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SHORT COMMUNICATION

Hydroponics maize fodder: biochemical digestibility and feed values analysis in different types of maize

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Abstract: India is getting fodder deficit day by day, putting the livestock productivity at risk. The need of the hour is to explore the research interventions for green fodder production that ensure all-around availability of quality green fodder and that too in a cost-effective manner. Nowadays, the low-cost hydroponics technique, adaptable at small and large scale is becoming very popular for green fodder maize production. Maize grain is a good fit for hydroponics technology due to its fast growth, high biomass accumulation in a short period, and nutritional value. Hence, this study explored the hydroponics technology for comparison of biomass gain and nutritional value of fodder maize variety J-1006 with that of F_2 of quality protein maize (QPM) hybrid, and a mixture of maize grains (hybrids and inbreds). These three treatments were grown in hydroponics trays (1.80 kg seeds per tray) in two replications for eight days. At the end of 8th day, highest green fodder weight was recorded in the mixed grain (6.00 kg), followed by J-1006 (5.23 kg) and then F_2 grain of QPM (5.00 kg). Biochemical analysis of the same revealed highest dry matter and crude protein in J-1006, followed by QPM, and then mixed seeds. J-1006 and QPM recorded high neutral detergent fiber (NDF), acid detergent fiber (ADF), and ash content, whereas high organic matter and dry matter digestibility were recorded in mixed seeds. Conclusively, J-1006 and mixed seeds are better for hydroponics fodder due to its high biomass and quality.

Keywords: Hydroponics, QPM, grain, NDF and Fodder

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Maize is the cereal crop with highest production in world. It is used in diverse forms such as food, feed, fodder and fuel. It is a highly versatile crop suited to diverse agro-ecologies, accounting for around 36% of the world's grain production. After rice and wheat, maize is India's third-most significant food crop. Increasing livestock population demands more nutritious green fodder and feed for enhanced milk production. Feeding green fodder enhances their reproductive and productive capacities.

India alone is currently experiencing a net shortfall of 23.40% green fodder, 11.40 % dry agricultural leftovers, and 28.90 % concentrate feeds (Roy et al. 2019, Kumar et al. 2025). The primary obstacle to expanding green fodder production is the declining land available for fodder cultivation due to the ever-growing growth of cereals and cash crops (Chaudhary et al. 2013). Over the past one decade, the production of green feed has undergone a revolution thanks to state-of-the-art technology called hydroponics. The word "hydroponics" comes from the Latin words "hydro," which means water, and "ponos," which means work; it signifies working water. Usually, cereal grains like maize, barley, oats, wheat, and sorghum, or legumes like alfalfa, clover, or cowpea are sprouted in hydroponic fodder systems. Over the years, limited emphasis has been laid on production of fodder crops through traditional cultivation methods due to number of reasons such as requirement of more land, manure and fertilizer and labour for cultivation (sowing, earthing up, weeding, harvesting, etc.), higher water requirement, takes longer to grow (approximately 60 days), and is subjected to natural disasters. With the development of hydroponics technology, fodder can be grown in a single week as compared to over 6-8 weeks in traditional methods. Many changes take place in the fodder seed as it develops into the fodder plant in hydroponic (Naik et al. 2011b).

Hydroponically grown fodder maize offers various advantages over traditional method such as monsoon- independency and risk free, lesser labour and water requirement, low production cost, constant supply of fodder, optimum nutritional value and reduced growth time from 45 days to 8 days, serving as a viable alternative technology for green fodder production all around the year (Naik et al. 2013). Moreover, hydroponically grown green fodder maize contains grass juice, which is crucial for improving ruminant performance by enhancing microbial activity in the digestive system.

Maize is a highly acceptable fodder crop due to its large biomass output, rapid growth, lack of anti-nutritional components, and exceptional palatability. However, normal maize is deficient in two vital amino acids, lysine and tryptophan, which results in an imbalance of amino acids and low biological value in conventional maize genotypes. The same amino acids were enriched in maize and known as QPM is virtually equivalent to conventional maize in terms of cultivation. Numerous studies concluded that feeding QPM grains to pig and poultry production is highly effective (Vaswani et al. 2016). Hence, to harness the benefits of hydroponics technology, an experiment was planned to hydroponically grow fodder cultivars, J 1006, QPM and mixed grain. These three treatments were compared for biomass production and biochemical quality traits, advocating the best viable options for hydroponically grown green fodder maize production.

The experiment was designed in hydroponics trays for fodder production. The experiment was planned in April, 2022, which included each treatment (variety) in two replications (trays). Three maize varieties were tested as the methodology explained below with Figure 1. The dry matter intake (DMI), digestible dry matter (DDM), relative feed value (RFV), relative feed quality (RFQ), total digestible nutrients (TDN) and net energy for lactation (NEL) were also worked out (Schroeder 2004) DMI (% BW) = 120 / (% NDF) DDM = 88.9 - (0.779 ×% ADF) RFV = (% DDM ×% DMI) / 1.29 RFQ = (TDN × intake) / (16.8 + 39.2) TDN = 87.84 - (0.79×% ADF) NE L (Mcal/kg) = 0.0245 × TDN - 0.12. About 375±5 mg of the dried ground sample of each maize hybrids (on DM basis) was incubated at 39ºC for 24 h in triplicate in 100 mL calibrated glass syringes (Haberle Labortechnik, Germany) with buffered rumen fluid collected for assessing the net gas production, true organic matter (OM) and neutral detergent fiber (NDF) digestibility (Menke and Steingass 1988).

1. F_2 grain of QPM (IQPMH 202)
2. Maize fodder variety (J 1006)
3. Maize grain mixture (includes F_2 grains of various hybrids and open seeds of inbreds)

Procedure

Weight 1.80 kg grain
↓
Add 2 teaspoons of salt in water and soaked the seeds for 12 hours
↓
Soaked seeds putted into jute bags for 24 hours for germination
↓
Spread the germinated seeds into hydroponic trays
↓
Watering after every 2 hours by sprinkler during dat time
↓
Harvested at end of 8th day

Table 1: Proximate analysis of hydroponically grown QPM, J 1006 and mixed grain maize

Parameters (%)	Genotypes		
	QPM	J 1006	Mix grain
Dry Matter (DM)	28.75 ± 0.22^{b}	31.98 ± 2.00^{a}	26.66 ± 0.60^{b}
Crude Protein (CP)	10.977 ± 0.171^{b}	12.050 ± 0.072^{a}	11.163 ± 0.095^{b}
Ether Extract (EE)	5.967 ± 0.058^{b}	6.233 ± 0.115^{a}	6.30 ± 0115^{a}
Neutral Detergent Fibre (NDF)	25.200 ± 1.510^{a}	23.800 ± 1.249^{ab}	21.933 ± 0.902^{b}
Acidic Detergent Fibre (ADF)	7.667 ± 0.058^{a}	7.500 ± 0.300^{a}	6.300 ± 0.000^{b}
Acidic Detergent Lignin (ADL)	0.533±0288	0.400±0.173	0.400±0.000
Hemi cellulose (HC)	17.533±1.504	16.300±0.964	15.633±09.02
Cellulose	7.133 ± 0.153^{a}	7.100 ± 0.173^{a}	5.900 ± 0.000^{b}
Ash	2.223 ± 0.029^{a}	2.283 ± 0.076^{a}	2.017 ± 0.104^{b}
Organic Matter (OM)	97.767 ± 0.029^{b}	97.717 ± 0.076^{b}	97.983 ± 0.104^{a}
Feed values			
Dry Matter Intake (DMI)	4.773 ± 0.281^{b}	5.053 ± 0.272^{ab}	5.473 ± 0.226^{a}
Digestible Dry Matter (DDM)	82.927 ± 0.046^{b}	83.057 ± 0235^{b}	83.990 ± 0.000^{a}
Total Digestible Nutrients (TDN)	82.473 ± 0.04^{b}	82.590 ± 0.21^{b}	83.430 ± 0.00^{a}
Relative Feed Value (RFV)	306.843 ± 18.211^{b}	325.277 ± 18.362^{ab}	356.633 ± 14.741^{a}
Relative Feed Quality (RFQ)	7.027 ± 0.417^{b}	7.450 ± 0418^{ab}	8.160 ± 0.336^{a}
NE_{LACT} M cal/kg (Net energy)	1.900 ± 0.000^{b}	1.903 ± 0.006^{b}	1.920 ± 0.000^{a}

Different superscript letters indicate significant differences at $P \leq 0.05$.

Growth and chemical composition

Hydroponically grown fodder formed a mat in tray at end of 8th day, consisting of seeds, roots and plants (Naik et al. 2011a). The final fodder weight at end of 8th day was 5.00, 5.23 and 6.00 kg for F, QPM grain, J 1006 and mixed maize grains, respectively (grown using 1.80 kg seed as input). The conversion of 1.8 kg seed to yield 6 kg of fodder yield approximates to 3-3.5 fold, corroborating with results of Naik et al. (2014) who reported 3.5 to 5-fold fresh fodder yield in maize. Notable differences were observed in digestibility quality when a J-1006, a QPM and mix grains were grown in parallel in hydroponics fodder condition. The chemical composition and feed value parameters were also estimated in all three samples (Table 1). J-1006 reported significantly higher dry matter (DM) content (31.98%) compared to QPM (28.75%) and grain mixture (26.66%). Similarly, crude protein (CP) content also followed a similar trend with J-1006 having the higher content (12.05%) than fodder mix (11.16%) and QPM (10.97%). Similarly, Naik et al. (2012) reported the range of CP content from 9.14 to 13.57 % from day 1 to day 7 hydroponically grown maize fodder. In another study, Naik et al. (2017) also reported 12.38 % crude protein in hydroponically grown maize fodder. J-1006 and fodder mix showed similar ether extract (EE) content as compared to QPM. However, neutral detergent fibre (NDF) quality was higher in QPM followed by J-1006 and then mix grain. Similar trend was observed for acidic detergent fiber (ADF). There was no significant difference among the three samples for acid detergent lignin (ADL) and hemi cellulose.

Additionally, the feed values of the three samples also showed varying trends. Dry matter intake (DMI), indicating how much is finally digested by the animal, was found to be highest in mix grain (5.47) as compared to J-1006 (5.05) and QPM (4.77). It

Fig 1. Day-wise growth stages (0–8 days) of hydroponically grown maize fodder from seed soaking to harvest

Table 2: Correlation matrix of different biochemical traits

Traits	DM	CP	EE	NDF	ADF	ADL	Celluose	HC	Ash	OM	DMI	DDM	TDN	RFV	RFQ	NEI
DM	1	0.787*	0.775*	0.453	0.71*	0.2	0.712*	0.258	0.71*	-0.71*	-0.476	-0.709*	-0.71*	-0.504	-0.502	-0.718*
CP		1	0.452	-0.02	0.257	-0.125	0.306	-0.158	0.452	-0.452	-0.006	-0.257	-0.257	-0.031	-0.028	-0.21
EE			1	0.654	0.945***	0.176	0.969***	0.414	0.904***	-0.904***	-0.67*	-0.945***	-0.945***	-0.705*	-0.702*	-0.907***
NDF				1	0.811**	0.586	0.726*	0.955***	0.507	-0.507	-0.997***	-0.811**	-0.811**	-0.995***	-0.995***	-0.831**
ADF					1	0.397	0.975***	0.601	0.839**	-0.839**	-0.827**	-1***	-1***	-0.853**	-0.851**	-0.986***
ADL						1	0.181	0.6	0.053	-0.053	-0.567	-0.397	-0.397	-0.557	-0.558	-0.436
Celluose							1	0.497	0.886**	-0.886**	-0.747*	-0.974***	-0.975***	-0.778*	-0.776*	-0.951***
HC								1	0.267	-0.267	-0.943***	-0.601	-0.601	-0.926***	-0.927***	-0.634
Ash									1	-1***	-0.522	-0.839**	-0.839**	-0.557	-0.555	-0.779*
OM										1	0.522	0.839**	0.839**	0.557	0.555	0.779*
DMI											1	0.827**	0.827**	0.999***	0.999***	0.847**
DDM												1	1***	0.853**	0.851**	0.986***
TDN													1	0.853**	0.851**	0.986***
RFV														1	1***	0.87**
RFQ															1	0.869**
NEI																1

*** Correlation is significant at 0.001, **significant at 0.01 level, * significant at 0.05 level

Dry Matter (DM), Crude Protein (CP), Ether Extract (EE), Neutral Detergent Fibre (NDF), Acidic Detergent Fibre (ADF), Acidic Detergent Lignin (ADL), Hemi cellulose (HC), Organic Matter (OM), Dry Matter Intake (DMI), Digestible Dry Matter (DDM), Total Digestible Nutrients (TDN), Relative Feed Value (RFV), Relative Feed Quality (RFQ), NELACT M cal/kg (Net energy) NEI indicates that mixed grain is relatively more digestible than J 1006 and QPM. Similarly other feed value parameters, total digestible nutrients (TDN), relative feed value (RFV), relative feed quality (RFQ) and NELACT M cal/kg (Net energy) were also found to be on higher side in the mix grain type, similarly it was found by Raghavendran et al. (2019).

Trait correlations help to find the out the association or magnitude of relationship among the traits (Table 2). DM showed positive significant correlation with CP, EE, ADF, Cellulose, ash, and a negative significant correlation with OM, DMI, DDM, TDN, and NEI. Crude protein did not show significant correlation with any of the biochemical parameters. However, ether extract showed significant positive correlation with ADF, cellulose, ash and negative significant correlation with OM, DMI, DDM, TDN, RFV, RFQ and NEI. NDF exhibited positive and significant correlation with ADF, Cellulose and hemicellulose, whereas significantly negative correlation with DMI, DDM, TDN, RFV, RFQ and NEI. ADF also showed positive significant correlation with cellulose and hemicellulose but negatively significant correlation with OM, DMI, DDM, TDN, RFV, RFQ, and NEI. Cellulose showed negatively significant correlation with all other traits, except positively significant correlation with ash. Hemicellulose was negatively significant correlated to DMI, RFV and RFQ whereas Ash showed negative significant correlation with OM, DDM, TDN, and NEI. Positive significant correlation of organic matter was observed with DDM, TDN and NEI. Similarly, DMI showed positive significant correlation with DDM, TDN, RFV, RFQ and NEI. Similar relationship was noticed in TDN with RFV, RFQ and NEI. Also, RFV showed positive significant correlation with RFQ and NEI. RFQ also showed positively significant correlation with NEI. As per our best knowledge, studies lack on correlation studies on biochemical traits for hydroponically grown maize fodder.

Conclusion

Maize is used in a wide variety of forms, including food, animal feed, industrial products, fodder and bio fuels. Based on this study the QPM and J 1006 grains recorded highest dry matter and crude protein, whereas rest of the parameters were relatively on higher side in mixed types of grains. Crude protein and dry matter content are major component for fodder, enhancing the nutritional quality of green fodder. Hence, F_2 QPM grain and J 1006 may be grown separately to provide dry matter and protein rich green fodder to supplement the mixed grains based hydroponically grown fodder maize.

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