



Research Paper

Comparative nutritional evaluation of hydroponically produced corn (*Zea mays L.*) and rice (*Oryza sativa L.*) fodder as alternative feed resources for ruminants under tropical conditions

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Abstract

Feed scarcity, seasonal deterioration in pasture quality and competition for agricultural land increase the need for alternative forage resources in tropical livestock systems. This study compared the chemical composition of hydroponically produced corn (*Zea mays L.*) and rice (*Oryza sativa L.*) fodder cultivated under greenhouse conditions in Trinidad and Tobago. Replicated samples were analysed for dry matter (DM), crude protein (CP), ash, organic matter (OM), crude fat, gross energy (GE), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent insoluble nitrogen (ADIN) and acid detergent lignin (ADL). Data were evaluated by one-way analysis of variance, with mean separation by Tukey's honestly significant difference test at $P < 0.05$. Dry matter did not differ significantly between fodder species. Corn fodder contained more CP (132 vs. 117 g/kg DM) and had significantly greater ash, OM, GE, NDF, ADF and ADIN than rice fodder, whereas crude fat and ADL did not differ significantly. These findings indicate that hydroponically produced corn fodder had a more favourable chemical profile than rice fodder under the conditions evaluated. However, chemical composition alone does not establish feeding value or animal performance. Further work should quantify biomass yield, digestibility, voluntary intake, animal response, water-use efficiency and production economics before broad commercial recommendations are made.

Keywords: climate resilience; dry season; land use; nutrient composition; small island systems

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I. Introduction

Ruminant production in tropical and subtropical regions is frequently constrained by seasonal variation in forage availability and quality, increasing feed costs and competition for land. These constraints are especially relevant to small island production systems, where a limited agricultural land base can intensify pressure on livestock feed resources. Forage maturity is also associated with changes in fibre concentration and feeding value, making the maintenance of a consistent supply of nutritious forage an important production objective (Minson, 1990; Van Soest, 1994).

Hydroponic fodder production is one approach to producing fresh cereal forage without soil over a short growth cycle. Hydroponically sprouted cereal fodder consists of shoots, roots and residual grain and can be produced in controlled systems where conventional green forage production is constrained. Reviews of hydroponic fodder systems describe potential advantages related to year-round production and comparatively low land requirements, while also emphasising that seed cost, dry-matter yield and production economics must be considered when assessing practical value (Naik et al., 2015). Recent work further shows that hydroponic maize production can be influenced by nutrient source, with consequences for dry-matter yield, water-use efficiency and chemical composition (Ojo et al., 2024), reinforcing the need to evaluate both nutritive composition and production efficiency.

Germination changes the chemical composition of cereal grain because stored carbohydrate is used to support respiration and seedling development. Studies of sprouted barley have reported proportional changes in crude protein, fibre fractions and other nutrients during germination, but such changes do not necessarily represent

a net gain in nutrients because dry matter is simultaneously lost through respiration (Dung et al., 2010; Fazaeli et al., 2012). Consequently, hydroponic fodder should be evaluated on both composition and dry-matter recovery rather than fresh biomass yield alone.

Corn (*Zea mays L.*) is widely used for hydroponic fodder because of its rapid germination and biomass production, whereas rice (*Oryza sativa L.*) has received less attention as a hydroponic ruminant feed. Recent feeding studies indicate that hydroponic maize fodder can influence nutrient intake, digestibility and rumen fermentation in ruminants, although responses depend on inclusion level and the basal diet (Arif et al., 2023; Benu et al., 2024; Sulistijo et al., 2024). Direct comparison of cereal species under the same tropical production conditions can therefore provide useful baseline information for selecting species for subsequent feeding, production-efficiency and economic evaluation.

The objective of this study was therefore to compare the chemical composition of hydroponically produced corn and rice fodder cultivated under greenhouse conditions in Trinidad and Tobago and to assess their potential, on the basis of chemical composition, as alternative forage resources for tropical ruminant feeding systems.

II. Material and methods

Study location

Hydroponically produced corn (*Zea mays L.*) and rice (*Oryza sativa L.*) fodder were cultivated under greenhouse conditions in Curepe, Trinidad and Tobago. Chemical analyses were undertaken at the Animal Nutrition Laboratory, Biosciences, Agriculture and Food Technologies (BAFT), University of Trinidad and Tobago, Eastern Caribbean Institute of Agriculture and Forestry (ECIAF).

Experimental design and sample preparation

A completely randomised design was used to compare hydroponically produced corn and rice fodder. Three replicate samples ($n = 3$) of each fodder species were collected from greenhouse container sub-plots during the dry season. Representative plant material was harvested, chopped, packaged and transported to the laboratory. Samples were oven-dried at 65°C to constant weight and ground through a 1-mm screen before chemical analysis. Laboratory determinations were conducted in triplicate to reduce analytical variation.

Chemical analyses

Samples were analysed for dry matter (DM), crude protein (CP), ash, organic matter (OM), crude fat, gross energy (GE), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent insoluble nitrogen (ADIN) and acid detergent lignin (ADL). Standard procedures described by AOAC International were used where applicable (AOAC International, 1995, 2019). Organic matter was calculated from ash-free dry matter. Nitrogen was determined by an AOAC-recognised procedure and CP was calculated as total nitrogen $\times 6.25$. NDF and ADF were determined using an ANKOM fibre analyser following detergent-fibre principles described by Van Soest et al. (1991) and Mertens (2002). ADL was determined from the acid-detergent residue after sulphuric-acid treatment, and ADIN was determined from nitrogen associated with the acid-detergent fibre residue.

Statistical analysis

Data were analysed using one-way analysis of variance (ANOVA) in Minitab® version 17 to test the effect of fodder species. Where a significant species effect was detected, means were compared using Tukey's honestly significant difference test. Statistical significance was declared at $P < 0.05$. Results are presented as treatment means with the corresponding standard error of the mean (SEM), where available.

III. Results

Chemical composition of hydroponically produced corn and rice fodder

Dry matter concentration did not differ significantly ($P > 0.05$) between hydroponically produced corn and rice fodder (933.4 vs. 929.7 g/kg DM; Table 1). Corn fodder contained significantly more crude protein than rice fodder (132 vs. 117 g/kg DM; $P < 0.05$), and also had greater ash (204 vs. 186 g/kg DM), organic matter (901.8 vs. 873.4 g/kg DM), gross energy (4634 vs. 3965 kcal/kg), neutral detergent fibre (265 vs. 236 g/kg DM), acid detergent fibre (201 vs. 196 g/kg DM) and acid detergent insoluble nitrogen (16 vs. 11 g/kg DM) ($P < 0.05$). Crude fat (44.9 vs. 33.8 g/kg DM) and acid detergent lignin (56 vs. 49 g/kg DM) did not differ significantly between species ($P > 0.05$).

Table 1. Chemical composition of hydroponically produced corn and rice fodder.

Parameter	Corn fodder	Rice fodder	SEM
Dry matter (g/kg DM)	933.4 ^a	929.7 ^a	12.5

Parameter	Corn fodder	Rice fodder	SEM
Crude protein (g/kg DM)	132 ^a	117 ^b	4.5
Ash (g/kg DM)	204 ^a	186 ^b	8.8
Organic matter (g/kg DM)	901.8 ^a	873.4 ^b	14.7
Crude fat (g/kg DM)	44.9 ^a	33.8 ^a	2.0
Gross energy (kcal/kg)	4634 ^a	3965 ^b	66.2
Neutral detergent fibre (g/kg DM)	265 ^a	236 ^b	22.7
Acid detergent fibre (g/kg DM)	201 ^a	196 ^b	11.2
Acid detergent insoluble N (g/kg DM)	16 ^a	11 ^b	4.0
Acid detergent lignin (g/kg DM)	56 ^a	49 ^a	6.6

Note. Within a row, means with different superscript letters differ at $P < 0.05$. SEM = standard error of the mean. Gross energy is expressed as kcal/kg; all other compositional values are expressed as g/kg DM.

IV. Discussion

The greater CP concentration observed in hydroponically produced corn fodder indicates a higher concentration of nitrogenous constituents than in rice fodder under the conditions evaluated. During cereal germination, respiratory use of stored carbohydrate can increase the proportional concentration of protein and some other nutrients even when absolute nutrient yield does not increase (Dung et al., 2010; Fazaeli et al., 2012). The present findings should therefore be interpreted as differences in concentration rather than evidence that hydroponic production created additional protein.

NDF and ADF are important descriptors of forage fibre and are widely used in the evaluation of ruminant feeds (Van Soest et al., 1991; Mertens, 2002). Corn fodder had greater NDF and ADF concentrations than rice fodder. This does not, by itself, establish superior feeding value: increasing fibre can affect potential intake and digestibility, and the biological response depends on fibre digestibility, particle characteristics and the composition of the complete diet (Van Soest, 1994). Direct digestibility and animal-response measurements are therefore needed.

The greater ash concentration in corn fodder indicates a difference in total inorganic residue, but ash alone cannot identify the supply or balance of individual minerals. Mineral profiling would be needed before conclusions could be drawn regarding calcium, phosphorus, magnesium, potassium, sodium or trace-element adequacy.

Corn fodder also had greater gross energy than rice fodder. Gross energy represents heat released on complete combustion and should not be interpreted as metabolisable energy available to the animal because energy is lost through faeces, urine, gases and heat production (McDonald et al., 2022). Future work should therefore include digestible or metabolisable energy estimates and *in vivo* or *in vitro* digestibility.

Hydroponic fodder may have practical relevance where conventional green forage production is constrained, but its value depends on more than chemical composition. Seed cost, dry-matter recovery, water and energy use, labour, microbial hygiene and animal performance all affect commercial feasibility. Recent animal studies support this cautious interpretation: hydroponic maize fodder has altered nutrient intake, digestibility and rumen fermentation in calves and goats, but responses have varied with substitution level and diet composition (Arif et al., 2023; Benu et al., 2024; Sulistijo et al., 2024). Hydroponically produced fodders may also modify rumen fermentation and methane production, although *in vitro* responses differ among forage species and require confirmation in animal studies (Li et al., 2024). Agronomic work likewise demonstrates that nutrient source can affect hydroponic maize dry-matter yield, water-use efficiency and composition (Ojo et al., 2024). These findings strengthen the case for evaluating production efficiency alongside nutritive characteristics. For Trinidad and Tobago and other small-island tropical systems, such considerations are especially important because limited land availability and imported feed costs can influence livestock production decisions.

The study provides baseline comparative information for corn and rice fodder produced under the same tropical greenhouse conditions. Its principal limitations are the small number of biological replicates, evaluation at a single production period, and the absence of measurements of biomass yield, dry-matter recovery, digestibility, intake, animal performance and economics. Accordingly, the results support further evaluation of hydroponic corn fodder but do not establish that it will improve animal productivity.

V. Conclusion

Hydroponically produced corn and rice fodder differed in several aspects of chemical composition under the tropical greenhouse conditions evaluated. Corn fodder contained more crude protein and had greater ash, organic matter, gross energy, NDF, ADF and ADIN, while dry matter, crude fat and ADL did not differ significantly between species. On the basis of chemical composition, corn fodder warrants further investigation as a supplementary forage resource for tropical ruminants. However, the study does not provide direct evidence of improved digestibility, intake or animal performance. Future research should integrate dry-matter yield and recovery, nutrient digestibility, feeding trials, mineral composition, water-use efficiency and economic analysis to determine the practical value of hydroponic cereal fodder in tropical livestock systems.

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Conflict of interest

The authors declare that they have no conflict of interest.

Author contributions

Kishma Anthony: Investigation, laboratory analyses, data collection, preliminary statistical analysis and manuscript preparation. Andell Edwards: Conceptualisation, supervision, methodology, data interpretation, manuscript review and editing.

Data availability

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

Ethics statement

This study involved laboratory evaluation of plant materials and did not involve human participants or experimental animals. Ethical approval was therefore not required.

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