Range Management and Agroforestry 46 (1) : 170-175, 2025
ISSN 0971-2070 (Print); 2249-5231 (Online)
https://doi.org/10.59515/rma.2025.v46.i1.24

Short communication

Nutritional quality evaluation of maize byproducts for green fodder and silage potential

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Received: 28th May, 2024 Accepted: 16th April, 2025

Abstract

Study assessed nutritive value (fresh and ensiled samples) and silage quality of various maize byproducts: baby corn husk, whole plant post baby corn picking, whole plant post sweet corn harvesting, whole plant with cobs at silage stage, and whole plant post mature cob harvesting. All the samples/genotypes/hybrids were significantly (p <0.01) different for dry matter (DM), ether extract (EE) and crude protein (CP) at the fodder stage. The highest DM (33.6%) was observed in whole plant, including the grain sample and the least in baby corn husk (14.66%). Similarly, the least CP (3.25%) was observed in the whole plant after harvesting the mature cob, and the highest was in the sweet corn plant (9.36%). The silage pH of samples was in the range of 3.3-4. Baby corn husk as green fodder and silage maintained good quality (DM, CP, NDF, ADF and ash contents), while others followed quality sequence IQPMH 18-2>IBCH 1>Sugar 75> LQPMH 1. This study revealed the potential of utilizing various maize crop byproducts as silage.

Keywords: Baby corn, Fodder, *In-vitro*, Quality evaluation, Silage, Sweet corn

In India, cultivation of forage covers only about 4% of the agricultural land and is inadequate to support 535.78 million animals (20th Livestock Census, 2019). Moreover, the uneven availability of green fodder in different seasons and regions of the country further complicates the feed scenario. The use of new, high-yielding fodder varieties and the preservation of green fodder during glut seasons to feed animals during lean periods is a good solution. Apart from the genetic makeup of milch animals, the deficiency in feed and fodder is one of the major constraints in achieving the desired level of livestock productivity. The country's net shortages in dry fodder, green fodder, and concentrates are 23.40%, 11.24%, and 28.90%, respectively (Roy *et al*., 2019). To address this gap, alternative fodder sources, such as silage, need to be explored.

Whole maize plant silage quality is superior and can vary depending on the type of variety, such as quality protein maize (QPM), floury, leafy, and high oil hybrids, as well as different agronomic practices (Hundal *et al*., 2019; Singh *et al*., 2020; Lauer, 2013). Maize byproducts, such as baby corn husks or whole plant parts after harvesting baby corn, sweet corn, or mature corn, offer a scope for utilizing plant leftovers as a fodder source. Silage quality depends on the efficient microbial conversion of soluble carbohydrates into organic acids, which is influenced by factors such as humidity, temperature, oxygen availability, available sugars, and plant characteristics (Neumann, 2001). Several studies indicated that the heterogeneous composition of maize biomass controls enzymatic hydrolysis and degradability (Bootsma and Shanks, 2005; Duguid *et al*., 2009; Mourtzinis *et al*., 2014). Most authors agree that maize grains represent 50 to 53% of the plant's dry weight, depending on agricultural practices and climate. Similarly, on the mass basis of maize residue at the time of harvest, stover consisted of 50% stalks, 22% leaves, 15% pieces of cobs, and 14% husks (Sokhansanj *et al*., 2002). This ratio will be different for baby corn and sweet corn. Although these residues are part of the crop's productive processes, only about 6% is usually collected and removed from the field (Sokhansanj *et al*., 2002). Worldwide, approximately 204 million tons of dry matter are returned to the soil annually through maize residues (Sorensen *et al*., 2008). Proper utilization of these residues can help the livestock sector meet dry fodder requirements. This study evaluates maize hybrid plant byproducts for their fodder quality and ensiling characteristics under north Indian climatic conditions.

The byproducts of different maize hybrids (IBCH1, G5417, LQPMH1, Sugar 75, IQPMH 18-2; Table 1) were sown at 60 cm row to row and 20 cm plant to plant spacing in 5 m^2 plot size without replication at Ladhowal research farm of ICAR-Indian Institute of Maize Research, Ludhiana in spring season 2021 following recommended agronomic packages and practice. One byproduct of each hybrid was used for silage preparation (Table 1). The experiment was conducted on a pilot basis, as it was a preliminary study regarding silage. In the future, we will conduct it in replications.

Maize hybrids harvested at different stages *viz*., IBCH 1, after harvesting baby corn leftover plant (after 60 days of sowing-DAS), similarly baby corn husk after taking baby corn in G5417 hybrid (after 60 DAS), another sample of quality protein maize (QPM) was harvested at desired silage stage (when milk line was 1/3 to ½ down the kernel or after 84 days of sowing) for silage preparation (LQPMH 1), sweet corn plant/stover of sweet corn (Sugar 75; harvested after 76 days of sowing) and IQPMH 18-2 sample was taken at maturity stage stover or after harvesting the matured cob after 95 days.

Maize byproducts were chopped to approximately 1-2 cm particle length and were ensiled individually for 45 days in low-density polyethylene (LDPE) bags under anaerobic condition and without adding any additives in two replicates.

The ground samples of both maize green fodder and silage in LDPE were analyzed for dry matter (DM), crude protein (CP) and total ash (AOAC, 2007), cellulose (Crampton and Maynard, 1938) and cell wall constituents (Van Soest *et al*., 1991). The dry matter intake (DMI), digestible dry matter (DDM), relative feed value (RFV) index, relative feed quality (RFQ) index, total digestible nutrients (TDN) and net energy for lactation (NE_L) 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

The Fleig points were measured using the mathematical equation, where Fleigh points = 220 + (2×DM%– 5)– 40 × pH (Denek and Can, 2006); Silage samples were analyzed for pH, sugars (Dubois *et al.,* 1956) and lactic acid (Barker and Summerson, 1941).

About 375±5 mg of the dried ground sample of each maize hybrid and conventional maize fodder was incubated at 39ºC for 24 h in triplicate in 100 ml calibrated glass syringes (Haberle Labortechnik, Germany) with buffered rumen fluid for gas production, true organic matter (OM) and neutral detergent fiber (NDF) digestibility (Menke and Steingass, 1988). *In-vitro* organic matter digestibility (IVOMD) was determined using technique of (Tilley and Terry, 1963). Metabolizable energy (ME) content was estimated from IVOMD according to MAFF (1984): ME (MJ/kg) = 0.16 (IVOMD)

The data were analyzed using SPSS (2009) version 16.0 and the means were tested for the significant difference by using Duncan's multiple range test at 5% level of significance (p <0.05).

The chemical composition of maize hybrids as green fodder (Table 2) showed significant (p <0.01) difference in DM, EE and CP contents, whereas other parameters remained comparable (p >0.05). Similar findings were recorded for EE, ADL, hemicellulose, cellulose and ash (Hundal *et al*., 2019; 2020). A significant difference in dry matter (DM) content was observed among the maize byproducts. Baby corn husk from G-5417 collected post-harvest, had the lowest DM (14.66%; p <0.05), while LQPMH-1, harvested as a whole plant at the silage stage, recorded the highest DM (33.60%). According to Beukes (2013), a DM range of 30-40% is ideal for silage preparation, making LQPMH-1 the only sample within the optimal range. No significant differences were detected for ash, organic matter, NDF, ADF, ADL, cellulose, hemicellulose, or other feed quality parameters. These results were in line with Choudhary *et al*. (2022), who reported similar ranges of ADF, NDF and cellulose in biochemical analyses

Table 1. Details of maize hybrids and their byproducts used for silage preparation

S. No.	Hybrids/Samples	Type of hybrid	Stage of harvest	Byproducts used for silage
1	IBCH 1	Baby corn	After baby corn picking	Whole plant without cob
2	G 5417	Baby corn	After baby corn picking	Baby corn husk
3	LQPMH 1	QPM	Silage stage (milk line 1/3 to ½ down the kernel)	Whole plant including cob
4	Sugar 75	Sweet corn	After sweet corn harvesting	Whole plant without cob
5	IQPMH 18-2	QPM	After harvesting matured cobs	Whole plant without cob

Table 2. Quality parameters of different maize hybrids at green fodder stage (as mentioned in Table 1 in column 4)

Parameters (Nutrient composition %)	IBCH1	G5417	IQPMH 18-2	Sugar75	LQPMH 1	SEM	P-value
Dry matter %	24.26^c	14.66^d	26.98^b	26.96^b	33.6^a	0.411	<0.001
Ash	7.07	5.99	6.65	5.92	6.05	1.146	0.860
Organic matter	92.9	94.0	93.3	94.0	93.9	1.146	0.860
Crude protein	8.76^b	9.11^b	8.49^b	9.36^b	3.25^a	1.079	0.012
Ether extract	1.87^b	1.86^b	1.90^b	1.52^b	0.85^a	0.131	0.001
Neutral detergent fiber	64.7	62.6	63.7	65.8	66.7	1.328	0.172
Acid detergent fiber	35.3	31.7	35.4	38.4	39.3	1.961	0.060
Acid detergent lignin	5.40	4.22	4.40	5.40	4.93	0.998	0.753
Cellulose	29.9	27.5	31.1	33.1	34.4	1.282	0.073
Hemi-cellulose	29.4	30.9	28.2	27.3	27.3	1.212	0.142
Feed and quality parameters							
Dry matter intake (DMI) % BW	1.86	1.91	1.89	1.82	1.80	0.028	0.182
Digestible dry matter (DDM) %	61.4	64.2	61.3	58.9	58.2	1.528	0.060
Total digestible nutrients, (TDN)%	63.1	65.6	63.0	60.9	60.3	1.373	0.060
Relative feed value (RFV) index	88.5	95.4	89.7	83.3	81.2	3.880	0.085
Relative feed quality (RFQ) index	2.09	2.25	2.13	1.98	1.94	0.086	0.088
$NE_{L,}$ M cal/kg	1.43	1.49	1.42	1.37	1.36	0.034	0.060

NE_L. net energy for lactation; Figures with different letter superscripts indicate significant difference

of 47 fodder landraces. Notably, G-5417 husk contained the lowest levels of digestion-resistant components- NDF, ADF, lignin and cellulose, particularly at the green fodder stage, indicating superior digestibility. In contrast, LQPMH-1 exhibited the highest ADF content, suggesting lower feed digestibility compared to other samples. CP content was lowest in LQPMH 1 (3.25), while other samples had similar CP, ranging from 8.49 (IQPMH 18-2) to 9.36 (Sugar 75).

Feed quality parameters, viz., DMI, DDM, TDN, RFV, and RFQ (Table 2), showed no significant differences among the byproducts of maize hybrids. The lowest values for TDN (60.3%), NE_L (1.36), digestible DM (58.2%), relative feed value (81.2%) and relative feed quality (1.94) were observed in normal corn leftover. *In-vitro* NDF digestibility was higher in the husk of G5417 (59.5%) and IBCH 1 (50.0%) maize samples, while it was least in LQPMH 1 and Sugar 75. Bakshi *et al.* (2017) found that the fresh baby corn husk was more digestible relative to conventional fodder maize. Hundal *et al.* (2020) reported that higher NDF digestibility enhances the forage or fodder intake. Net gas production (ml/g/24 h), OM digestibility, ME and partitioning factor were (p >0.01) higher in G5417 husk while least in LQPMH 1 and Sugar 75.

The pH (3.31-4.39) and lactic acid content (3.17-6.86% DM) across all ensiled samples were within the desirable range for quality silage fermentation (Table 3), consistent with previous findings (Wang *et al*., 2022; Kung and Stokes, 2001; Seglar, 2003), which recommended lactic acid levels between 4–7% for optimal preservation. Dry matter (DM) content varied significantly, with the lowest in G-5417 husk (12.73%) and the highest in LQPMH-1 (29.65%), followed by Sugar 75 (24.80%). DM content from only baby corn husk was found to be relatively lower than the whole plant-based silage (Srichana *et al*., 2014). Ash content was the lowest in Sugar 75 (6.5%) and highest in IBCH-1 (9.02%). Crude protein (CP) was highest in G-5417 (11.60%) and lowest in LQPMH-1 (3.86%). Quality Protein Maize (HQPM) cultivars did not show higher content of CP than that of G-5417 and Sugar 75. These results aligned with Wadhwa *et al*. (2018), who reported higher CP, OM and hemicellulose but lower ash content in baby corn fodder. G-5417 husk-based silage also showed higher hemicellulose, though reduced compared to its fodder form, likely due to acid-sensitive degradation during ensiling. Notably, fiber fractions (NDF, ADF, and ADL) which are negatively correlated with digestibility, were lower in G-5417 and higher in LQPMH-1. Given that ADL levels remained below 6% threshold reported by Van Soest *et al*. (1991) to impair digestibility, all samples maintained acceptable digestibility. The low lignin content of baby corn husk, particularly in G-5417, highlights its potential as a high-quality silage resource (Horst *et al*., 2021).

Ensiling for 45 days notably influenced key silage quality parameters, with a general decline observed in most *in-vitro* traits except MBM. Among the samples,

Table 3. Quality parameters of different maize hybrids after preparing silage of plant parts at the stage (as mentioned in table 1 column 5)

Parameters (Nutrient composition %)	IBCH 1	G 5417	IQPMH 18-2	*Sugar 75*	*LQPMH 1*	*SEM*	*p*-value
Dry matter (%)	21.43^{c}	12.73^{d}	22.45^{c}	24.80^{b}	29.65^{a}	0.456	<0.001
Ash	9.02^{e}	5.85^{a}	8.03^{d}	6.5^{b}	6.85^{c}	0.095	<0.001
Organic matter	90.9^{e}	94.1^{a}	91.9^{d}	93.5^{b}	93.1^{c}	0.095	<0.001
Crude protein	8.56^{b}	11.6^{c}	8.92^{b}	8.90^{b}	3.86^{a}	0.122	<0.001
Ether extract	1.47^{b}	2.12^{c}	2.20^{c}	1.60^{b}	0.80^{a}	0.146	<0.001
Neutral detergent fiber	66.6^{b}	64.7^{a}	64.4^{a}	67.8^{c}	70.8^{d}	0.366	<0.001
Acid detergent fiber	39.1^{b}	35.4^{a}	38.1^{b}	39.2^{b}	42.1^{c}	0.802	<0.001
Acid detergent lignin	5.38^{b}	3.75^{a}	4.47^{ab}	5.93^{b}	5.53^{b}	0.396	0.001
Cellulose	33.7^{ab}	31.7^{a}	33.6^{ab}	32.3^{ab}	36.5^{b}	0.826	0.004
Hemi-cellulose	27.4^{ab}	29.3^{b}	26.3^{a}	28.6^{ab}	28.7^{ab}	0.654	0.015
Feed and quality parameters							
Dry matter intake, % BW	1.80^{b}	1.86^{c}	1.86^{c}	1.77^{b}	1.69^{a}	0.010	<0.001
Digestible dry matter, %	58.4^{a}	61.3^{b}	59.2^{ab}	58.3^{a}	56.9^{a}	0.736	0.001
Total digestible nutrients (TDN), %	60.5^{b}	63.1^{c}	61.2^{b}	60.4^{b}	58.4^{a}	0.562	<0.001
Relative feed value (RFV)	81.7^{b}	88.2^{d}	85.6^{cd}	80.1^{b}	74.7^{a}	1.344	<0.001
Relative feed quality (RFQ)	1.95^{b}	2.09^{c}	2.04^{c}	1.91^{b}	1.77^{a}	0.027	<0.001
$NE_{L,}$ M cal/kg	1.36^{b}	1.42^{c}	1.38^{b}	1.36^{b}	1.31^{a}	0.014	<0.001
pH	4.33^{c}	3.96^{b}	4.06^{b}	3.31^{a}	4.39^{c}	0.036	<0.001
Lactic acid	3.83^{b}	6.86^{c}	-	-	3.17^{a}	0.112	<0.001
Fleig Score	74.7^{a}	71.9^{a}	87.5^{b}	97.4^{c}	83.2^{b}	2.123	<0.001

Figures with different letter superscripts indicate significant difference

Table 4. *In-vitro* quality evaluation of different maize hybrids at green fodder stage

Parameters	IBCH 1	G 5417	IQPMH 18-2	Sugar 75	LQPMH 1	SEM	P-value
NGP, ml/g DM/24 hr	150^{b}	165^{c}	148^{b}	119^{a}	112^{a}	3.476	<0.001
NDFD, %	50.0^{c}	59.5^{d}	43.7^{b}	37.9^{a}	38.0^{a}	0.828	<0.001
TOMD, %	65.7^{c}	73.4^{d}	62.9^{b}	57.4^{a}	56.9^{a}	0.513	<0.001
MBM, mg/gm of DM	327^{a}	371^{b}	303^{a}	312^{a}	327^{a}	10.447	0.008
ME, MJ/kg DM	6.96^{c}	7.44^{d}	6.80^{c}	6.21^{b}	5.50^{a}	0.084	<0.001

NGP : Net gas production; NDFD: Neutral detergent fiber digestibility; TOMD: True organic matter digestibility; MBM: Microbial biomass production; ME: Metabolizable energy; Figures with different letter superscripts indicate significant difference

Table 5. *In-vitro* quality evaluation of different maize hybrids after preparing silage of plant parts at the stage (as mentioned in Table 1 column 5)

Parameters	IBCH 1	G 5417	IQPMH 18-2	Sugar 75	LQPMH 1	SEM	*p*-value
NGP, ml/g DM/ 24 hr	114^{b}	167^{c}	120^{b}	98.3^{a}	97.5^{a}	3.073	<0.001
NDFD, %	48.2^{c}	61.1^{a}	42.5^{b}	35.3^{a}	35.7^{a}	0.821	<0.001
TOMD, %	62.7^{d}	73.7^{e}	60.8^{c}	54.0^{b}	51.1^{a}	0.477	<0.001
MBM, mg/gm of DM	376^{c}	369^{c}	344^{bc}	324^{ab}	296^{a}	7.926	<0.001
ME, MJ/kg DM	5.18^{a}	6.47^{c}	6.39^{c}	5.71^{b}	5.18^{a}	0.074	<0.001

NGP: Net gas production; NDFD: Neutral detergent fiber digestibility; TOMD: True organic matter digestibility; ME: Metabolizable energy; MBM: Microbial biomass production; Figures with different letter superscripts indicate significant difference

G-5417 exhibited superior silage quality, reflected in significantly higher NGP, NDFD, and TOMD, indicating enhanced fermentability and fiber utilization (Table 4). MBM remained stable in G-5417 but increased in IBCH-1, suggesting differential microbial efficiency. Notably, G-5417 silage exhibited the highest metabolizable energy and digestibility values, indicating better nutrient availability. Despite a higher MBM in IBCH-1, the overall nutrient use efficiency was marginally better in baby corn silage compared to normal corn silage (Wadhwa *et al.*, 2018). These findings align with previous reports that silage quality, particularly NDF content, varies between 64.4 and 70.8%, depending on the resource material used (Chaudhary *et al*., 2016; Brar *et al*., 2019).

The feed quality (Table 3) and *in-vitro* digestibility parameters (Table 5) for silage were higher in G5417 and lower in LQPMH 1, whereas in IBCH 1, IQPMH 18-2 and Sugar 75 quality parameters were in an acceptable range. Both TDN and NE_L are indicators of energy density in the silage and were found to be comparatively higher in G5417 husk. Previous studies have reported that baby corn husk-based silage has higher nutrient digestibility and biological value, providing a favorable rumen environment (Bakshi and Wadhwa, 2012; Srichana *et al*., 2014). A similar increase in values for the aforementioned parameters was reported in LG 34.04 silage (Hundal *et al*., 2019). LQPM1 had lower values for the *in-vitro* digestibility parameters because the energy content decreased with an increase in indigestible constituents, such as lignin (Hundal *et al*., 2020). Rankings were observed for green fodder as well: G5417> IQPMH 18-2>IBCH 1>Sugar 75> LQPMH 1. The higher values of RFV and RFQ indicates the good quality of silage (Moore and Undersander, 2002) and were found to be higher in G 5417 (baby corn husk), agreeing with previous studies with fresh baby corn husk (Bakshi and Wadhwa, 2012; Srichana *et al*., 2014). Additionally, the Fleig score (Ziaei and Molaei, 2010) determines the quality of the silage, with samples ranging from very good silage (85–100) to good silage (60–80; Table 3).

This study highlights the considerable potential of various maize byproducts particularly baby corn husk for silage production. Among the tested materials, baby corn husk emerged as a superior option due to its favorable nutritional profile, including a higher crude protein content and lower lignin levels, in both fresh and ensiled forms. The silage quality, as indicated by optimal pH and consistency in dry matter and protein levels, confirmed its suitability as a high-quality livestock feed. Notably, this is the first documented case of silage preparation using baby corn husk, establishing a novel and value-added use for this agricultural byproduct. The quality ranking of samples (G 5417 > IQPMH 18-2 > IBCH 1 > Sugar 75 > LQPMH 1) further supports the selective use of maize hybrids for dual-purpose benefits, providing both food and feed resources.

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