**Evaluation of silage quality and in-situ digestibility coefficient of different maize varieties**

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**ABSTRACT**

The current study was conducted to evaluate the silage characteristics of eight maize varieties (BF-92, MS-449, 36S46, LG-181, LS1122, 13E33, 5456 and 7786) and their nutrient digestibility. The *in-situ* experiment was conducted using cannulated Nili Ravi buffalo bulls in a completely randomized design. The silage samples of each variety were subjected to ruminal fermentation for 0, 12, 24, 36, 48, 72 and 96 hours intervals, in reverse order and removed at the same time and washed with running tap water. Data regarding various digestibility parameters (dry matter, crude protein, neutral detergent fiber digestibility, acid detergent fiber, ether extract and ash) were collected after ruminal fermentation. The results showed that the rate of disappearance of dry matter, neutral detergent fiber, acid detergent fiber, crude protein, starch, ether extract and ash were highest (P < 0.05) in varieties BF-92, 5456, or 13E33, and LS1122 respectively. The extent of degradation of dry matter, neutral detergent fiber, acid detergent fiber, crude protein, starch, ether extract and ash were highest (P < 0.05) for variety 7786. Ruminal lag time of dry matter, neutral detergent fiber, acid detergent fiber, crude protein, starch, ether extract and ash were lower (P < 0.05) for varieties BF-92, MS-449 and 7786, respectively. It was concluded from the results of this trial that variety BF-92 showed the better rate of disappearance and lag time of dry matter and neutral detergent fiber as compared to others.

Keywords: Maize, Silage quality, Cannulated bull, In-situ Digestibility, Ruminal fermentation.

**Abbreviations:** ADF, Acid detergent fiber; ANOVA, Analysis of variance; BMR, Brown midrib; CF, Crude fiber; CP, Crude Protein; DM, Dry matter; ED, Extent of digestion; Ln, Natural log; ME, Metabolizable energy; NDF, Neutral detergent fiber; NDFD, Digestibility of NDF; RD, Rate of disappearance; SPSS, Statistical package for the social sciences; TDN, Total digestible nutrient; WPSC, Whole-plant corn silage

**INTRODUCTION**

The current scenario of the livestock industry is showing an overwhelming increase in fodder demand, especially during the season when fresh fodder is not available i.e. lean period. An immediate solution is that farmers should be encouraged to cultivate more productive varieties of fodder. Maize (*Zea mays L*.) is a major forage source for ruminants around the world (Wei *et al.* 2018). It belongs to the family *Poaceae* and is a C4 plant having high genetic potential and photosynthetic efficiency (Katiyar *et al.* 2018). In the livestock industry, the maize crop is the best choice for silage production (Klein *et al*. 2018) due to its high nutritional quality as it contains CP 8.33 %, dry matter (DM) 35.84 %, crude fiber (CF) 23.28 %, ash 5.96 % and total digestible nutrient (TDN) 60% (Azim *et al.* 2000). Moreover, it also contains neutral detergent fiber (NDF) 52.46% and acid detergent fiber (ADF) 32.5% (Patel, 2012). Maize is a rich starch source (27%), which provides fermentable energy to the rumen microbes and enhances productivity of dairy animals (Klevenhusen and Zebeli 2021). It is widely grown across the world and often referred to as the “king of grain crops” (Hunje *et al.* 2011).

The key "ensile ability'' criteria for a crop are: 1) DM content; 2) sugar content and 3) buffering capacity (resistance to acidification). In these respects, maize is a nearly perfect crop because buffering capacity declines with maturity, high DM contents and adequate water-soluble carbohydrates at maturity (Mannetje 2016) are available for fermentation to lactic acid (Darby and Lauer 2002). It decreases its pH up to 3-4, which stops the growth of the microbes (Soundharrajan *et al.* 2021) and thus makes fodder desirable for animal consumption (McDonald *et al.* 1991). So, silage is an alternative that fulfills the shortage of conventional fodder (Iqbal *et al*. 2015) without any adverse effects on intake and digestibility. Owing to developing suitable maize genetic material for its sustainable utilization in animal feed, researchers have developed suitable maize varieties with a major focus on silage production (CHAYANONT *et al.* 2021).

Dietary nutrient bioavailability of feed or feed ingredients provides essential information to ensure that the nutrient requirements of animals are met. The *in-situ* technique that requires rumen cannulated animals has been extensively used to measure the potential digestibility of the feed materials in the ruminants (Castillo and Hernández 2021) for many decades (Mohamed and Chaudhry 2008). For the determination of digestive kinetics of feed contents many studies have been carried out i.e. in buffalo (Sarwar and Khan, 2004), cow (Di Marco *et al.* 2002) sheep (Zagorakis *et al.* 2015) and goat (Ghavipanje *et al.* 2016).

It is hypothesized that all new maize silage varieties will show a better nutritional profile followed by their digestibility in ruminant animals. Therefore, the present study is planned to evaluate the nutritional profile of maize silage varieties and *in-situ* digestibility using cannulated Nili Ravi buffalo bulls.

**MATERIALS AND METHODS**

The proposed study was carried out to evaluate the silage quality of eight different maize varieties (BF-92, MS-449, 36S46, LG-181, LS1122, 13E33, 5456 and 7786) and their nutrient digestibility using cannulated buffalo bulls. Different maize varieties were grown under normal agronomic conditions. Maize fodder was chopped with an average length of ½ inches and was thoroughly filled in airtight polythene plastic bags. In this way, 8 silos were prepared for 8 different maize varieties. After 40 days, silage was analyzed for DM, CP, NDF, ADF, starch, fat and ash contents.

***In-situ* digestibility**

For the *in-situ* experiment, cannulated buffalo bulls (bodyweight 350 kg) were used at Raja Muhammad Akram Animal Nutrition Research Center, University of Agriculture, Faisalabad. The experimental animals were reared in a well-aerated pan with a concrete floor and open yard. The animal was dewormed before the start of the experiment. Precautionary measures were ensured to create a healthy and conducive environment in the shed. The bulls were given 10 days adaptation period, during which the bulls fed wheat straw, berseem and mott grass; mott grass as C4 plant incubated in the rumen to develop ruminal microbes and to avoid the effects of diet on ruminal fermentation. The ingredients and chemical composition of ration is given in Table 1.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Ingredient | Parts | DM  Contribution  (%) | CP  Contribution  (%) | TDN Contribution (%) | NDF Contribution (%) |
| Berseem | 30 | 4.8 | 7.05 | 19.02 | 13.23 |
| Mott Grass | 30 | 5.37 | 3.48 | 18.69 | 18.75 |
| Wheat Straw | 40 | 37.10 | 1.04 | 17.2 | 32.4 |
| Total | 100 | 47.27 | 11.57 | 54.91 | 64.38 |

Table 1.Ingredients and chemical composition of ration

Maize silage samples were dried at 55°C and then each was ground at 2 mm size. The size of maize silage was ground to 2 mm through Wiley mill. Nylon bags 10 × 23 cm with 50 µm pore size were used. Triplicate bags containing 10 g sample along with a blank bag were used. Each bag was closed and tied with nylon fishing thread. These bags were soaked in distilled water at 39°C for 15 minutes just before placing into the rumen to remove soluble and >50 μm ﬁlterable material to adjust the temperature of the bags to the temperature in the rumen. These bags were exposed to *in-situ* ruminal fermentation for 0, 12, 24, 36, 48, 72 and 96 hours. Bags were placed in the rumen in a reverse sequence, starting with a bag to be incubated for the longest period and ending with a bag incubated for the shortest time and all bags were removed at the same time to reduce variation associated with the washing procedure. After removing, these bags were washed with running tap water until rinse was clear and dried in a forced air oven at 55°C. After an equilibration with air for 48 hours, the bags were weighed back, and the dried residues were transferred into bottles and stored for proximate analysis.

**Chemical analysis**

The DM was determined by drying the samples in an oven at 55℃ for 48 hours and ash contents were determined by igniting samples at 550-600°C. The CP was measured using Kjeldahl apparatus method. The ether extract was determined by using the soxhlet apparatus (AOAC 2000). The NDF and ADF contents were analyzed as described previously (Van Soest *et al.* 1991).

The extent of digestion was determined at each time interval. Degradation rates were determined by subtracting residue from the amount in the bag at each time point and then regressing the natural log (Ln) of that value against time (Sarwar *et al.* 1998). Lag time was probably related to hydration rate of NDF, ADF, or time needed for microbial association with NDF, or ADF lag time was calculated using the following equation.

Lag time (% hour) =

**Statistical Analysis**

The recorded data were statistically analyzed using the general linear model procedure of statistical package for the social sciences (SPSS 1999) and means were compared by Duncan’s Multiple Range Test (Steel and Torrie 1980).

**RESULTS**

The present investigation was focused to assess the silage characteristics of different maize varieties and *in-situ* digestibility coefficient using cannulated buffalo bulls.

**Chemical composition (%) of maize silages varieties**

The DM, NDF, ADF, crude protein, starch, ether extract, ash and total digestible nutrients (TDN) fractions of different maize varieties ranged from 23.6-28.2, 45.1-56.6, 23.4-32.7, 5.4-6.5, 56.9-62, 1.5-3.4, 6.4-7.4 and 72.85-81.47%, respectively as shown in Table 2. The highest (P < 0.05) values for DM, NDF, ADF, crude protein, starch, ether extract, ash and TDN were in variety BF-92, LG-181, 13E33, BF-92, 7786, LG-181, LG-181 and 7786, respectively.

Whereas DM, NDF, ADF, crude protein, starch, ether extract, ash and TDN were the lowest (P < 0.05) for varieties 7786, 7786, LG-181, MS-449, BF-92, BF-92, 5456, 13E33, respectively as shown in table 2.

Table.2 Chemical composition (%) of eight maize silage.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameters | Treatments | | | | | | | | | |  | | |
| V1 | V2 | V3 | V4 | V5 | V6 | V7 | V8 | SEM | *P*-Value | | |
| Dry matter | 28.2a | 25.7abc | 25.6abc | 26.3ab | 25.4b | 24.3bc | 25.2bc | 23.6c | 0.54 | <0.001 | |
| Neutral detergent fiber | 47.1c | 56.2a | 52.1b | 56.6a | 48.4c | 52b | 53.2ab | 45.1c | 0.62 | <0.001 | |
| Acid detergent fiber | 24.3b | 26.1b | 24b | 23.4b | 26.1b | 32.7a | 31.4a | 26.5b | 0.67 | <0.001 | |
| Crude protein | 6.5a | 5.4b | 5.4b | 6.5a | 4.3c | 5.4b | 5.4b | 5.4b | 0.19 | <0.001 | |
| Starch | 26.4b | 22.4c | 25.1b | 28.7a | 22.4c | 25.3b | 25.2b | 29.2a | 0.26 | <0.001 | |
| Ether extract | 1.5c | 2.5ab | 3a | 3.4a | 2.5ab | 2.2b | 2.1b | 2.6bc | 0.17 | <0.001 | |
| Ash  TDN | 6.5ab  80.45ab | 6.5ab  78.35ab | 6.5ab  78.3ab | 6.1b  77.8b | 7a  77.85b | 6.1b  72.85c | 7.4a  72.96c | 6.9a  81.47a | 0.11  0.66 | <0.001  <0.001 | |

***V1***: BF-92; ***V2***: MS-449; ***V3***: 36S46; ***V4***: LG-181; ***V5***: LS1122; ***V6***: 13E33; ***V7***: 5456; ***V8***: 7786

SEM = standard error mean Means with superscripts within rows are statistically significant (P < 0.05)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameters | Treatments | | | | | | | | | | |
| V1 | V2 | V3 | V4 | V5 | V6 | V7 | V8 | SEM | *P*-Value |
| Extent of digestion (%) of DM | 61.4ab | 63a | 62.3a | 60.1ab | 62.5a | 56.3b | 58.6ab | 63.9a | 1.11 | 0.003 |
| Extent of digestion (%) of NDF | 61.2a | 53.5c | 58.2ab | 57.1b | 59.1ab | 57.6b | 55.3bc | 62.2a | 1.61 | 0.026 |
| Extent of digestion (%) of ADF | 38.1bc | 37c | 40.5a | 39.5ab | 39ab | 37.5bc | 40a | 41a | 0.77 | 0.019 |
| Extent of digestion (%) of CP | 71.2ab | 70.5ab | 67.1b | 69.1ab | 72.3a | 68.8ab | 69.9ab | 73a | 1.53 | 0.024 |
| Extent of digestion (%) of starch | 81.3ab | 80.5bc | 82.2ab | 81.7ab | 82.7ab | 83.1ab | 79.7b | 84.4a | 0.88 | 0.037 |
| Extent of digestion (%) of ether extract | 78.3ab | 77.5b | 79.2ab | 78.1ab | 79.4ab | 80.1ab | 76.2c | 81.2a | 0.85 | 0.022 |
| Extent of digestion (%) of ash | 47.5ab | 46.1b | 48.2ab | 44.2c | 45.3c | 47.9ab | 45.6bc | 49.7a | 1.07 | 0.038 |

**In-situ extent of digestion (%) of eight Maize silage varieties**

The extent of digestion (ED) was represented as a maximum percentage of digestion after 96 hours. The variety 7786 showed highest (P < 0.05) ED values (%) for dry matter (63.9), NDF (62.2), ADF (41), CP (73), starch (84.4), ether extract (81.2) and ash (49.7) in cannulated buffalo bulls as shown in Table 3.

Table 3. Comparative in-situ extent of digestion of eight maize silage varieties

***V1***: BF-92; ***V2***: MS-449; ***V3***: 36S46; ***V4***: LG-181; ***V5***: LS1122; ***V6***: 13E33; ***V7***: 5456; ***V8***: 7786

SEM = Standard error mean with superscripts within rows are statistically significant (P < 0.05)

**In-situ rate of disappearance (%) of eight Maize silage varieties**

The rate of disappearance (RD) was estimated as a percentage of DM digestion per hour. Rate of disappearance of eight maize silage varieties (BF-92, MS-449, 36S46, LG-181, LS1122, 13E33, 5456 and 7786) in experimental trial were 3.92, 3.8, 3.58, 3.23, 3.76, 3.42, 3.7 and 3.91 respectively. The RD was highest (P < 0.05) in variety BF-92, whereas it was lowest (P < 0.05) for variety LG-181. Moreover, the highest (P < 0.05) RD of NDF (4.4), ADF (3.6), CP (4.7), starch (6.4), ether extract (5.3) and ash (4.1) were shown by BF-92, 5456, 5456, BF-92, 5456

and 5456, respectively as shown in Table 4.

Table 4**.** Comparative in-situ rate of disappearance of eight maize silage varieties.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameters | Treatments | | | | | | | | | | |
| V1 | V2 | V3 | V4 | V5 | V6 | V7 | V8 | SEM | *P*-Value |
| Rate of disappearance (%) of DM | 3.92a | 3.80ab | 3.58bc | 3.23d | 3.76ab | 3.42c | 3.70b | 3.91a | 0.14 | 0.002 |
| Rate of disappearance (%) of NDF | 4.4a | 4ab | 3.8ab | 3.78b | 3.8ab | 4.3a | 3.6c | 3.9ab | 0.16 | 0.030 |
| Rate of disappearance (%) of ADF | 3.3ab | 2.9c | 3.2ab | 3.2ab | 3b | 2.9c | 3.6a | 3.3ab | 0.01 | 0.04 |
| Rate of disappearance (%) of CP | 4.4ab | 4.2ab | 4.2ab | 3.6b | 4ab | 4.3ab | 4.7a | 4.4ab | 0.16 | 0.013 |
| Rate of disappearance (%) of starch | 6.4a | 6.3ab | 5.9b | 6.3ab | 6.3ab | 6.4a | 6.2ab | 6.3ab | 0.08 | 0.017 |
| Rate of disappearance (%) of ether extract | 5b | 4.8c | 5.1ab | 5b | 4.9bc | 5b | 5.3a | 4.8c | 0.09 | 0.039 |
| Rate of disappearance (%) of ash | 4ab | 4ab | 3.8c | 3.9b | 4.1a | 3.9b | 4.1a | 3.8c | 0.04 | 0.040 |

***V1***: BF-92; ***V2***: MS-449; ***V3***: 36S46; ***V4***: LG-181; ***V5***: LS1122; ***V6***: 13E33; ***V7***: 5456; ***V8***: 7786

SEM = Standard error mean with superscripts within ows are statistically significant (P < 0.05)

***In-situ* lag time (h) of eight Maize silage varieties**

Lag time values were as hours taken to start the digestion process. The highest (P < 0.05) lag time of dry matter (2.74), NDF (5.27), ADF (5.71), CP (1.5), starch (1.39), ether extract (1.84) and ash (2.8) were shown by LG-181, 5456, LS1122, LG-181, 13E33, 7786 and 13E33, respectively as shown in Table 5.

Table 5. Comparative *in-situ* lag time (h) of eight maize silage varieties

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **Treatments** | | | | | | | | | |
| **V1** | **V2** | **V3** | **V4** | **V5** | **V6** | **V7** | **V8** | **SEM** | ***P*-Value** |
| Lag time (h) of M | 1.60c | 1.84ab | 2ab | 2.74a | 1.79c | 2.05ab | 2.04ab | 1.67c | 0.02 | <0.001 |
| Lag time (h) of DF | 4.04c | 4.28b | 4.43ab | 4.95ab | 4.66ab | 4.72ab | 5.27a | 4.48ab | 0.24 | 0.043 |
| Lag time (h) of  ADF | 4.92c | 5.45ab | 5.25b | 5.12bc | 5.71a | 5.45ab | 5.22bc | 5.48ab | 0.14 | 0.031 |
| Lag time (h) of  CP | 0.94c | 0.86c | 1.18b | 1.50a | 1.29ab | 1.20b | 1.23b | 0.86c | 0.06 | <0.001 |
| Lag time (h) of  starch | 0.84d | 0.98c | 1.01c | 0.85d | 0.99c | 1.39a | 1.20b | 0.89c | 0.02 | 0.001 |
| Lag time (h) of  ether extract | 1.36c | 1.03d | 1.75ab | 1.36c | 1.52bc | 1.64b | 1.39c | 1.84a | 0.11 | 0.001 |
| Lag time (h) of  ash | 2.38c | 2.6b | 2.73ab | 2.53bc | 2.58b | 2.8a | 2.56bc | 2.55bc | 0.07 | 0.031 |

***V1***: BF-92; ***V2***: MS-449; ***V3***: 36S46; ***V4***: LG-181; ***V5***: LS1122; ***V6***: 13E33; ***V7***: 5456; ***V8***: 7786

SEM = Standard error mean with superscripts within ows are statistically significant (P < 0.05)

**DISCUSSION**

Silage is an alternative that fulfills the shortage of conventional fodder without any adverse effect on intake and digestibility. Owing to developing suitable maize genetic material for its sustainable utilization in animal feed, researchers (Erdal *et al.* 2017; Hundal *et al.* 2019) have developed suitable maize varieties with a major focus on better nutritional profile for silage production. Variation exposed by ANOVA encourages effective selection based on the extent of digestion, lag time and rate of disappearance of DM, CP, NDF and ADF.

**Chemical composition (%) of maize silages varieties**

Results of the DM (23.6-28.2%) coincide with that of Ali et al. (2016) in which a DM content of 23.7% for maize silage was reported. Similarly, O’mara *et al.* (1998) determined the DM of maize silage was 25.7% in comparison with grass silage (ryegrass sward) which was 22.3%. The study conducted by O’mara *et al.* (1998) also reported that NDF of maize silage was 56.5%, which was comparable with the NDF range from 45.1-56.6% for maize silage varieties in the present experiment as described in Table 3. Similarly, Schwarz *et al.* (1996) noticed that NDF content of different maize silage varieties varied from 41-46%. Different varieties have similar agronomic characteristics so the variations might be due to the different genetic capacities of the varieties (Allard 1999). The results of the present study for acid detergent fiber (23.4-32.7%) was in accordance with the findings of Gruber *et al.* (2018) who reported that ADF of different maize silage varieties was within the range of 23.2-25.2%. The results were also similar to the finding of O’mara *et al.* (1998) in which the ADF of maize silage was 27.2%. Similarly, Ali *et al.* (2016) reported that ADF contents of maize silage were 21.8% in comparison with grass silage (perennial ryegrass) that was 29.7%. Schwarz *et al.* (1996) also reported that the ADF of different maize silage varieties varied from 22-25%. According to Chahine *et al.* (2009), normal ADF for corn silage is between 20% to 33%. The high acid detergent fiber was probably due to maize silage varieties with different maturity indexes differed significantly regarding quality parameters, when cultivated in the same experimental field and harvested at the same time (Gruber and Hein 2006). Ebling and Kung Jr (2004) reported a CP content of maize silage (6.18%) that was in accordance with CP of the maize silage varieties (5.4-6.5%) in the present study. The results were also similar to the findings of Ali *et al.* (2016) in comparison of the CP contents of maize silage that was 6.8% with ryegrass silage which was 15.8%. Similarly, Baldinger *et al.* (2014) reported that CP of maize silage was 7.5% and Italian ryegrass was 9.9%, but maize silage enabled an efficiency of gross nitrogen utilization as high as 0.304% that was considerably higher than the level of 0.259% observed when the ryegrass diet was fed. Moreover, Gruber *et al.* (2018) reported that the CP of different maize silage varieties was ranged from 7-7.6% was slightly higher than that of the present study. It may be due to progressing maturity of the maize crop during the grain-ﬁlling period that increased the content of DM and starch which ultimately decreased the content of NDF and CP (Johnson *et al.* 1999). The result of the present study for ash (6.4-7.4%) was in accordance with the results of (Johnson *et al.* (2002) who reported that the ash content of different maize silage varieties was 7.11-7.75%. Similarly, O’mara *et al.* (1998) determined the ash content of maize silage that was 6.4% in comparison with ryegrass which was 8.8%. In contrast, Baldinger *et al.* (2014) compared the ash content of maize silage that was 3.3% with Italian ryegrass which was 9.8%. Phipps *et al.* (1995) reported that starch contents of 33.9% for maize silage compared with that of 21.6-33.4% for maize silage in the present study. Similarly, Johnson *et al.* (2002) reported that the starch content of different maize silage varieties was 27.4-29% showing similar findings with the present study.

***In-situ* digestibility**

Results of the present study indicated that there were significant (P < 0.05) effects of in-situ degradation kinetics of eight different maize silage varieties in Nili Ravi buffalo bull. The results of the dry matter digestibility 56.3 to 63.9% were coincide with the finding of Pirmohammadi *et* *al.* (2006) who reported that DM digestibility of maize silage was 65.4%. These results were also similar to the findings of Nazli *et al.* (2019) who stated that the DM digestibility of four corn silage varieties Sweet Corn, Suwan, BTL 2, BTL 1 were 65, 62.4, 61.7, 62.6%, respectively at the dough stage. The highest DM digestibility was observed in Sweet Corn. The reason for these findings was probably due to Sweet Corn having the lowest lignin content among the varieties because shorter stems with larger cob portions in Sweet Corn lower the lignin deposition in maturing stem cell walls. Another reason that the crude protein content (11.7 %) was higher in sweet corn as compared to other varieties is due to the concentration of crude protein in the rear portion of the corn plant. Similarly, Horst *et al.* (2020) examined the *in-situ* DM digestibility of three maize silage hybrids (Maximus VIP3, Defender VIP and Feroz VIP) who reported that hybrid named “Maximus VIP3” had greater dry matter digestibility (52.39%) than Defender VIP (50.42%) and Feroz VIP (49.23%) hybrids. Because Maximus hybrid is commercially known for having a more pronounced stay-green attribute compared to other hybrids. The DM digestibility of leafy silage hybrid was higher when compared with grain and blend silage diets. In the present study, the rate of disappearance of dry matter was significantly higher and the lag time was lower for maize silage variety BF-92. It might be due to a higher level of DM and CP contents when compared with other varieties.

Moreover, Bal *et al.* (2000) investigated the impact of corn silage hybrids on ruminal DM disappearance. Results revealed that the ruminal dry matter disappearance for conventional maize silage and brown midrib (BMR) was 56.1 and 60.2%, respectively which was in accordance with the present study. The results showed that ruminal DM disappearance was higher for BMR. Differences in digestibility of maize hybrids in nutritive and agronomic characteristics may be due to genetic variation when compared at the same maturity stage (Hetta *et al.* 2012). Because BMR leafy hybrids are characterized by a greater number of leaves and contain less lignin when compared with other varieties (Oba and Allen 1999).

Nazli *et al.* (2019) stated that digestibility of NDF was 62.2-65.2% for their different maize silage varieties compared with 53.5-62.2% for the maize silage in this experiment. The results of the present study were in accordance with the findings of Horst *et al.* (2020) who examined the effect of harvesting three maize hybrids (Maximus VIP3, Defender VIP and Feroz VIP). The potential degradability of NDF was higher for the Maximus VIP3 (53.63%) from other hybrids because the “Maximus” hybrid is commercially known for having a more pronounced stay-green attribute compared to that of the other hybrids evaluated herein. Thus, it could be expected that the vegetative fraction of this hybrid could be more digestible than that of the other hybrids. The present results were in line with Jung *et al.* (1998) who reported that NDF digestibility was markedly affected by variety. In contrast, Kuehn *et al.* (1999) found that the content of in-vitro digestible NDF was not affected by varieties. In a further study, Darby and Lauer (2002) reported that variety did not influence either in-vitro DM or NDF digestibility of maize silage. Eastridge (1999) reported that on average, BMR corn silages contained 34% less lignin and had 19% higher in-situ or in-vitro NDF digestibility when compared with non-BMR hybrids.

The results of the present study for ADF digestibility (37-41%) were justified with the findings of Andrae *et al.* (2001) who determined the in-situ ADF digestibility of two corn silage varieties (3335, 3489) at half milking stage for 24, 48 and 96 hours of incubation the digestibility was 17.15, 34.41 and 57.59%, respectively for variety 3335 and the digestibility was 15.24, 40.20 and 46.85%, respectively for variety 3489. The decrease in ADF digestibility as maturity advanced tended to be greater for hybrid 3489 than for hybrid 3335. This response was of particular interest because hybrid 3489 visually appeared to have harder and denser kernels during feeding than hybrid 3335 (Jung and Allen 1995). Gruber *et al.* (2018) also studied the nutritive effects of whole crop maize silage of different maize varieties. Results showed that ADF content was significantly affected by variety. Exceeded level of ADF in all harvest stages indicated the lower overall quality in terms of digestibility.

Results of the starch digestibility (79.7-84.4%) coincided with the findings of Bal *et al.* (2000) who investigated the impact of whole-plant corn silage (WPCS) maturity and hybrids on ruminal starch disappearance. Results revealed that the digestibility of starch for conventional maize silage was 81.6% and BMR for 78.3%. Starch contents were tended to be lower for the leafy WPCS. However, ruminal starch disappearance was greater (P < 0.01) for leafy that was 87.2% compared to grain 73.1% of WPCS. Increased starch disappearance for leafy WPCS may be related to reduced kernel hardness compared to the grain WPCS (Dwyer *et al.* 1995). Similarly, Andrae *et al.* (2001) determined the starch digestibility of two corn silage varieties (3335, 3489) at the half milking stage. The starch digestibility for variety “3335” was 84.82% and for variety “3489” was 83.81%. The decrease in starch digestibility as maturity advanced tended to be greater for hybrid 3489 than for hybrid 3335 response was of particular interest because hybrid 3489 visually appeared to have harder and denser kernels during feeding than hybrid 3335 (Jung and Allen 1995)

The highest (P < 0.05) CP was observed in variety “7786” that was 73%, whereas the lowest (P < 0.05) for variety “36S46” which was 67.1%. It was probably due to high leafy content or different maturity indexes between varieties. These results were justified in accordance with the findings of Pirmohammadi *et al.* (2006) who determined the CP digestibility of maize silage was 78.9%, compared with the dried apple pomace and ensiled apple pomace which was 72.1 and 68.5% respectively. Similarly, Ebling and Kung (2004) determined the CP digestibility of hybrid (P-BMR, U-BMR, and conventional corn silage that was processed P-7511) who reported CP digestibility of variety “P-7511” was 64.2% as compared to that of U-BMR which was 58.2% digestibility. However, processed-BMR (P-BMR) had a greater CP digestibility 65.7% than P-7511 (64.2%). It was due to mechanical processing increased the surface area of feed and more exposure to rumen microbes and facilitate digestion.

The ether extract digestibility of different maize silage varieties (76.2-81.2%) coincided with the results of Atwell *et al.* (1988) was 85.9% that higher than high oil corn silage which was 82.2%. In contrast, Drackley *et al.* (1996) reported that high oil corn silage had higher fatty acid digestibility that was 77.2% than that of conventional corn silage which was 73.2%. The reasons for the disparities among studies were not known. In another study, Weiss and Wyatt (2000) reported that the digestibility of ether extract with conventional unprocessed corn silage was lower 78.7% than processed corn silage that was 82.5%.

**CONCLUSION**

During in-situ digestibility, the rate of digestion, rate of disappearance, and lag time showed significant results (P < 0.0.5) among dry matter, crude protein, neutral detergent fiber, acid detergent fiber, Starch, ether extract, crude fiber and ash among all dietary treatment groups. So, It was concluded from the results of this trial that nutritional profile and digestion kinetics of dry matter, neutral detergent fiber, acid detergent fiber, crude protein, starch, ether extract and ash were found to be significantly different across all the treatments. Variety BF-92 showed a better rate of disappearance and lag time of dry matter and neutral detergent fiber as compared to other varieties. However, variety 7786 had a superior extent of digestion.

**Conflict of Interest**

The authors do not have any conflict of interest.

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**Data Availability**

Data is available.

**Ethics Approval**

All the experimental protocols were reviewed and approved by the Departmental Scrutiny Committee of the University of Agriculture, Faisalabad.

**REFERENCES**

Ali M, JW Cone, G Van Duinkerken, A Klop, MC Blok, M Bruinenberg, NA Khan, WH Hendriks (2016). Variation between individual cows in in situ rumen degradation characteristics of maize and grass silages. *NJAS-Wageningen J Life Sci* 78: 167–173.

Allard RW (1999). Principles of plant breeding. John Wiley and Sons.

Andrae JG, CW Hunt, GT Pritchard, LR Kennington, JH Harrison, W Kezar, W Mahanna (2001). Effect of hybrid, maturity, and mechanical processing of corn silage on intake and digestibility by beef cattle. *J Anim Sci* 79(9): 2268–2275.

AOAC (2000). Official methods of analysis of AOAC International. 17th ed., Association of Official Analytical Chemists. Gaithersburg, Maryland, USA.

Atwell DG, EH Jaster, KJ Moore, RL Fernando (1988). Evaluation of high oil corn and corn silage for lactating cows. *J Dairy Sci* 71(10): 2689–2698.

Azim A, AG Khan, MA Nadeem, D Muhammad (2000). Influence of maize and cowpea intercropping on fodder production and characteristics of silage. *Asian-Australasian J Anim Sci* 13(6): 781–784.

Bal MA, RD Shaver, KJ Shinners, JG Coors, JG Lauer, RJ Straub, RG Koegel (2000). Stage of maturity, processing, and hybrid effects on ruminal in situ disappearance of whole-plant corn silage. *Anim Feed Sci Technol* 86(1–2): 83–94.

Baldinger L, W Zollitsch, WF Knaus (2014). Maize silage and Italian ryegrass silage as high-energy forages in organic dairy cow diets: Differences in feed intake, milk yield and quality, and nitrogen efficiency. *Renew Agric Food Syst* 29(4): 378–387.

Castillo C, J Hernández (2021). Ruminal fistulation and cannulation: a necessary procedure for the advancement of biotechnological research in ruminants. *Animals* 11(7): 1870.

Chahine M, TE Fife, GE Shewmaker (2009). Target values for corn silage. *Idaho Alfalfa and Forage Conference Proceedings* 1–5.

CHAYANONT N, S JENWEERAWAT, J CHAUGOOL, S TUDSRI, T CHAISAN, S CHOTCHUTIMA (2021). Plant Spacing and Variety of Field Corn (*Zea mays L.*) Affecting Yield, Yield Components and Silage Quality. *Walailak J Sci Technol (WJST)* 18(6): 9014–9038.

Darby HM, JG Lauer (2002). Harvest date and hybrid influence on corn forage yield, quality, and preservation. *Agron J* 94(3): 559–566.

Di Marco ON, MS Aello, M Nomdedeu, S Van Houtte (2002). Effect of maize crop maturity on silage chemical composition and digestibility (*in vivo, in situ and in vitro*). *Anim Feed Sci Technol* 99(1–4): 37–43.

Drackley JK, DW LaCount, LS Emmert, TR Overton, JH Clark, N Bajjalieh (1996). Intake production, and nutrient digestibilities by dairy cows fed TopCrossTM high-oil corn as grain or silage. *J Dairy Sci* 79(Suppl. 1): 211.

Dwyer LM, CJ Andrews, DW Stewart, BL Ma, J Dugas (1995). Carbohydrate levels in field‐grown leafy and normal maize genotypes. *Crop Sci* 35(4): 1020–1027.

Eastridge ML (1999). Brown midrib corn silage. *Nutr Anim Heal* 178.

Ebling TL, L Kung Jr (2004). A comparison of processed conventional corn silage to unprocessed and processed brown midrib corn silage on intake, digestion, and milk production by dairy cows. *J Dairy Sci* 87(8): 2519–2526.

Erdal S, RCengiz, AOzturk, M Pamukcu, E Ozata, A Duman (2017). Developing Silage Maize Hybrids with the Cooperation Among Public Agricultural Research Institutes of Turkey. *Eurasian J Agric Res* 1(2): 49–53.

Ghavipanje N, MHF Nasri, H Farhangfar, J Modaresi (2016). In situ, in vitro and in vivo nutritive value assessment of Barberry leaf as a roughage for goat feeding. *Small Rumin Res* 141: 94–98.

Gruber L, W Hein (2006). Ertrag und Futterqualität von Silomais in Abhängigkeit von Vegetationsstadium, Sorte und Standort. Kongressband, 118: 244–259.

Gruber L, G Terler, W Knaus (2018). Nutrient composition, ruminal degradability and whole tract digestibility of whole crop maize silage from nine current varieties. *Arch Anim Nutr* 72(2): 121–137.

Hetta M, Z Mussadiq, AM Gustavsson, C Swensson (2012). Effects of hybrid and maturity on performance and nutritive characteristics of forage maize at high latitudes, estimated using the gas production technique. *Anim Feed Sci Technol* 171(1): 20–30.

Horst EH, S López, M Neumann, FJ Giráldez, VH Bumbieris Junior (2020). Effects of hybrid and grain maturity stage on the ruminal degradation and the nutritive value of maize forage for silage. *Agriculture* 10(7): 251.

Hundal JS, G Singh, M Wadhwa, A Sharma (2019). Adaptability, yield and in vitro evaluation of some promising silage maize hybrids under tropical climate. *Indian J Anim Sci* 89(6): 671–675.

Iqbal MA, B Ahmad, MH Shah, K Ali (2015). A study on forage sorghum (*Sorghum bicolor L.*) production in perspectives of white revolution in Punjab, Pakistan: Issues and future options. *Agric Environ Sci* 15(4): 640–647.

Johnson L, JH Harrison, C Hunt, K Shinners, CG Doggett, D Sapienza (1999). Nutritive value of corn silage as affected by maturity and mechanical processing: A contemporary review. *J Dairy Sci* 82(12): 2813–2825.

Johnson LM, JH Harrison, D Davidson, M Swift, WC Mahanna, K Shinners (2002). Corn silage management II: Effects of hybrid, maturity, and mechanical processing on digestion and energy content. *J Dairy Sci* 85(11): 2913–2927.

Jung HG, MS Allen (1995). Characteristics of plant cell walls affecting intake and digestibility of forages by ruminants. *J Anim Sci* 73(9): 2774–2790.

Jung HG, DR Mertens, DR Buxton (1998). Forage quality variation among maize inbreds: in vitro fiber digestion kinetics and prediction with NIRS. *Crop Sci* 38(1): 205–210.

Katiyar P, AK Singh, SR Mishra, AN Mishra, R Chaudhari, RK Aryan, N Kumar (2018). Phenological growth and development of Rabi maize (Zea mays L.) under various moisture regimes. *IJCS* 6(5): 2007–2010.

Klein JL, AFP Viana, PM Martini, SM Adams, C Guzatto, RA Bona, LS Rodrigues, DC Alves Filho, IL Brondani (2018). Productive performance of maize hybrids for the production of silage using the whole plant. *Rev Bras Milho e Sorgo* 17(1): 101–110.

Klevenhusen F, Q Zebeli (2021). A review on the potentials of using feeds rich in water‐soluble carbohydrates to enhance rumen health and sustainability of dairy cattle production. *J Sci Food Agric* 101(14): 5737–5746.

Kuehn CS, JG Linn, DG Johnson, HG Jung, MI Endres (1999). Effect of feeding silages from corn hybrids selected for leafiness or grain to lactating dairy cattle. *J Dairy Sci* 82(12): 2746–2755.

Mannetje L (2016). Silage for animal feed. *Encyclopedia of Life Support Systems* 123–135.

McDonald P, AR Henderson, SJE Heron (1991). The biochemistry of silage. *Chalcombe publications.*

Mohamed R, AS Chaudhry (2008). Methods to study degradation of ruminant feeds. *Nutr Res Rev* 21(1): 68–81.

Nazli MH, RA Halim, AM Abdullah, G Hussin, AA Samsudin (2019). Potential of four corn varieties at different harvest stages for silage production in Malaysia. *Asian-Australasian J Anim Sci* 32(2): 224.

O’mara FP, JJ Fitzgerald, JJ Murphy, M Rath (1998). The effect on milk production of replacing grass silage with maize silage in the diet of dairy cows. *Livest Prod Sci* 55(1): 79–87.

Oba M, MS Allen (1999). Evaluation of the importance of the digestibility of neutral detergent fiber from forage: effects on dry matter intake and milk yield of dairy cows. *J Dairy Sci* 82(3): 589–596.

Phipps RH, JD Sutton, BA Jones (1995). Forage mixtures for dairy cows: the effect on dry-matter intake and milk production of incorporating either fermented or urea-treated whole-crop wheat, brewers’ grains, fodder beet or maize silage into diets based on grass silage. *Anim Sci* 61(3): 491–496.

Pirmohammadi R, Y Rouzbehan, K Rezayazdi, M Zahedifar (2006). Chemical composition, digestibility and in situ degradability of dried and ensiled apple pomace and maize silage. *Small Rumin. Res* 66(1–3): 150–155.

Sarwar M, SA Bhatti, CS Ali (1998). In situ ruminal digestion kinetics of forages and feed byproducts in cattle and buffalo. *Asian-Australasian J Anim Sci* 11(2): 128–132.

Sarwar M, MA Khan (2004). Influence of ad libitum feeding of urea-treated wheat straw with or without corn steep liquor on intake, in situ digestion kinetics, nitrogen metabolism, and nutrient digestion in Nili-Ravi buffalo bulls. *Aust J Agric Res* 55(2): 229–236.

Schwarz FJ, EJ Pex, M Kirchgessner (1996). Influence of different maize varieties on digestibility and energy content of maize silage by cattle and sheep. *Wirtschaftseigene Futter (Germany)*.

Soundharrajan I, HS Park, S Rengasamy, R Sivanesan, KC Choi (2021). Application and future prospective of lactic acid bacteria as natural additives for silage production—a review. *Appl Sci* 11(17): 8127.

SPSS (1999). SPSS Use’s Guide: Release 10.0.1 Edition. SPSS Inc., Chicago, IL.

Steel RGD, JH Torrie (1980). Principles and procedures of statistics, a biometrical approach. (Issue Ed. 2). McGraw-Hill Kogakusha, Ltd.

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

Wei M, Z Chen, S Wei, G Geng, P Yan (2018). Comparison among methods of effective energy evaluation of corn silage for beef cattle. *Asian-Australasian J Anim Sci* 31(6): 851.

Weiss WP, DJ Wyatt (2000). Effect of oil content and kernel processing of corn silage on digestibility and milk production by dairy cows. *J Dairy Sci* 83(2): 351–358.