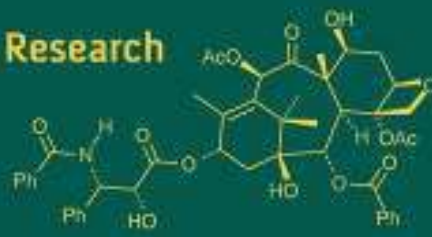
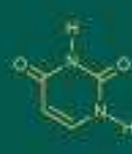
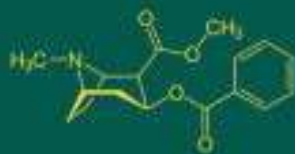


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Evaluation of chemical composition of sorghum (*Sorghum bicolor*) silage enriched with Jaggery, mineral mixture & whey.

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Abstract

The present research “Enrichment of sorghum silage using jaggery and mineral mixture” was conducted at Livestock Department of Animal Husbandry and Dairy science, College of Agriculture, Latur during the year 2022-2023. Total twelve treatments were studied namely T₀ - Control (CSH22SS), T₁- 2% Jaggery + CSH22SS, T₂ - 2% mineral mixture + CSH22SS, T₃ - 2% whey + CSH22SS, T₄ - Control (Dagdi Jowar), T₅-2% Jaggery + Dagdi Jowar, T₆ - 2% mineral mixture + Dagdi Jowar, T₇ - 2% whey + Dagdi Jowar, T₈ - Control (Phule Suchitra), T₉ - 2% Jaggery + Phule Suchitra, T₁₀ - 2% mineral mixture + Phule Suchitra, T₁₁- 2% whey + Phule Suchitra respectively. The fodder crop were chaffed into small pieces preferably 2-4 cm length using a chaff cutter. The bags were packed in such a way that neither air enters into the bags nor the gas comes out from the bags. To improve the nutritional quality of ensiling materials (2%) Mineral mixture was evenly sprinkled and thoroughly mixed over the chopped fodders in all treatments. Jaggery (2%) was diluted with water in a 2:1 ratio for easy application. While, whey (2%) was added as an inoculant to improve the fermentation quality. The fermentation process was done upto 60 days and silage obtained was subjected to the physical and chemical analysis. The chemical composition of the silage samples collected from various treatment bags was examined and the highest dry matter content was observed in T₁₀ (52.60%), whereas the lowest content was observed in T₆ (39.32%). Similarly, treatments T₆ (39.82%), T₇ (52.5%). The mean crude protein content ranged approximately from 5.1% to 9.1%. The highest crude protein content was recorded in T₁₀ (9.93%), followed by T₂ (9.26%) and the lowest CP value (5.17%) was estimated in T₄. Among all the treatments, T₇ recorded the highest mean extract content (3.25%) followed by T₆ and T₁₁ (2.78%). Whereas, the lowest mean value was observed in T₅ (1.55%) treatment. Whereas, T₆ recorded the highest mean total ash content (9.38%) followed by T₁₀ (8.50%) and T₉ (8.45%) and lowest total ash content (6.95%) was observed in T₄ treatment.

Keywords: Sorghum silage, jaggery, mineral mixture, whey, chemical composition, fermentation

Introduction

Forages are the biggest source of nutrient supply for the dairy animals therefore, they occupy central place in feed supply chain of the dairy animals. Fodder crops are cultivated and harvested for feeding the animals in the form of forage (fresh green fodder), silage (preserved under anaerobic conditions) and hay (dehydrated or dried green). Green forage supply must rise at a rate of 1.69 per cent per annum to satisfy the deficit; however the area under cultivated fodder accounts for only 4 per cent of the total cultivated land (8.4 million ha) in the country and remain unchanged over last few decades (Dagar *et al.*, 2017) [10]. Sorghum is the most important staple food and fodder crop of dry land areas. Sorghum as a source of dry fodder has potential to meet the dairy sector needs. Single cut sorghum varieties yield about 100-150 quintal per hectare of dry fodder. It contains 8 -10 per cent crude protein, 60 -65 per cent neutral detergent fiber, 37-42 per cent acid detergent fiber and 32 per cent cellulose when harvested at flowering stage. (Kumar *et al.*, 2012) [18].

Sorghum crop is rich in soluble sugars/ carbohydrates which is most suitable for ensiling. There are many varieties of sorghum but their composition does not differ enough to affect the feeding qualities to great extent. Mostly sorghum is slightly higher in protein but low in oil than maize (Pande, 2019) [28]. Sorghum grains contain about 70-75% carbohydrates, 10-12% protein and 2-3% fat, in addition to minerals such as phosphorus, iron, and zinc.

Silage may be defined as, “Any crop which is harvested green and preserved in succulent condition by the partial fermentation in more or less airtight container such as silos.” Silages are known to be an most effective feed resources in the milking animals as it helps in improving the health of the ruminants, yield more milk, solids and the forages. Silage is a high-moisture content forage that is used to feed livestock and using silage as feed is economically feasible and suitable for the cattle management. Silage production techniques play an important role in silage quality, as well as the characteristic of the silage material and for this purpose many crops can be used to make silage, either sole or mixtures (Ozyazici *et al.*, 2022) ^[27].

Jaggery also contains minerals and vitamins that help to enhance the fermentation process and improves the quality of silage. It also act as a natural preservative which helps to prevent spoilage and mold growth in the silage. Animals cannot synthesize minerals inside its body usually feeds and fodders fed to the dairy animals do not provide all the minerals in the required quantity. Therefore, animals should be provided with adequate and balanced amount of good quality minerals in their ration (Gupta *et al.*, 2020) ^[14].

Whey is used as an additive to silage, which improves its fermentation quality and increases nutritional value. Scotta is a dairy industry waste obtained by ricotta cheese production because of its high availability and its high lactose content. Ricotta cheese whey, also known as scotta, is a valuable source of the lactose (about 4 per cent) so it could be used as silage additive. Most of scotta is used as a supplement feed for livestock (Mariotti *et al.*, 2020) ^[22].

Materials AND Methods

Location

The livestock farm is located at latur, which is one of „Marathwada“ region in Maharashtra state. The environmental conditions directly affects the performance of animal and indirectly to the quality of fodder. Therefore, it is necessary to describe the topographical and climatological situation of the place. Latur is located on the latitude of 18.050 to 18.70 North and longitude of 73.250 to 77.250 East with a height of 636 meter above sea level.

Forage Production and Ensiling

The materials required for research include three varieties of sorghum CSH22SS, Phule Suchitra and Dagdi jowar procured from International crops Research Institute for the Semiarid (ICRISAT) Hyderabad, Mahatma Phule Krishi Vidyapeeth (MPKV) Rahuri and local market of Latur. These varieties were grown in the field of Department of Animal Husbandry and Dairy science, College of Agriculture, Latur. The crop was grown upto 75 days of sowing and harvested at dough stage which occurs 15 to 25 days after flowering, when approximately 50 per cent of the grain weight accumulated is used for preparation of silage. The fodder crop were chopped by an Mechanical chaff cutter with size of 2 cm for easy compacting and for purpose of removing air when it is packed in heavy micron plastic bags. Total 36 bags of 5 kg were prepared and kept for fermentation process at room temperature.

Silage Preparation

The optimum dry matter for crop harvesting for silage depends on the stage of harvesting. Most of the crops are harvested at 50% flowering to dough stage when the

moisture content varies between 18-22 per cent. Silage making involves four major steps viz., harvesting and transportation, chaffing, filling, compaction and covering of silos. The crop had to be chaffed into small pieces preferably 2-4 cm length using a chaff cutter. This improves the packing density which favours the growth of lactic acid bacteria, naturally present in crops. Add the fermentation mixtures in small quantities layer by layer after chaffing. Level the chaffed pieces evenly and press it hard so that all the air comes out. Pressing and removing air is very important. Chaffed material should be spread evenly over entire surface of silo (the structure) and then compacted through trampling (in case of small silo). The bags should be packed in such a way that neither air enters into the bags nor the gas comes out from the bags. The entire surface of polythene bags should be covered with straw or any other dried material upto 6-8 inches. The silage will be ready in 45 to 60 days depending upon the types of material used and the silage of thin stem crop like oats become ready in 45 days while thick stem crops like maize, sorghum and bajra becomes ready in 60 days. After completion of fermentation period the bags will be opened for further chemical analysis.

Silage Additives

To improve the nutritional quality of ensiling materials (2%) Mineral mixture was evenly sprinkled and thoroughly mixed over the chopped fodders in all treatments. Jaggery (2%) was diluted with water in a 2:1 ratio for easy application. While, whey (2%) was added as an inoculant to improve the fermentation quality. The fermentation process was done upto 60 days and silage obtained was subjected to the physical and chemical analysis.

Experimental Details

A Randomized block design with 3 replicates was applied and the treatment details are as follows

Table 1: Treatment Details

Sr.	Treatment	Contents
1.	T ₀	Control (CSH22SS Jowar)
2.	T ₁	2% Jaggery + CSH22SS
3.	T ₂	2% Mineral mixture + CSH22SS
4.	T ₃	2% Whey + CSH22SS
5.	T ₄	Control (Dagdi Jowar)
6.	T ₅	2% Jaggery + Dagdi Jowar
7.	T ₆	2% Mineral mixture+ Dagdi Jowar
8.	T ₇	2% Whey + Dagdi Jowar
9.	T ₈	Control (Phule Suchitra)
10.	T ₉	2% Jaggery + Phule Suchitra
11.	T ₁₀	2% Mineral mixture + Phule Suchitra
12.	T ₁₁	2% Whey + Phule Suchitra

Statistical Analysis

The data generated during the experimental period were subjected to statistical analysis of variance (ANOVA) by Randomized block design for testing the differences as per the procedure described by Panse and Sukhatme.

Chemical Analysis of Ensiled Sorghum

The silo bags of each treatment were opened at 15,30 and 45 and 60 days of ensiling, the silage samples of each treatment were collected for the immediate chemical analysis which include Dry matter, Crude protein, Crude fiber, Ether Extract and Total Ash as per the BIS IS :7874 (Part- 1)1975.

A. Dry matter (DM)

Weighed accurately 10 gm of the feed and fodder into aluminium dish. Heat the dish containing the material in hot air oven maintained at 100-120°C for about 3 hours and cooled it and weighted with the cover on. Repeat the process of drying, cooling and weighting at 30 minutes intervals for appropriate reading.

Calculation

$$\text{Moisture percentage by weight (\%)} = \frac{100 \times (W_1 - W_2)}{W_1}$$

Dry matter (%) = Weight of sample - Weight of moisture in sample

B. Crude protein (CP)

Crude Protein percentage was calculated by multiplying the percentage of total nitrogen by 6.25.

After determining the moisture content, the oven dried sample was ground and further processed for chemical analysis. Weighed 10 gm of sample was transferred to the Kjeldahl's flask. About 10 gm of potassium sulphate and 0.5 gm of copper sulphate were added to 25 ml flask and concentrated sulphuric acid was added. The flask was placed on digestion chamber and heated gently to boil until contents were clear and allowed the liquid to cool and diluted with 200 ml of distilled until all ammonia was passed over and was received over standard sulphuric acid which was then back titrated with standard NaOH in order to determine the amount of standard acid used to neutralize the ammonia evolved from digested material. Similarly blank sample was run.

Calculation

$$\text{Total Nitrogen} = \frac{1.4 \times (B - A) N}{W}$$

Total protein = Total Nitrogen X 6.25

C. Ether extract

The ether extract percentage was determined as per the procedure recommended by AOAC (2007).

Weighed accurately about 10 g of the given sample (rendered moisture free) on a piece of paper and transfer into an extraction thimble. The sample left in the determination of moisture was preserved in a desiccator. The clean, dry receiver from the Soxhlet assembly was taken and weighted accurately. Introduce the thimble with sample into the Soxhlet and the top of the thimble was over the level of siphon bend. The apparatus was assembled and the Soxhlet filled with petroleum ether through the condenser at the top by means of glass funnel. The amount of solvent taken was about 1.5 times the capacity of the Soxhlet and Place the apparatus on a water bath at 60-80°C.

The cold water circulation in the condenser was started. After, extraction is over the thimble with material from Soxhlet was removed and again the apparatus was assembled, heated on water bath to recover all the ether from the receiver flask. Then, the receiver flask was disconnected and wiped outside the flask thoroughly with a clean dry cloth to remove the film of moisture, dust and dried it in a hot air oven at 100°C for one hour, cooled it in a desiccator and weighed.

Calculation

$$\text{Ether extract content (\%)} = \frac{\text{Weight of extract}}{\text{Weight of substance taken}} \times 100$$

D. Crude Fiber (CF)

After determining ether, the oven dried sample was ground. A 10 g of sample was transferred into a flask and boiled with 1.25% sulphuric acid and 1.25% sodium hydroxide for half an hour. Then left residue was dried, weighted and ignited. Loss in weight was taken as fiber contents of the sample.

E. Total Ash (TA)

The total ash percentage was determined as per the procedure recommended by AOAC (2007).

The empty and dried silica crucible was weighed. Accurately 10 g of feed sample was taken into a crucible. Transfer the crucible to a muffle furnace with the help of a pair of long tongs and keep it at 600°C for two hours (At this temperature all the organic matter will be burnt leaving white ash). Remove the crucible from the furnace, cool it in a desiccator and weigh. The previously recorded empty crucible weighted and subtracted. Thus, the weight of ash was determined.

Calculation

$$\text{Ash or mineral matter (\%)} = \frac{\text{Weight of ash (g)}}{\text{Original weight of sample (g)}} \times 100$$

Results and Discussion**1. Dry Matter**

The table 1 shows that Dry matter content of sorghum silage was significantly affected by the effect of additives in which the highest dry matter content was observed in T₁₀ (52.60%), whereas the lowest content was observed in T₆ (39.32). Similarly, treatments T₁₁ (39.82%), T₇ (52.55%), T₈ (43.67%) also shows the at par results. The results obtained in the study are in agreement with the result obtained by Querol *et al.*, who reported the DM varies from 35.6% to 37.0% in sorghum bicolor and fresh citrus fruit pulp silage. Additionally, Andrade *et al.*, (2019) [3] reported that the increasing level of leucaena increases the DM 33.47% to 34.75% in sorghum silage.

Table 2: Effects of different additives and ensiling duration on Dry matter of Sorghum silage.

Sr No.	Treatments	Fermentation period (Days)				Mean
		15 days	30days	45 days	60 days	
1	T ₀	54.0	52.2	52.1	50.0	52.07
2	T ₁	43.0	42.8	42.0	39.9	41.92
3	T ₂	48.2	42.0	40.0	42.2	43.1
4	T ₃	41.9	41.2	42.2	40.8	41.52
5	T ₄	54.0	50.8	50.8	51.8	51.85
6	T ₅	40.8	40.0	39.6	38.9	39.82
7	T ₆	40.6	39.9	38.8	38	39.32
8	T ₇	52.9	52.3	53.0	52	52.55
9	T ₈	43.9	43.8	44.0	43	43.67
10	T ₉	48.0	47.2	48.0	48.2	47.85
11	T ₁₀	54.0	52.9	52.7	50.8	52.60
12	T ₁₁	40.8	40.0	39.6	38.9	39.82
S.E.± 0.55 C.D. at 5% 1.60						

2. Crude Protein

On an average, the highest crude protein was observed in T₁₀ (9.93%) followed by T₂ (9.26%) which were at par with T₉ (7.88), whereas an T₄ (5.1%) recorded the lowest value. Contrary to the present findings, Calabro *et al.* reported

9.70% and 7.66% CP in chopped and ensiled sorghum. While, Jalajakshi *et al.* observed 8.44% CP for sweet sorghum silage. Whereas, Querol *et al.* recorded the protein between 6.7 to 9.9% varied according to the contents of raw materials in sorghum *bicolor* and fresh citrus pulp.

Table 3: Effects of different additives and ensiling duration on Crude Protein content of Sorghum silage.

Sr No.	Treatments	Fermentation period (Days)				Mean
		15 days	30days	45 days	60 days	
1	T ₀	5.4	6.1	6.3	6.5	6.10
2	T ₁	6.3	6.5	6.6	6.4	6.44
3	T ₂	8.8	9.4	9.3	9.6	9.26
4	T ₃	6.2	6.5	6.7	7.2	6.65
5	T ₄	4.8	5.4	5.2	5.3	5.17
6	T ₅	5.4	5.7	5.8	6.2	5.78
7	T ₆	7.1	7.3	7.3	8.7	7.45
8	T ₇	5.2	5.6	5.5	7.6	5.98
9	T ₈	6.7	7.3	7.4	7.5	7.23
10	T ₉	7.2	7.7	8.2	8.5	7.88
11	T ₁₀	9.6	9.7	10.2	10.4	9.93
12	T ₁₁	7.6	7.5	7.8	8.3	7.82
S.E.± 0.10 C.D.at 5% 0.28						

3. Crude Fiber (CF)

The crude fiber percentage of sorghum silage (on dry matter basis) was significantly affected by both the treatments and storage duration.

Among different treatments, the crude fiber values was found to be highest in T₂ (33.71%) and lowest in T₄ (24.03%) treatment. Similarly, treatment T₁₀ (30.18%), T₃ (28.00%) and T₉(28.00%) shows at par result.

Table 4: Effects of different additives and ensiling duration on Crude fiber of sorghum silage.

Sr No.	Treatments	Fermentation period (Days)				Mean
		15 days	30days	45 days	60 days	
1	T ₀	27.23	28.50	29.13	29.30	28.53
2	T ₁	28.27	28.37	28.60	28.67	28.43
3	T ₂	32.13	33.67	34.40	34.70	33.71
4	T ₃	27.50	27.77	28.20	28.63	28.00
5	T ₄	23.27	23.73	24.50	24.70	24.03
6	T ₅	22.30	24.33	25.13	25.33	24.26
7	T ₆	26.70	26.77	27.63	27.77	27.18
8	T ₇	24.60	24.63	25.30	25.47	24.98
9	T ₈	25.40	25.45	26.57	26.60	25.98
10	T ₉	26.70	27.30	27.73	30.33	28.00
11	T ₁₀	29.50	30.10	30.40	30.77	30.18
12	T ₁₁	26.60	26.40	26.45	26.57	26.49
S.E.± 0.27 C.D. at 5% 0.28						

The results obtained in this study are in agreement with the results obtained by calabro *et al.*, who reported the crude fibre of chopped sorghum (30.5%) and ensiled sorghum

(35.1%). Randa *et al.*, (2017) ^[31] shows the result in 100% NP (34.68%), 75%NG + 25% BP (25.23%), 50% NG + 50% BP (23.97%), 100% BP(13.71%) respectively. Similarly,

Amuda *et al.*, (2017) ^[2] reported 31.4% CF in maize stover as compared to unensiled (32.3%) and (31.9%) in control.

4. Ether Extract (EE)

Among all the treatments on mean basis, T₇ (3.25%) had recorded the highest ether extract which were at par with T₆ (2.78), T₁₁ (2.78), T₁₀ (2.68) and T₂ (2.68) while T₅ (1.55) was the lowest.

Consistent with the present findings, Calabro *et al.* assessed 3.10% and 3.29% ether extract in chopped and ensiled sorghum. Andrade *et al.* (2019) ^[3] observed 1.97% to 2.51% ether extract in sorghum silage with increasing level of leucaena. Mahanta and Pachauri (2004) reported 1.69, 1.78 and 1.53% EE for three different varieties of sorghum silages.

Table 5: Effects of different additives and ensiling duration on Ether extract of Sorghum Silage.

Sr No.	Treatments	Fermentation period (Days)				Mean
		15 days	30days	45 days	60 days	
1	T ₀	0.77	2.27	3.70	3.61	2.60
2	T ₁	1.33	2.50	3.38	3.37	2.65
3	T ₂	1.77	2.40	3.17	3.53	2.68
4	T ₃	1.70	2.57	3.30	3.60	2.52
5	T ₄	1.33	1.70	2.50	2.90	2.11
6	T ₅	0.77	1.37	2.07	2.27	1.55
7	T ₆	1.80	2.20	3.40	3.70	2.78
8	T ₇	2.20	2.87	3.70	4.30	3.25
9	T ₈	0.63	2.30	3.45	3.50	2.53
10	T ₉	1.30	1.70	2.50	2.90	2.57
11	T ₁₀	1.33	2.40	3.47	3.67	2.68
12	T ₁₁	1.70	2.57	3.30	3.60	2.78
S.E.± 0.14 C.D. at 5% 0.40						

5. Total Ash

On mean basis, the highest ash content was retained in T₆ (9.38%) which were at par with T₁₀ (8.50%) and T₉ (8.45%) whereas, the T₄ (6.95%) was noticed as the lowest value. Consistent with the present findings, Ozturk *et al.* reported 4.71% to 11.64% ash in different silage mixtures. Whereas, it is also similar to Andrade *et al.* (2019) ^[3] also discussed the total ash content ranging from 7.45% to 8.20% in sorghum silage with increasing level of leucaena.

Table 6: Effects of different additives and ensiling duration on Total ash content of sorghum silage.

Sr No.	Treatments	Fermentation period (Days)				Mean
		15 days	30days	45 days	60 days	
1	T ₀	10.13	8.27	7.27	7.22	8.03
2	T ₁	9.50	8.13	7.40	6.70	7.93
3	T ₂	10.07	8.17	7.20	7.13	8.28
4	T ₃	9.27	8.20	7.17	7.10	7.90
5	T ₄	8.23	7.13	6.40	6.13	6.95
6	T ₅	8.20	7.63	6.27	6.20	7.05
7	T ₆	9.57	8.16	9.27	9.15	9.38
8	T ₇	8.33	8.17	7.20	6.15	7.43
9	T ₈	8.57	7.50	8.13	7.50	7.90
10	T ₉	9.40	8.20	8.15	8.10	8.45
11	T ₁₀	8.23	8.53	8.70	8.66	8.50
12	T ₁₁	8.50	7.40	7.27	7.20	7.58
S.E. ± 0.27 C.D. at 5% 0.78						

Conclusion

At 15 days, higher DM values were recorded ranging from 40.6% in T₆ to 54.0% in T₀. With progressive fermentation,

values declined by 60 days, reaching 38.0% (T₆ and T₇) at the lowest and 52.07% (T₀) at the highest. Among treatments, the highest mean DM content was observed in the control T₀ (52.60%), followed by T₂ (51.85%) and T₃ (51.83%), while the lowest means were recorded in T₆ (39.32%) and T₇ (39.82%). This indicates that some additives caused greater DM loss compared to others. Crude protein The crude protein (CP) content of sorghum silage showed a consistent variation across treatments and fermentation periods. At 15 days, CP values ranged from 4.8% to 8.3% in T₄ and T₂, while by 60 days, the values ranged from 5.0% to 9.7% in T₄ and T₁₁. This indicates that silages supplemented with additives, particularly T₂, T₁₀, and T₁₁, achieved the higher CP levels as compared to control and untreated treatments.

The mean CP content across treatments varied from lowest value (5.3%) in T₄ to highest value (10.2%) in T₁₁ treatment. The additive-based silages preserved crude protein more effectively, while the control T₀, T₄ and T₆ showed significantly lower CP content in the silage. The overall study revealed that the highest CP content was recorded in whey and jaggery based treatments, followed by mineral mixtures while the untreated silages showed the poor result. At 15 days, the values ranged from 22.30% to 32.13% in T₄ and T₂ treatment. while on 60 days, the values extended from 24.20% (T₄) to 34.73% (T₂). Across treatments, T₂, T₃, T₁₁, and T₁₂ had recorded the highest CF values (32-34%), whereas T₄, T₅, and T₆ maintained the lowest values (22-27%). The mean crude fiber content ranged from 26.45% (T₆) to 30.77% (T₁₁), with significant difference. Overall, the data suggest that additives and treatment type influenced crude fiber concentration, with some treatments enhancing fiber preservation. While, T₄ and T₆ lead to lowest CF, which could be considered as superior in terms of nutritive quality as they preserved more digestible nutrients.

The values ranged from lowest (1.37%) to highest (4.30%) across the different treatments. The overall treatment means varied between lowest (1.55%) and highest (3.25%) was recorded in T₈ or in T₉ which are the additive based treatments. The Treatments supplemented with jaggery, mineral mixtures and whey was recorded with higher ether extract values (2.5-3.3%), while the untreated and control treatments showed (1.5-2.1%) lower EE values reflecting the greater nutrient losses. At 15 days, ash values ranged between 7.13% (T₅) and 9.40% (T₁₀), while at 60 days, the range was 6.13% (T₅) to 9.15% (T₇) treatments. The mean total ash values across treatments ranged from 6.95% (T₅) to 9.38% (T₇), with significant differences. Treatments T₇, T₉, and T₁₁ concluded the highest ash content due to additive supplementation that improves mineral preservation during ensiling. The lowest ash values recorded in T₅ and T₆ indicated the greater mineral losses, which reduce the nutrients. Overall, the results show that ash content stability was enhanced by the use of additives, particularly whey and jaggery-based treatments, which helped preserve essential minerals.

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