ISSN: 1991-0037 (print), 2710-3285 (online)

SOUTH ASIAN JOURNAL OF AGRICULTURE

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Agrotechnology Discipline, Khulna University

https://ku.ac.bd/discipline/at

OPEN ACCESS

South Asian J. Agric.

Research Article | Vol. 10, No. 1&2, 2024: 01-10

Title: Determination of Physical and Nutritional Quality of Silages Prepared from Three Different Species of Fodder

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Article Info:

Received: *January 10, 2024*

Accepted: *April 25, 2024*

Keywords: *Fodder, livestock, nutritional value, physical properties, silage*

ABSTRACT

Livestock production is often limited by the availability of high-quality forage. Most of the fodders and grasses are grown seasonally and are particularly scarce during the dry season. Silage making is a good technology for fodder conservation to ensure green fodders for livestock throughout the year. This study was carried out to observe the efficiency of small-scale silage production using simple low-cost technology and to ascertain the nutritional value of the silage. Cultivation of fodder species and preparation of silage were carried out in the field laboratory of Agrotechnology Discipline, Khulna University. The fodder for making silage was cut into 2 to 3 cm pieces, packed in plastic bags, carefully sealed and stored in drums with adequate sealing for 60 days. Three fodder species viz. oat (*Avena sativa* L.), maize (*Zea mays* L.) and sorghum (*Sorghum bicolour* L.) were selected for silage preparation. Three replicates were maintained for each species. To determine the physical characteristics of silages; color, aroma, texture and presence/absence of fungi were examined. Chemical analysis was performed in the animal husbandry laboratory, at Khulna University. Statistical analysis was carried out using the SPSS (version 22) computer program. It was found that color, odor and texture of silages were acceptable in all the samples and no fungus was observed in any of the samples. Chemical analysis showed the highest dry matter (DM) content (g 100 g^{-1}) in sorghum silage (22.72±0.88) and the lowest in maize silage (13.64±0.69) ($p<0.001$). The highest ($p<0.001$) crude protein (CP) content (g 100 g^{-1}) was recorded in sorghum silage (15.49±1.05) and the lowest in maize silage (8.78±1.15). Crude fiber content (g 100 g^{-1}) was found to be highest in oat silage (34.11±1.59) and lowest in maize silage (31.68±1.40). Ether extract content (g 100 g^{-1}) was highest in oat silage (4.60±1.25) followed by sorghum silage (1.99±0.08) and maize silage (1.22±0.41) ($p<0.01$). It could be concluded that silage prepared by using local knowledge and low-cost inputs, forage could be preserved well. However, the silages prepared from the three forage species, sorghum silage was found to have better nutritional value in terms of DM and CP contents.

DOI: https://doi.org/10.3329/saja.v10i1.80234

To cite this article: Salam, N. B., Islam, S. S., Islam, M. S., Rahman, M. M., & Moin, T. M. (2024). Determination of physical and nutritional quality of silages prepared from three different species of fodder. *South Asian Journal of Agriculture, 10*(1&2), 1–10.

INTRODUCTION

Silage provides a means of fodder preservation that reduces the potential for loss of nutritional value as a result of adverse conditions. Many different plants are being developed to be used in the production of silage, such as sorghum and maize fodder (Colombini et al., 2012). The low productivity rate of the global livestock production system can be attributed to seasonality and low-quality feed. While maintaining the forage's nutritional content, ensilage provides an alternate method of preserving fodder throughout the wet season (Kallah et al., 1997). The best solution for forage conservation to deal with this issue is ensiling. Silage is often considered to be higher quality feed than hay since it requires less time to wilt the forage, which results in a slight decrease in the feed's nutritional value (Ramos et al., 2016). For this reason, farmers are currently eager to manufacture high-nutrient silage feeds for their animals due to its excellent flavor, texture, and taste. Making silage is one way to maintain grass if there is a lot of production during the monsoon. During the dry season, high-quality feed can be stored as silage from grass (Mellish and Karinga, 2005).

Different silo designs, such as tower, pit, bunker, pile, trench, and plastic bag systems, are widely used in silage processing (Rafiuddin et al., 2017). The ability of silage bags to efficiently store tiny amounts of readily available fodder for extended periods of time is one of their main benefits. Their easy use in handling, dispensing, packaging, filling, and sealing provides a great deal of utility (Batra et al., 2016; Reiber et al., 2009). Although it has been suggested in recent years that maize can yield high-quality silage that improves dairy cattle's milk output, not all farmers grow maize. An annual crop that is widely grown in temperate regions is oat (Sterna et al., 2016) and they are utilized in many countries as both grain and feed (Kim et al., 2014). Oats are regarded as a functional food since they contain 113 different phytochemicals (Sterna et al., 2016). As a flavorful, juicy, fast-growing fodder crop that is high in nutrients, oats are unique (Irfan et al., 2016).

A similar crop to maize in terms of agronomy and nutritional value is sorghum. However, because sorghum is more suited to drought and low soil fertility than maize, it is an appealing substitute in terms of requirements (Borba et al., 2012). Sorghum plants are more tolerant of lower pH soils than maize plants, and therefore require less fertilizer and pest control (AERC, 2007). Considering the explained facts, the current study was conducted to determine the physical and nutritive quality of silages prepared from three different fodder species.

MATERIALS AND METHODS

Experimental site

Cultivation of fodder and preparation of silage were carried out in the field laboratory of the Agrotechnology Discipline of Khulna University. The proximate composition of the silage samples was determined at the animal husbandry laboratory of the Agrotechnology Discipline, Khulna University, Khulna.

Selection of fodder species

Oat (*Avena sativa* L.), maize (*Zea mays* L.) and sorghum (*Sorghum bicolour* L.) fodders were used to prepare the silages.

Land preparation and fodder cultivation:

Three experimental plots with each of 12 m^2 were prepared by properly weeding, ploughing, laddering and manuring for oat, maize and sorghum cultivation. Sheep manure, urea, triple super phosphate (TSP) and muriate of potash (MoP) were applied prior to ploughing. After land preparation, oat, maize, and sorghum seeds were sowed. In oat’s, maize’s and sorghum’s plots line to line distance was 25 cm, 40 cm and 30 cm, respectively and seed to seed distance was 10 cm, 25 cm and10 cm, respectively.

Harvesting of fodder

Oats and maize were harvested after 96 days from sowing, while sorghum took 93 days from sowing to harvesting.

Silage preparation

Nine plastic bags were used to prepare the silages. After harvesting, the fodders were chopped at 2 to 3 cm and the plastic bags were filled with chopped fodder. It was compacted as much as possible to ensure anaerobic conditions. The filled bags were sealed properly and kept in a drum with proper sealing.

Layout of experiment

The experiment was based on a completely randomized design (CRD), where the treatments were different fodder species (maize, oat, and sorghum).

Opening of silage and sample collection

Fodders were kept for 60 days to complete the ensiling process. After 60 days of ensiling, silages were opened to collect the samples for further analysis.

Assessment of physical properties

To assess the physical properties, the samples were subjected to observe their color, odor and texture.

Assessment of chemical properties

To determine the chemical properties, the samples were subjected to the proximate analysis. Proximate analysis of silage samples was done according to AOAC (1990) in the animal husbandry laboratory of the Agrotechnology Discipline, Khulna University.

Statistical analysis

Data were recorded and analyzed using the SPSS program in a computer.

RESULTS AND DISCUSSION

Physical characteristics of silages

The physical properties of silage samples are presented in Table 1. A dark green color was observed for maize silage while both oat and sorghum silages showed yellowish green color. Non-acid aroma was observed in maize silage but acid aroma in oat and sorghum silage. Dense/solid texture was present in oat and sorghum silages but the maize silage showed a slightly soft texture. No fungus appeared for any type of silage under study. Podkowka and Podkowka (2011) claim that color and scent can be utilized to identify well-fermented silage. Poorly fermented silage will be olive, blue-green, or dark brown in color (Podkowka and Podkowka, 2011), whereas well-fermented silage should be pale green or dull yellow in color. All of the silages prepared in this experiment had pleasing physical characteristics, including a brownish-green color and a delicious aroma.

Table 1. Physical properties of silage samples

Properties	Maize silage	Oat silage	Sorghum silage	Remarks
Color	Dark green	Yellowish green	Yellowish green	Acceptable
Aroma	Not acid or not rotten	Acid (keep fresh)	Acid (keep fresh)	Acceptable
Texture	Slightly soft	Dense/solid	Dense/solid	Acceptable
Appearance of fungus	None	None	None	Desirable

According to Gordon et al. (1963), mold infections can be noticed when the forage is very damp. According to Karsten et al. (2003), a well fermented maize silage should exhibit leafy characteristics, soft to touch, a yellowish-brown coloration, a mild and pleasing fragrance, along with a sour odor. But we found dark green coloration, non-acidic smell but not rotten and slightly soft texture. Also, no fungus was seen. Ishiaku et al. (2020) noticed that physical characteristics of 70:30 sorghum and lablab mixed silage made in pit silo displayed a yellowish green hue, highly sweet aroma and a very soft texture and we found similar color but acidic aroma and dense texture. Variation can be attributed to the fermentation process, silage mixed ingredient and silo type. In oats silage, it was also found yellowish green coloration, acidic smell and dense texture in the present study. Differences in the physical characteristics of these silages can be due to the temperature variation during fermentation process as Adesogan and Newman (2008) conducted a study on silage temperatures and found out that it is vital to maintain temperatures below 37.7°C for optimal silage fermentation process. Higher temperatures can negatively impact the quality of the silage which leads to increased protein degradation and a slower decline in pH levels, which in turn affects the efficiency of degradation.

Chemical composition of silages and fodder

Chemical analyses of all samples were based on dry matter (DM), except for the dry matter of fresh grasses and silages. According to data in Table 2, sorghum silage had the highest average DM content (g 100 g^{-1}), and maize silage had the lowest (13.64).

Table 2. Dry matter (DM) contents (%) fresh fodders and silages

Fodder/Silage	Number	Mean ± SE	Minimum	Maximum
Maize silage	3	13.64±0.69	12.34	14.69
Maize fodder	3	14.80±0.46	14.00	15.60
Oat silage	3	16.00±0.56	15.02	16.97
Oat fodder	3	13.67±0.55	12.70	14.60
Sorghum silage	3	22.72±0.88	21.08	24.07
Sorghum fodder	3	30.33±0.55	29.60	31.40
Overall	18	18.52±1.50	12.34	31.40
F-value		113.67		
p-value		0.000		

Among fresh grasses, sorghum had the greatest average DM content (30.33%) and oat had the lowest (13.67%). The DM content in maize fodder was 14.80%. The highest crude protein (CP) value (g 100 g^{-1}) of the silage samples was found in sorghum (15.49), followed by oat (9.86) and maize (8.78) (Table 3).

Table 3. Crude protein (CP) contents (%) fresh fodders and silages

Fodder/Silage	Number	Mean ± SE	Minimum	Maximum
Maize silage	3	8.78±1.15	7.05	10.96
Maize fodder	3	6.77±0.74	5.48	8.04
Oat silage	3	9.86±0.99	8.36	11.73
Oat fodder	3	11.77±0.81	10.80	13.38
Sorghum silage	3	15.49±1.05	13.88	17.46
Sorghum fodder	3	13.27±0.77	11.73	14.08
Overall	18	10.99±0.77	5.48	17.46
F-value		11.53		
p-value		0.000		

For fodder, sorghum had the greatest CP (13.27%), followed by oat (11.77%) and maize (6.77%). The highest crude fiber (CF) content (g 100 g^{-1}) was found in oat silage (34.11) and lowest in maize silage (31.68) (Table 4). The crude fiber content of sorghum silage was 32.84%. In the case of fodder, the highest CF content was found in oat fodder (30.12%) followed by maize (28.19%) and sorghum fodders (24.48%). Oat silage had the highest ether extract (EE) concentration (g 100 g^{-1}), and maize silage had the lowest (1.22) (Table 5).

The sorghum silage had an EE content of 1.99%. Oat fodder had an EE content of 3.28%, whereas maize fodder had 2.55%, and sorghum fodder had 1.48%. The NFE concentration (g 100 g^{-1}) of the silage samples shown in Table 6 ranged from 33.59 to 43.39, being lowest in oat and highest in maize silage.

Table 4. Crude fiber (CF) contents (%) fresh fodders and silages

Fodder/Silage	Number	Mean ± SE	Minimum	Maximum
Maize silage	3	31.68±1.40	29.40	34.22
Maize fodder	3	28.19±1.03	26.43	29.99
Oat silage	3	34.11±1.59	31.01	36.26
Oat fodder	3	30.12±1.09	28.23	32.01
Sorghum silage	3	32.84±1.75	29.43	35.21
Sorghum fodder	3	24.48±1.83	21.23	27.55
Overall	18	30.24±0.93	21.23	36.26
F-value		5.60		
p-value		0.007		

Table 5. Ether extract (EE) contents (%) fresh fodders and silages

Fodder/Silage	Number	Mean ± SE	Minimum	Maximum
Maize silage	3	1.22±0.41	0.43	1.79
Maize fodder	3	2.55±0.07	2.48	2.70
Oat silage	3	4.60±1.25	3.04	7.08
Oat fodder	3	3.28±0.08	3.15	3.43
Sorghum silage	3	1.99±0.08	1.83	2.11
Sorghum fodder	3	1.48±0.09	1.29	1.60
Overall	18	2.52±0.34	0.43	7.08
F-value		5.41		
p-value		0.008		

Table 6. Nitrogen free (NFE) extract contents (%) fresh fodders and silages

Fodder/Silage	Number	Mean ± SE	Minimum	Maximum
Maize silage	3	43.39±2.59	38.22	46.29
Maize fodder	3	50.81±0.57	49.66	51.43
Oat silage	3	33.59±2.23	29.44	37.06
Oat fodder	3	38.76±0.31	38.23	39.30
Sorghum silage	3	43.10±2.87	38.06	47.98
Sorghum fodder	3	55.89±2.38	52.46	60.47
Overall	18	44.26±1.92	29.44	60.47
F-value		14.98		
p-value		0.000		

The NFE contents of fresh fodders ranged from 55.89% to 38.76%, with sorghum fodder having the highest percentage and oat fodder having the lowest. Ash contents of silages and fresh fodders samples are shown in Table 7. Among silage samples, ash contents (g 100 g^{-1}) were highest in oat silage (17.84) and lowest in oat silage (6.58). Among fresh fodders samples, ash contents (g 100 g^{-1}) were highest in oat fodder (16.07) and lowest in sorghum (4.88).

Maize silage had 34% DM content, according to Pilipavicius et al. (2003), which was higher than that of the present study. According to Abeysekara (2003), oat silage had an average DM content of 30.5%, which was greater than the findings of the current study. Higher DM content was observed in sorghum silage by Touqir et al. (2007) (27.5%) than that of the current study. Heuze et al. (2017) observed a DM content of 23.3% in maize fodder, which was generally higher than the current study.

Table 7. Total ash contents (%) fresh fodders and silages

Fodder/Silage	Number	Mean ± SE	Minimum	Maximum
Maize silage	3	14.93±0.26	14.55	15.43
Maize fodder	3	11.67±0.49	10.84	12.55
Oat silage	3	17.84±0.52	17.18	18.86
Oat fodder	3	16.07±0.54	15.21	17.07
Sorghum silage	3	6.58±0.39	5.89	7.25
Sorghum fodder	3	4.88±0.09	4.70	4.98
Overall	18	12.00±1.18	4.70	18.86
F-value		161.25		
p-value		0.000		

Arelovich et al. (2003) found DM in oat fodder to be 26.3% which was higher than that of the current study. Sorghum fodder had a DM content of 22.1%, according to Bandara et al. (2016), which was lower than in the current study. Chakravarthi et al. (2017) showed that DM content of sorghum fodder was 26.30±0.50% which was lower than present result. Abdullah et al. (2017) found that, the DM content of maize, sorghum and oats silage prepared in bag was 28.24±0.04%, 28.30±0.08% and 27.43±0.05% respectively, which was higher than our findings. Nusrathali et al. (2021) showed that, DM content of maize and sorghum in bag silo system was 33.20± 0.72% and 29.00± 0.66% respectively, which was also higher than our findings. Medhi et al. (2010) noticed that, after ensiling the DM content of the oat silage prepared in pacca silo was 30.27% which was also much higher than our findings. This can be due to the difference in ensiling process.

Pilipavicius et al. (2003) found 9.16% CP concentration in maize silage, which was generally consistent with the current investigation. Abeysekara (2003) noted 9.5% CP, which was primarily in line with the current study in oat silage. In sorghum silage, Touqir et al. (2007) found 9.55% CP, which was less than that of the current study. Heuze et al. (2017) observed CP contents of 7.8% in maize fodder, which was greater than that of the current study. In oat fodder, Arelovich et al. (2003), observed 10.5% CP, which was less than that of the current study. Sorghum fodder had 11.63% CP, according to Bandara et al. (2016), which was slightly less than the findings of the current study. Htet et al. (2016) showed that, CP content of maize fodder harvested at 97days was 6.1±0.17% which was similar to the present results. Chakravarthi et al. (2017) noticed that CP content of sorghum fodder was 12.42± 0.47% which was similar to our findings. Abdullah et al. (2017) noted that, CP contents of maize, sorghum and oats silage prepared in bag were 6.15±0.03%, 5.31±0.02% and 5.60±0.02%, respectively which was lower than our findings. Study conducted by Nusrathali et al. (2021) revealed that, CP content of silage prepared in bag was 9.25±0.09% in maize silage which was similar to our findings and incase of sorghum it was 10.54 ±0.39% which was lower than our findings. Medhi et al. (2010) showed that in case of oat silage prepared in pacca silo CP content was 6.62% which was lower than our findings. Htet et al. (2016) showed that, CP content of maize silage prepared in polythene bags was 8.9±0.32% which was similar to the current findings.

In contrast to the current investigation, Pilipavicius et al. (2003) identified CF in Maize silage at a rate of 20.2%. Compared to the current investigation in oat silage, Abeysekara's (2003) observation of 32.4% CF was slightly higher. In comparison to this study, Touqir et al. (2007) discovered 42.0% CF in sorghum silage. Heuze et al. (2017) detected a slightly lower CF of 25.6% in maize fodder than that of the current study. An averageof 30.2% CF was found in oat fodder by Arelovich et al. (2003) was nearly identical to the results of the current investigation. Sorghum fodder had a CF content of 36.8%, according to Bandara et al. (2016), which was greater than the results of the current study. Htet et al. (2016) noticed that, CF content of maize fodder which was harvested at 97 days was 28.9±0.72% which is similar to our result. Chrisdiana (2018) revealed that CF content of sorghum fodder harvested at 16 days was 19.66% which was lower than our findings. Difference in outcomes can be attributed to plant variety and harvest day along with environmental factors. According to Nusrathali et al. (2021), CF content of maize and sorghum silage prepared in bag silo was 31.77±0.40% and 35.39±0.31% which was similar to our findings. Medhi et al. (2010) noticed that in case of oats silage prepared in pacca silo the CF content after ensiling was 41.13% which was higher than our findings. Htet et al. (2016) revealed that, CF content of maize silage prepared in polythene bags was 28.8 ± 0.62% which was little bit higher than our findings.

Pilipavicius et al. (2003) observed EE in maize silage at a level of 2.2%, which was somewhat higher than in the current study. Abeysekara (2003) found 5.8% EE, which is greater than the findings of the current study in oat silage. The average 1.2% ash observed by Touqir et al. (2007) in sorghum silage was largely identical to the results of the current investigation. Heuze et al. (2017) observed EE of 2.9% in maize fodder, which was largely consistent with the current findings. The average 3.4% EE observed in oat fodder by Arelovich et al. (2003), was almost identical to the results of the current investigation. Sorghum fodder had 1.76% EE, according to Bandara et al. (2016), which was nearly identical to the findings of the current investigation.

In comparison to this study, Pilipavicius et al. (2003) foundthat 3.7% ash in maize silage was significantly lower. An averageof 9.4% ash was reported by Abeysekara in 2003, which is less than the findings of the current investigation. Htet et al. (2016) revealed that, EE content of maize fodder 97days harvest was 6.6±0.20% which was higher than our findings. Chrisdiana (2018) noticed that EE content of sorghum was 5.80% harvested at 16day which was higher than our findings. Nusrathali et al. (2021) showed that, EE content of maize and sorghum silage prepared by bag silo was 3.64±0.18% and 5.31±0.08%, respectively. It was higher than our findings. Medhi et al. (2010) also revealed that, EE content of oats silage after ensiling prepared by pacca silo was 2.40% which was lower than our findings. Htet et al. (2016) noticed that, EE content of maize silage prepared in polythene bags was 7.1±0.43% which was higher than our findings. An average of 9.50% ash was reported in sorghum silage by Touqir et al. (2007), which was more than in the current study. Heuze et al. (2017) found ash in maize fodder to be 8.7%, which was generally lower than the current study. According to Arelovich et al. (2003), oat fodder had 10.1% ash, which was less than the result of the current study. Sorghum fodder had an ash level of 8.59%, according to Bandara et al. (2016), which was less than that of the current study. Htet et al. (2016) noticed that, ash content of maize fodder 97 days harvest was 6.0±0.13 which was lower than our findings. Chrisdiana (2018) revealed that ash content of sorghum fodder was 3.69% harvested at 16 day, which is lower than our findings. According to Reddy (2001), DM, CP, EE, CF, NFE and ash content of oats fodder are 25, 3, 0.8, 6, 14 and 1.2. But we found higher CP, EE, CF, NFE, ash content and lower DM content in our study. Nusrathali et al. (2021) noticed that, ash content of maize silage prepared by bag silo method was 9.42±0.22% which was lower than our findings and in case of sorghum silage ash content was 10.81 ±0.06% which was higher than our findings. Medhi et al. (2010) revealed that ash content of oats silage after ensiling made with pacca silo was 6.73% which was lower than our findings and NFE was found 43.12% in oats silage which was higher than our findings. According to Htet et al. (2016), NFE content of maize silage prepared by polythene bags was 48.7± 0.42% which is a little higher than our findings. Nitrogen-free-extract (NFE) content of maize fodder at 97days of harvesting was 47.1±0.42% which was similar to our findings. The variations observed in the proximate analysis of the silage can be attributed to variances in harvesting techniques, fermentation processes, storage conditions, genetic variability, analytical methods, or a combination of these factors.

CONCLUSION

Silage production has established to be an effective and cost-effective solution in addressing forage scarcity. Considering the findings of the study the beneficial physical qualities and substantial nutritional values of the silage samples was verified. Sorghum silage exhibited superior dry matter and crude protein content as compared to oat and maize silage. Hence, the opportunity of locally-produced silage as a practical substitute for costly feed choices is feasible which will help reduce animal protein scarcity and promote livestock output in resource-limited environments. The present study also recommends that in term of crude fiber content oat was superior and this component is essential to promote rumen health and efficient digestion in ruminants. By employing efficient procedures and utilizing affordable resources, farmers can successfully overcome the boundaries posed by forage scarcity and maintain a steady supply of nutritious feed throughout the year.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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