensory evaluation and microbial analysis contribute to overall quality determination (Chamberlain *et al.*, 1993). Integrating these analyses provides a comprehensive understanding of forage suitability for animal nutrition, aiding in formulation of balanced diets and ensuring optimal livestock health and performance (Moore *et al.*, 2017).

Hydroponic quality forage holds significant importance in modern livestock production due to its numerous advantages. Firstly, hydroponic systems enable year-round forage production regardless of weather conditions, ensuring a consistent and reliable feed source for livestock. This reliability reduces dependence on seasonal fluctuations and mitigates risks associated with adverse weather events, such as droughts or floods. Secondly, hydroponically grown forage offers superior nutrient content and quality control compared to traditional methods. By optimizing growing conditions, such as light, temperature, and nutrient levels, hydroponic systems can produce forage with higher protein content, increased digestibility, and lower levels of anti-nutritional factors (Bartok and Bucklin, 1995). This results in improved animal health, performance, and feed efficiency. Additionally, hydroponic forage production requires less land, water, and inputs compared to conventional forage cultivation, making it environmentally sustainable and economically viable (Godia and Montesinos, 2005). The ability to produce high-quality forage in smaller spaces is particularly advantageous in urban or peri-urban settings where land availability is limited. Moreover, hydroponic systems offer flexibility in terms of forage varieties and can accommodate specific nutritional requirements of different livestock species. This adaptability allows for customized feed solutions, optimizing animal nutrition and production outcomes (Li and Yang, 2017; Rajapaksha *et al.*, 2017).

Fodder quality is paramount in ensuring the health, productivity, and profitability of livestock operations. High-quality fodder provides essential nutrients necessary for animal growth, reproduction, and overall well-being. It promotes optimal rumen function, efficient digestion, and nutrient utilization, leading to improved feed efficiency and performance (Moore *et al.*, 2017). Additionally, quality fodder enhances palatability, encouraging adequate feed intake and reducing the risk of metabolic disorders. By providing balanced nutrition, fodder quality contributes to enhanced milk production, meat yield, and reproductive success in livestock. Ultimately, investing in quality fodder translates to healthier animals, sustainable production practices, and increased profitability for farmers.

This research work was undertaken to achieve the following objectives. To evaluate the nutrient content of grain, hydroponic, and conventional fodder types.

To compare the nutrient profiles of maize, wheat, and Sudan grass within hydroponic green fodder systems.

Materials and Methods

Fodder samples

Grain, hydroponic fodder (maize, wheat, Sudan grass), and conventional fodder samples were collected from representative farms. NFT hydroponic system was used to measure the nutritional value of three types of green fodder. Cooper (1979) media was used as the nutrient medium in the hydroponic system. pH 6.5±0.5, EC level 1.2 to 2.4 mS/cm and TDS 1500±500 ppm of nutrient medium were maintained. Two weeks (14 days) old plants were harvested as samples for measurement of fodder nutritional value.

Laboratory analysis

Nutrient Composition: Dry matter, crude protein, fiber (ADF, NDF), were determined using standard analytical methods. Following this extraction procedure allows for the determination of acid detergent fiber content in fodder samples, providing valuable information for assessing their nutritional quality and suitability for animal feeding, particularly in ruminant nutrition studies.

A. Crude protein (AOAC, 2017)

1. Grind the fodder samples into a fine powder using a laboratory grinder to ensure uniformity.
2. Accurately weigh about 0.5 to 1.0 grams of the powdered fodder sample into a digestion flask.
3. Add 10 mL of concentrated sulfuric acid (H_2SO_4) to the flask containing the sample. Place the flask in a fume hood or a well-ventilated area and heat gently on a digestion block or hot plate until the mixture becomes clear. Continue heating until white fumes appear, indicating complete digestion. Allow the mixture to cool to room temperature.
4. Transfer the digested sample to a distillation apparatus, such as a Kjeldahl flask, and add distilled water to make up the volume. Attach the distillation apparatus to a Kjeldahl distillation unit. Add a few drops of antifoaming agent to prevent foaming during distillation. Distill the sample until about 150 mL of distillate is collected in the receiver flask.
5. Titrate the distillate with standardized 0.1 M hydrochloric acid (HCl) using a suitable indicator, such as methyl red or bromocresol green. Continue titration until a color change is observed, indicating the endpoint of the reaction.
6. Calculate the percentage of crude protein in the fodder sample using the following formula:
   Crude Protein (%) = (Volume of acid × Normality of acid × 6.25) / Weight of sample
7. Run blanks and standards alongside the samples to ensure accuracy and precision. Calibrate the titration apparatus regularly using standardized solutions.

B. Crude fiber (AOCS, 2009)

1. Grind the fodder samples into a fine powder using a laboratory grinder to ensure uniformity.
2. Accurately weigh about 2 to 3 grams of the powdered fodder sample into a suitable extraction flask.
3. Add 200-300 mL of dilute sulfuric acid (1.25%) to the extraction flask containing the sample. Boil the mixture gently for 30 minutes to facilitate the breakdown of soluble carbohydrates and proteins.
4. Filter the contents of the flask through a pre-weighed filter paper using a vacuum filtration setup. Wash the residue with hot water until the filtrate becomes clear.
5. Transfer the residue (fiber) from the filter paper back into the flask. Add 200-300 mL of 1.25% sodium hydroxide (NaOH) solution to the flask. Boil the mixture gently for 30 minutes to remove hemicellulose and other organic matter.
6. Repeat the filtration process as described in step 4 to separate the residue from the alkali solution. Wash the residue thoroughly with hot water to remove any alkali residue.
7. Dry the residue (crude fiber) in an oven at 105°C until a constant weight is achieved. Allow the crucible and contents to cool in a desiccator before weighing.
8. Calculate the percentage of crude fiber in the fodder sample using the following formula:

Crude Fiber (%) = [(Weight of dried residue - Weight of filter paper) / Weight of sample] × 100

C. Acid detergent fiber (Van Soest et al., 1991)

1. Grind the fodder samples into a fine powder using a laboratory grinder to ensure uniformity.
2. Accurately weigh about 0.5 to 1.0 grams of the powdered fodder sample into a suitable extraction flask or bag.
3. Add the weighed sample to an acid detergent solution consisting of 1 N sulfuric acid (H_2SO_4) in a flask or extraction bag. Place the flask or bag in a fiber analyzer or extraction apparatus designed for ADF determination.
4. Boil the sample in the acid detergent solution for 1 hour. Ensure continuous boiling throughout the process.
5. Filter the mixture through a pre-weighed crucible or filter bag using a vacuum filtration setup to separate the residue from the solution.
6. Wash the residue on the filter with hot water until the washings are free from acidity, indicating complete removal of the acid detergent solution.
7. Dry the residue in an oven at 105°C until a constant weight is achieved. Allow the crucible and contents to cool in a desiccator before weighing.
8. Calculate the percentage of acid detergent fiber in the fodder sample using the following formula:
   ADF (%) = [(Weight of dried residue - Weight of filter paper) / Weight of sample] × 100

D. Neutral detergent fiber (Goering et al., 1970)

1. Grind the fodder samples into a fine powder using a laboratory grinder to ensure uniformity.
2. Accurately weigh about 0.5 to 1.0 grams of the powdered fodder sample into a suitable extraction flask or bag.
3. Add the weighed sample to a neutral detergent solution consisting of 1 N sodium lauryl sulfate (SDS) or equivalent detergent in a flask or extraction bag. Place the flask or bag in an appropriate apparatus designed for NDF determination.
4. Boil the sample in the neutral detergent solution for 1 hour. Ensure continuous boiling throughout the process.
5. Filter the mixture through a pre-weighed crucible or filter bag using a vacuum filtration setup to separate the residue from the solution.
6. Wash the residue on the filter with hot water until the washings are free from detergent, indicating complete removal of the neutral detergent solution.
7. Dry the residue in an oven at 105°C until a constant weight is achieved. Allow the crucible and contents to cool in a desiccator before weighing.
8. Calculate the percentage of neutral detergent fiber in the fodder sample using the following formula:
   NDF (%) = [(Weight of dried residue - Weight of filter paper) / Weight of sample] × 100

E. Ether extracts (AOAC, 2016)

1. Grind the fodder samples into a fine powder using a laboratory grinder to ensure uniformity.
2. Accurately weigh about 2 to 3 grams of the powdered fodder sample into a suitable extraction thimble or flask.
3. Place the weighed sample into an extraction thimble or flask.
4. Add a suitable volume of petroleum ether or hexane as the extraction solvent to cover the sample completely.
5. Set up a Soxhlet extractor apparatus with a condenser, extraction chamber, and flask for collecting the extracted solvent. Heat the flask containing the sample and solvent mixture on a heating mantle or hot plate. Allow the solvent to vaporize, condense, and drip onto the sample, extracting the ether-soluble components. The process continues cyclically, with the solvent being evaporated and condensed back onto the sample for several hours until extraction is complete.
6. Remove the flask containing the extracted solvent from the Soxhlet apparatus. Transfer the solvent extract to a pre-weighed evaporation dish or flask.
7. Allow the solvent to evaporate at room temperature or under reduced pressure using a rotary evaporator until all the solvent has been removed.
8. After complete evaporation, weigh the residue to determine the mass of the ether extract.
9. Calculate the percentage of ether extract in the fodder sample using the following formula:
   EE (%) = [(Weight of extracted residue - Weight of empty dish or flask)/Weight of sample] × 100

F. Ashes (AOAC, 2016)

1. Grind the fodder samples into a fine powder using a laboratory grinder to ensure uniformity.
2. Accurately weigh about 2 to 3 grams of the powdered fodder sample into a pre-weighed crucible.
3. Place the crucible with the sample in an oven at 105°C to 110°C for several hours until a constant weight is achieved. This step removes moisture from the sample.
4. Transfer the crucible with the dried sample to a muffle furnace preheated to 550°C to 600°C. Incinerate the sample for at least 4 hours or until complete combustion occurs, leaving behind a white ash residue.
5. Allow the crucible and ash residue to cool to room temperature in a desiccator to prevent moisture absorption.
6. Once cooled, weigh the crucible containing the ash residue.
7. Calculate the percentage of ash content in the fodder sample using the following formula:

   Ash (%) = [(Weight of ash residue - Weight of crucible) / Weight of sample] × 100

Hydroponic system parameters

Growing Conditions; Light intensity, temperature, pH, nutrient solution concentration were monitored and optimized. Harvesting Protocol; Harvesting frequency, growth stage, and harvesting techniques were standardized. Calibration of laboratory equipment. Random sampling and replication to ensure accuracy and reliability of results. The obtained data were processed into multiple bar diagrams using Microsoft Excel (2016) application.

Results and Discussion

Chemical composition of different maize fodder

Hydroponic maize exhibits the highest crude protein content among the three fodder types, with a concentration of 140.91 gm/kg on a dry matter basis. This finding suggests that hydroponic cultivation methods may enhance protein synthesis and accumulation in maize plants, leading to increased protein content. Conventional maize displays the highest crude fiber, ADF, and NDF contents among the three fodder types. This result is consistent with expectations, as conventional farming practices may lead to increased fiber accumulation in maize plants. The higher fiber content in conventional maize may offer benefits for ruminant animals, such as maintaining rumen health and promoting rumination. Hydroponic maize exhibits the highest ether extract content among the three fodder types, indicating increased lipid accumulation. This finding suggests that hydroponic cultivation methods may influence lipid metabolism in maize plants, leading to higher lipid content. Conventional maize exhibits the highest ash content among the three fodder types. This result suggests that conventional farming practices may contribute to greater mineral accumulation in maize plants, leading to higher ash content. While minerals are essential for animal health and productivity, excessive ash intake may lead to imbalances and adverse effects on livestock (Fig. 1).

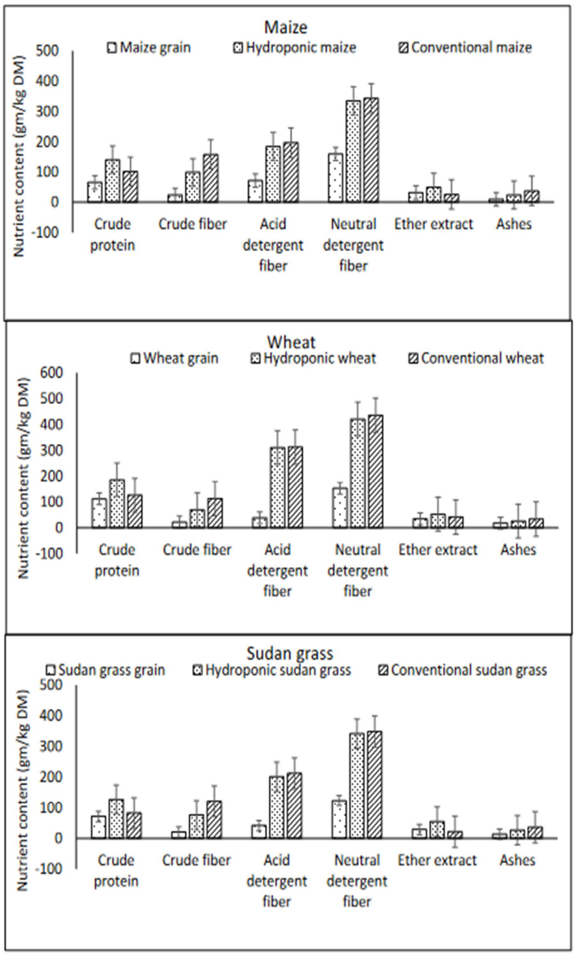

Fig. 1. Chemical composition of different maize, wheat and Sudan grass fodder.

The analysis indicates that hydroponically grown maize exhibits substantially higher levels of crude protein compared to both grain and conventional maize. This finding aligns with few research highlighting the potential of hydroponic systems to enhance nutrient uptake and synthesis in plants (Liorente and Causape, 2018; Ferraretto *et al.*, 2013). The increased protein content in hydroponic maize suggests its potential as a superior source of dietary protein for livestock, contributing to improved growth and performance (Tyagi *et al.*, 2017). Contrastingly, conventional maize demonstrates the highest levels of crude fiber, acid detergent fiber, and neutral detergent fiber among the three fodder types. This outcome is consistent with the expected fiber content in mature grain crops. However, the high fiber content may limit the digestibility and nutrient availability of conventional maize, necessitating supplementation or processing to enhance its utilization in livestock diets (Ferraretto *et al.*, 2013).

Chemical composition of different wheat fodder

Hydroponic wheat exhibits the highest crude protein content among the three fodder types, with a concentration of 185.63 gm/kg on a dry matter basis. This finding suggests that hydroponic cultivation methods may enhance protein synthesis and accumulation in wheat plants, leading to increased protein content. Conventional wheat displays the highest crude fiber, acid detergent fiber (ADF), and neutral detergent fiber (NDF) contents among the three fodder types. This result is consistent with expectations, as conventional farming practices may lead to increased fiber accumulation in wheat plants. The higher fiber content in conventional wheat may offer benefits for ruminant animals, such as maintaining rumen health and promoting rumination. Hydroponic wheat exhibits the highest ether extract content among the three fodder types, indicating increased lipid accumulation. This finding suggests that hydroponic cultivation methods may influence lipid metabolism in wheat plants, leading to higher lipid content. Conventional wheat exhibits the highest ash content among the three fodder types. This result suggests that conventional farming practices may contribute to greater mineral accumulation in wheat plants, leading to higher ash content.

The analysis underscores the importance of considering the chemical composition of wheat fodder when selecting feed for livestock diets (Khan and Arshad, 2019). Hydroponic wheat offers a higher protein and lipid alternative to conventional wheat, potentially meeting the nutritional needs of livestock with specific dietary requirements (Batista *et al.*, 2021; Selim *et al.*, 2019). The suitability of each wheat fodder type should be evaluated in the context of animal species, production objectives, and nutritional considerations (Rodehutscord and Pfeffer, 2021). Further research is needed to explore the implications of these findings on animal performance and feed formulation strategies.

Chemical composition of different Sudan grass fodder

Hydroponic Sudan grass exhibits the highest crude protein content among the three fodder types, with a concentration of 127.32 gm/kg on a dry matter basis. This finding suggests that hydroponic cultivation methods may enhance protein synthesis and accumulation in Sudan grass plants, leading to increased protein content. Conventional Sudan grass displays the highest crude fiber, acid detergent fiber (ADF), and neutral detergent fiber (NDF) contents among the three fodder types. This result is consistent with expectations, as conventional farming practices may lead to increased fiber accumulation in Sudan grass plants. Hydroponic Sudan grass exhibits the highest ether extract content among the three fodder types, indicating increased lipid accumulation. This finding suggests that hydroponic cultivation methods may influence lipid metabolism in Sudan grass plants, leading to higher lipid content. Conventional Sudan grass exhibits the highest ash content among the three fodder types. This result suggests that conventional farming practices may contribute to greater mineral accumulation in Sudan grass plants, leading to higher ash content. While minerals are essential for animal health and productivity, excessive ash intake may lead to imbalances and adverse effects on livestock.

Overall, the analysis highlight the importance of considering the chemical composition of Sudan grass fodder when selecting feed for livestock diets. Hydroponic Sudan grass offers a higher protein and lipid alternative to conventional Sudan grass, potentially meeting the nutritional needs of livestock with specific dietary requirements (Thabet *et al.*, 2019). However, the suitability of each Sudan grass fodder type should be evaluated in the context of animal species, production objectives, and nutritional considerations (El Khishin *et al.*, 2017; Abou-El-Ezz *et al.*, 2020; Al-Dobaib *et al.*, 2015). Further research is needed to explore the implications of these findings on animal performance and feed formulation strategies.

Conclusion

In conclusion, the chemical composition of fodder varies significantly depending on factors such as cultivation methods, processing, and environmental conditions. Through the analysis of maize, wheat, and Sudan grass fodder types, it is evident that hydroponic cultivation methods often result in higher protein and lipid content compared to conventional methods. This suggests the potential for hydroponic systems to enhance the nutritional quality of fodder, ultimately benefiting livestock health and productivity. Furthermore, conventional fodder types tend to have higher levels of fiber and ash content, which may impact digestibility and nutrient availability. However, they still serve as valuable feed sources, especially when considering their widespread availability and relatively lower production costs.

Overall, the findings highlight the importance of understanding the chemical composition of different fodder types to optimize livestock diets and promote animal health and productivity. Future research could focus on further exploring the effects of cultivation methods, processing techniques, and environmental factors on fodder composition to develop strategies for enhancing fodder quality and improving livestock nutrition.

Acknowledgement

We gratefully acknowledge the financial support provided by the Ministry of Education, Bangladesh for funding this project. Additionally, we extend our appreciation to the University Grants Commission, Bangladesh for awarding fellowship support, enabling the successful completion of this study. Their contributions have been instrumental in advancing our research efforts and facilitating the exploration of innovative solutions in the field of animal nutrition. We sincerely thank both organizations for their commitment to promoting academic excellence and supporting scientific endeavors.

References

Abou-El-Ezz MA, Kholif AE, El-Shafie MH, Gado HM. 2020. Productive performance, carcass characteristics and economic efficiency of rabbits fed hydroponic barley sprouts diet. Alexandria Journal of Veterinary Sciences **63**(1), 83-92.

Al-Dobaib SN, Al-Mufarrej SI, Al-Saiady MY, Al-Qhtani SA, Samara EM. 2015. Hydroponic maize fodder for dairy cows: Growth and physiological responses. Livestock Science **175**, 87-94.

Allen MS. 2014. Dairy cattle nutrition: Effects of fat and fatty acid supplementation on production and metabolic parameters. Animal Feed Science and Technology **189**, 60–75.

American Oil Chemists' Society (AOCS). 2009. Official Methods and Recommended Practices of the AOCS, 6th ed.

.

Association of Official Analytical Chemists (AOAC) International. 2016. Official Methods of Analysis of AOAC International (20th Ed.).

Bartok JW, Bucklin RA. 1995. Controlled Environment Agriculture: A Global Review of Greenhouse Food Production. CRC Press.

Batista AMV, Dias LS, Vieira RA, Veiga JB, de Oliveira LR, da Silva LFP, do Nascimento WG. 2021. Nutritional evaluation and digestibility of hydroponic corn, wheat, barley, and sorghum fodder for goats. Animal Feed Science and Technology **278**, 115024.

Chamberlain DG, Wilkinson JM, Oldham JD. 1993. Forage Intake and Satiety. Journal of Dairy Science **76**(2), 533–547.

El Khishin DA, Ahmed WM, El-Sherif AH, El-Tabbakh AM. 2017. Hydroponic barley fodder and its effect on growth performance, nutrient digestibility and blood metabolites of growing goats. Animal Feed Science and Technology **228**, 47-54.

Ferraretto LF, Crump PM, Shaver RD. 2013. Effect of cereal grain type and corn grain harvesting and processing methods on intake, digestion, and milk production by dairy cows through a meta-analysis. Journal of Dairy Science **96**(1), 533–550.

Ferraretto LF, Crump PM, Shaver RD. 2013. Effect of cereal grain type and corn grain harvesting and processing methods on intake, digestion, and milk production by dairy cows through a meta-analysis. Journal of Dairy Science **96**(1), 533–550.

Gòdia F, Montesinos JL. 2005. Plant production for life support systems: Hydroponic crop production. In R. M. Wheeler & S. S. Kumar (Eds.), Crop Science: Progress and Prospects (pp. 137–160). CABI Publishing.

Goering HK, Van Soest PJ. 1970. Forage fiber analyses (apparatus, reagents, procedures, and some applications). Agricultural Handbook No. 379. ARS, USDA, Washington, DC.

Huntington GB. 1997. Starch utilization by ruminants: From basics to the bunk. Journal of Animal Science **75**(3), 852–867.

Khan MJ, Arshad M. 2019. Nutritional and health perspectives of hydroponic fodder. Journal of Animal Physiology and Animal Nutrition **103**(3), 685-692.

Li YC, Yang SS. 2017. Comparison of two hydroponic systems for the production of green forage. Journal of Applied Animal Research **45**(1), 584–587.

Liorente BE, Causape AC. 2018. Use of hydroponic systems in animal nutrition. Emir. J. Food Agric. **30**(5), 374–380.

Moore JE, Brink GE, Koegh BE. 2017. Nutritional Evaluation of Forages. In Forages: The Science of Grassland Agriculture (7th ed., pp. 53–78). John Wiley & Sons.

Rajapaksha RMCP, Gunawardena AJSL, Jansz ER. 2016. Comparative study on hydroponic and conventional forage production for dairy cows in Sri Lanka. Tropical Agricultural Research **27**(1), 110–117.

Rodehutscord M, Pfeffer E. 2021. Evaluation of the nutritive value of hydroponically produced barley, wheat, maize and alfalfa for growing pigs. Animal Feed Science and Technology **276**, 114899.

Selim A, Ibrahim AA, El-Hamid AET. 2019. Nutritional evaluation of hydroponic barley and wheat green fodder for growing rabbits. World Rabbit Science **27**(4), 235-241.

Thabet HM, Khalafalla MM, Eltahir ME, Elmansy HA. 2019. Hydroponic Sudan grass as a new promising forage resource for ruminant feeding. International Journal of Veterinary Science and Medicine **7**(1), 20-25.

Tyagi N, Tyagi SK, Pandey S, Tyagi P, Sharma N. 2017. Hydroponic fodder: A new paradigm for food security. Journal of Pharmacognosy and Phytochemistry **6**(6), 2557–2559.

Undersander D, Mertens D, Thiex N. 2005. Forage Analysis Procedures (2nd ed.). National Forage Testing Association.

Van Soest PJ, Robertson JB, Lewis BA. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science **74**(10), 3583–3597.

Van Soest PJ. 1994. Nutritional Ecology of the Ruminant. Cornell University Press. Ithaca, 476.

Wilkinson JM. 2011. Re-defining efficiency of feed use by livestock. Animal **5**(7), 1014–1022.