

Effect of Jaggery, Mineral Supplementation, and Whey on Physical Quality of Sorghum Silage

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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, T₁, T₂, T₃, T₄, T₅, T₆, T₇, T₈, T₉, T₁₀, T₁₁ 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. The entire surface of polythene bags was covered with straw or any other dried material upto 6-8 inches. 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 result revealed that the physical quality of sorghum silage was significantly affected due to the effects of additives which showed the highest colour score the highest colour score (1.90 out of 2) was obtained in T₃, T₇ and T₁₁. However the lowest score (0.80 out of 2) was recorded in T₀ (Control). The Sensory score for odour among all the treatments was highest score (12.08 out of 14) in T₃ and the lowest score (9.05 out of 14) was recorded in T₄ (Control). Whereas, the texture score in T₁ and T₅ was highest (3.75 out of 4) and lowest (3.22 out of 4) in T₁₀ among all the treatments. In terms of DLG, the quality class showed that most treatment produced good quality of silage, while, treatment T₁, T₃ and T₉ were classified as very good and T₅ as medium. In all the treatments, T₉ was recorded as having the highest DLG score on basis of average score (17.57), whereas T₅ (13.18) had the lowest DLG score.

Keywords: Sorghum Silage, Jaggery, Mineral mixture, Chemical composition, Fermentation, Deutsche Landwirtschafts-Gesellschaft (DLG).

INTRODUCTION

Sweet sorghum [*Sorghum bicolor*(L.) Moench] is well adapted to the Semi-Arid Tropics (SAT) and is one of the most efficient dry land crop to convert atmospheric CO₂ into sugar. The crop is more water use efficient. Farmers still consider sweet sorghum a multipurpose crop from which they expect grain for human consumption and for the livestock fodder from the Stover [10]. Sorghum is considered one of the most promising forage crops for silage production due to its high green biomass yield, resilience to drought, and ability to grow in marginal soils. Unlike maize, sorghum requires comparatively less water and inputs, making it highly

suitable for tropical and semi-arid regions where fodder shortages are common[4].

Among different fodder crops, sorghum (*Sorghum bicolor*) has emerged as a promising crop for silage making due to its high biomass yield, drought tolerance, and adaptability to tropical and semi-arid regions. sorghum silage offers a sustainable solution for feed security in the face of climate variability and water scarcity, supporting resilient livestock production systems.

The study of silage is of great significance in livestock production, particularly under conditions of seasonal fodder scarcity.

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Silage is a scientific method of preserving green fodder in succulent form through lactic acid fermentation under anaerobic conditions. This process not only reduces wastage of surplus forage but also ensures round-the-year availability of feed with minimal nutrient loss [2] silage making reduces post-harvest losses, preserves nutrients for a longer duration, and supports efficient utilization of available fodder resources. This is particularly vital in regions where climatic fluctuations affect the availability of fresh green fodder. Additionally, sorghum silage contributes to lowering feed costs, improving milk productivity, and enhancing the economic returns of livestock farmers.

Jaggery is known to be good source of healthy and nutritious food for livestock as it rich in important minerals like calcium, magnesium, potassium, phosphorous, sodium, iron, manganese, zinc, copper, chloride and vitamins like A, B1, B2, B5, B6, C, D2, E, nicotinic acid and protein that are beneficial for their health [11]. The addition of jaggery leads to significant advantages in terms of fermentation, lactic acid composition and silage intake [13].

Mineral mixture supplementation during ensiling enriches the silage with essential macro- and micro-minerals, compensating for the deficiencies often observed in cereal fodders like sorghum. This practice not only improves the nutritive profile of the silage but also supports better animal health, milk production, and reproductive performance when fed to livestock [7].

Whey, a by-product of the dairy industry, is rich in lactic acid bacteria (LAB) and soluble sugars. Its addition serves as a natural inoculant, enhancing lactic acid fermentation, improving aerobic stability, and reducing the risk of secondary fermentation [1]. Utilization of whey in silage preparation also adds value to dairy by-products, contributing to sustainable and eco-friendly farming.

MATERIAL AND METHOD

Location

The study entitled “Enrichment of sorghum silage using jaggery and mineral mixture” was carried out at the Livestock Unit of the Department of Animal Husbandry and Dairy Science, College of Agriculture, Latur, during the academic year 2022–2023. The experiment was conducted using appropriate materials and well-defined methodologies, which are described in the following sections.

LOCATION OF THE RESEARCH PLACE

The livestock farm is situated in Latur, a district within the Marathwada region of Maharashtra. Environmental factors at this location play a significant role in influencing animal performance and, consequently, the quality of fodder produced. Hence, an understanding of the topography and climatic conditions of the area is essential. Geographically, Latur lies between 18.05° to 18.70° North latitude and 73.25° to 77.25° East longitude, at an elevation of approximately 636 meters above mean sea level.

FORAGE PRODUCTION AND ENSILING

The study utilized three sorghum varieties—CSH 22SS, Phule Suchitra, and Dagdi jowar—sourced from International Crops Research Institute for the Semi-Arid Tropics, Mahatma Phule Krishi Vidyapeeth, and the local market of Latur, respectively. These cultivars were raised under field conditions at the Department of Animal Husbandry and Dairy Science, College of Agriculture, Latur. The crop was maintained up to 75 days after sowing and harvested at the dough stage, typically occurring 15–25 days post-flowering, when nearly half of the grain weight had developed, making it suitable for silage preparation.

The harvested fodder was chopped into approximately 2 cm pieces using a mechanical chaff cutter to facilitate proper compaction and removal of entrapped air during ensiling. The processed material was then packed into heavy-gauge plastic bags, each containing about 5 kg of fodder. A total of 36 such bags were prepared and stored under ambient conditions to allow fermentation to take place.

SILAGE PREPARATION

The appropriate dry matter content for harvesting fodder intended for silage largely depends on the crop's growth stage. In most cases, crops are harvested between the 50 per cent flowering stage and the dough stage, when moisture levels are generally suitable for ensiling. The process of silage preparation involves key steps such as harvesting and transport of the crop, chopping, filling, compaction, and proper sealing of the storage unit. In this study, sorghum was harvested manually at the dough stage, at which time the fodder contained around 60–65 per cent moisture, considered ideal for silage making. The plants were cut near ground level using sickles, tied into bundles, and promptly moved to the chopping area. The harvested material was then reduced to pieces of about 2–4 cm using a chaff cutter to ensure efficient packing and air exclusion. After filling, the polythene bags were adequately covered with a layer of straw or similar dry material to a thickness of about 6–8 inches. The fermentation process was allowed to proceed for approximately 45 to 60 days, depending on the nature of the crop material, with finer-stemmed crops typically fermenting more rapidly. Upon completion of the fermentation period, the silage bags were opened and samples were collected for subsequent physical and chemical evaluation.

SILAGE ADDITIVES

To enhance the nutritive value of the ensiled material, a mineral mixture at 2 per cent level was uniformly applied and mixed thoroughly with the chopped fodder across all treatments. Jaggery, also at 2 per cent, was first dissolved in water in a 2:1 proportion to facilitate even distribution over the material. In addition, whey was incorporated at 2 per cent as a natural inoculant to promote desirable fermentation. The ensiling process was allowed to continue for a period of 60 days, after which the prepared silage was opened and evaluated for its physical characteristics as well as chemical composition.

EXPERIMENTAL DETAILS

Replications : 03

Design: Randomized Blocked Design

SR.	Treatments	Contents
1	T ₀	Control (CSH22SS Jowar)
2	T ₁	2% Jaggery+ CSH22SS Jowar
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 obtained during the experimental period was tabulated and this data was subjected to statistical analysis by Randomized block design (RBD) for testing their differences as per the procedure described.

ESTIMATION OF PHYSICAL QUALITIES OF SILAGE

The organoleptic evaluation of silage was carried out according to the DLG (Deutsche Landwirtschafts-Gesellschaft) classification system. The quality was assessed on the basis of colour, odour and texture. Odour was scored on basis of 0-14 scale, where higher scores indicated a pleasant, lactic and fresh smell, while lower scores represent the unpleasant, putrid or butyric odour. Colour and texture were evaluated on the basis of 0-5 scale in which the higher values represent the fresh green colour and good leafy structure, whereas lower scores reflected dark, mouldy colour and poor consistency.

The total DLG score (0-24) was calculated by adding odour, colour and texture scores and the silage was categorized as excellent (22-24), good (19-21), medium (16-18), satisfactory (13-15), poor (9-12) and very poor (0-8).

COLOUR

The data pertaining to the sensory score for colour in respect to the effect of additives on physical quality of sorghum silage are presented in Table 1 and graphically depicted in fig 1.

The results presented in Table 1 revealed that the colour score of Sorghum Silage was significantly affected due to the effect of different additives. The colour score of sorghum silage in T₀, T₁, T₂, T₃, T₄, T₅, T₆, T₇, T₈, T₉, T₁₀, T₁₁ respectively were recorded as 0.80, 1.75, 1.25, 1.90, 0.88, 1.78, 1.30, 1.90, 1.75, 1.28 and 1.90 respectively.

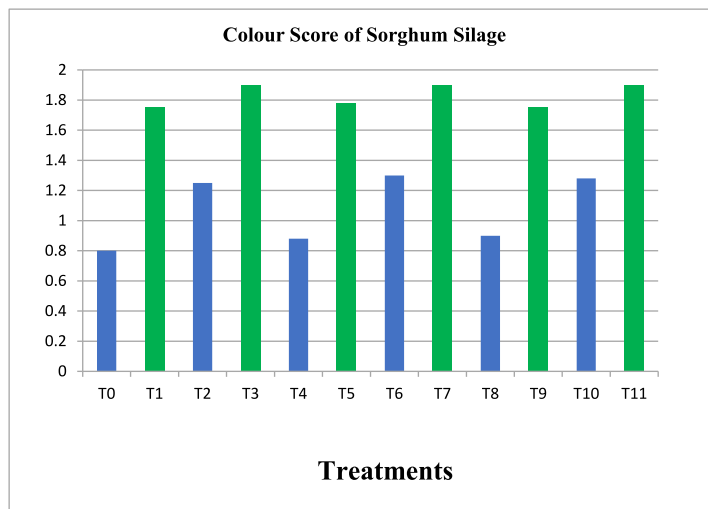
Table 1: Effects of different additives and ensiling duration on colour of sorghum silage

Sr No.	Treatments	Fermentation period (Days)				Mean
		15 days	30days	45 days	60 days	
1	T ₀	1.0	1.0	0.7	0.5	0.80
2	T ₁	1.5	2.0	2.0	1.5	1.75
3	T ₂	1.3	1.5	1.2	1.0	1.25
4	T ₃	1.6	2.0	2.0	2.0	1.90
5	T ₄	1.0	1.0	0.8	0.7	0.88
6	T ₅	1.5	2.1	2.0	1.6	1.78
7	T ₆	1.3	1.5	1.4	1.0	1.30
8	T ₇	1.6	2.0	2.0	2.0	1.90
9	T ₈	1.0	1.0	0.9	0.7	0.90
10	T ₉	1.5	2.0	2.0	1.5	1.75
11	T ₁₀	1.3	1.6	1.3	1.0	1.28
12	T ₁₁	1.6	2.0	2.0	2.0	1.90
S. E. ± 0.08					C.D. at 5% 0.24	

Table 2: ANOVA for the effect of different additives and ensiling duration on colour score of Sorghum silage

Source	DF	SS	MSS	F-cal	F-table	F-test
Treatment	11	8.1673	0.7425	26.72	2.09	S
Error	33	0.9169	0.0278			S
Total	47	9.9398				

Among all the treatment the highest colour score (1.90 out of 2) was obtained in T₃ (CSH22SS+Whey), T₇ (Dagdi Jowar+whey) and T₁₁ (Phule Suchitra +Whey). However the lowest score (0.80 out of 2) was recorded in T₀ (Control).



4.2.2 ODOUR

The sensory score for odour in respect to effect of additives on physical quality of sorghum silage are presented in Table 3 and graphically depicted in Fig 2.

It is observed from Table 2 that, the odour score of sorghum silage was significantly affected due to the effect of different additives. The Odour score in T₀, T₁, T₂, T₃, T₄, T₅, T₆, T₇, T₈, T₉, T₁₀, T₁₁ respectively were recorded as 10.05, 12.08, 10.67, 11.62, 9.05, 10.60, 9.60, 10.57, 10.15, 12.02, 10.50, 11.05 respectively.

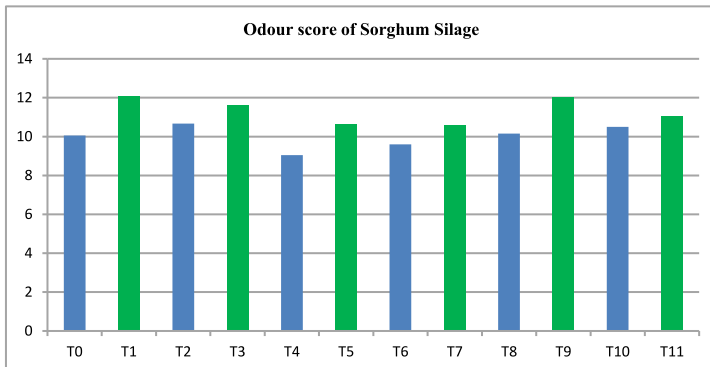
Table 3: Effects of different additives and ensiling duration on odour of Sorghum silage

Sr No.	Treatments	Fermentation period (Days)				Mean
		15 days	30days	45 days	60 days	
1	T ₀	12.0	11.0	9.0	8.2	10.05
2	T ₁	13.0	14.1	11.0	10.3	12.08
3	T ₂	12.0	11.2	10.0	9.5	10.67
4	T ₃	13.1	12.3	11.1	10.0	11.62
5	T ₄	11.0	10.0	8.0	7.2	9.05
6	T ₅	12.0	11.3	10.0	9.1	10.60
7	T ₆	11.1	10.1	9.0	8.2	9.60
8	T ₇	12.2	11.0	10.1	9.0	10.57
9	T ₈	11.0	12.5	9.0	8.1	10.15
10	T ₉	13.1	14.0	11.1	10.0	12.02
11	T ₁₀	12.0	11.0	10.0	9.0	10.50
12	T ₁₁	13.0	10.0	11.0	10.2	11.05
S.E.± 0.32		C.D.at 5%0.91				

Table 4: ANOVA for the effect of different additives and ensiling duration on Odour score of Sorghum silage

Source	DF	SS	MSS	F-cal	F-table	F-test
Treatment	11	37.4739	3.4067	8.54	2.09	S
Error	33	13.1576	0.3987			S
Total	47	122.4258				

Among all the treatments highest odour score (12.08 out of 14) was obtained in T₃ (CSH22SS+ Whey) and the lowest score (9.05 out of 14) was recorded in T₄ (Control).



The present investigation were comparable with [3] reported that the sorghum silage treated with fermentable additives showed the higher odour score (10.5-12.0) in untreated silage, whereas additive treated treatments showed lower mean odour score (9.0- 10.6) as compared to control. Similarly, [8] reported the average mean odour score from 8.5 to 10.2 and untreated silage showed the higher mean value (11.0-12.5).

4.2.3 TEXTURE

The sensory score for texture regarding to effect of additives on physical quality of sorghum silage are presented in Table 5 and graphically depicted in Fig 3.

It was noticed from Table 3, the texture score of sorghum silage was significantly affected due to the effects of different additives. The texture score in T₀ (Control), T₁(CSH22SS + Jaggery), T₂(CSH22SS + Mineral mixture), T₃(CSH22SS + Whey), T₄(Control), T₅ (Dagdi Jowar + Jaggery), T₆(Dagdi Jowar + Mineral mixture), T₇(Dagdi Jowar + Whey), T₈ (Control), T₉ (Phule Suchitra + Jaggery), T₁₀ (Phule Suchitra + Mineral mixture), T₁₁(Phule Suchitra + Whey) was recorded as 3.25, 3.75, 3.35, 3.80, 3.25, 3.75, 3.47, 3.57, 3.27, 3.80, 3.22, 3.80 respectively.

Table 5: Effects of different additives and ensiling duration on Texture of sorghum silage

Sr No.	Treatments	Fermentation period (Days)				Mean
		15 days	30days	45 days	60 days	
1	T ₀	4.0	3.5	3.0	2.5	3.25
2	T ₁	4.5	4.0	3.5	3	3.75
3	T ₂	4.0	3.5	3.3	2.6	3.35
4	T ₃	4.5	4.2	3.5	3.1	3.80
5	T ₄	4.0	3.5	3.0	2.5	3.25
6	T ₅	4.4	4.0	3.5	3.2	3.75
7	T ₆	4.1	4.3	3.2	2.3	3.47
8	T ₇	4.5	3.5	3.3	3.0	3.57
9	T ₈	4.2	3.4	3.0	2.5	3.27
10	T ₉	4.5	4.0	3.5	3.2	3.80
11	T ₁₀	4.1	3.4	3.0	2.4	3.22
12	T ₁₁	4.4	4.2	3.5	3.0	3.80
S.E.± 0.08		C.D.at 5% 0.24				

Table 6: ANOVA for the effect of different additives and ensiling duration on Texture score of Sorghum silage

Source	DF	SS	MSS	F-cal	F-table	F-test
Treatment	11	2.6700	0.2427	8.58	2.09	S
Error	33	0.9333	0.0283			S
Total	47	19.0100				

The texture score in T₁(CSH22SS+ Jaggery) and T₅(Dagdi Jowar +Jaggery) was highest (3.75 out of 4) and lowest (3.22 out of 4) in T₁₀ (Phule Suchitra+ Mineral mixture) among all the treatments.

The present results are similar with [9] reported the mean texture scores ranging from 3.2 to 3.7 in sorghum silage prepared with different additives and storage durations. [5] reported that average texture scores ranged from 3.4- 3.8 with the use of additives which closely agree with the higher mean texture score (3.80) observed in the present investigation.

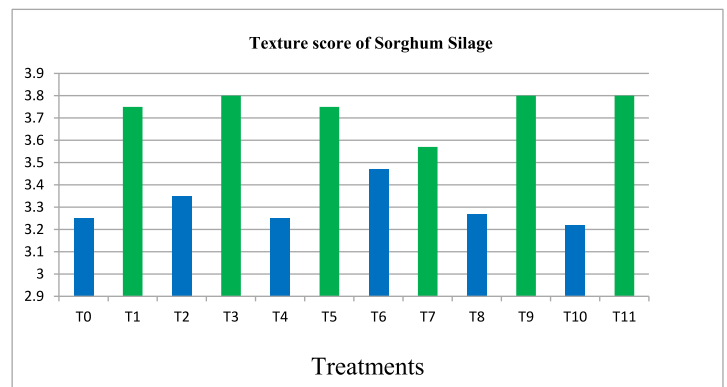
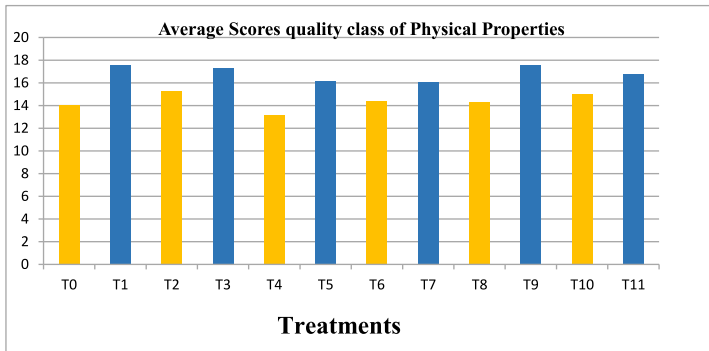


Table 7: Average scores quality class of physical properties sorghum silage with different additives

Treatments	colour	odour	Texture	DLG	Quality class
T ₀	0.80	10.05	3.25	14.01	Good
T ₁	1.75	12.08	3.75	17.58	Very good
T ₂	1.25	10.67	3.35	15.27	Good
T ₃	1.90	11.62	3.80	17.32	Very good
T ₄	0.88	9.05	3.25	13.18	Medium
T ₅	1.78	10.60	3.75	16.13	Good
T ₆	1.30	9.60	3.47	14.37	Good
T ₇	1.90	10.57	3.57	16.04	Good
T ₈	0.90	10.15	3.27	14.32	Good
T ₉	1.75	12.02	3.80	17.57	Very good
T ₁₀	1.28	10.50	3.22	15.00	Good
T ₁₁	1.90	11.05	3.80	16.75	Good
Mean	1.44	10.66	3.52	15.63	Good



The results presented Table 7 and graphically depicted in fig 4, shows that in terms of colour, the score ranged from 0.80 to 1.90, with mean of 1.44 and odour scores varied between 9.05 to 12.08 with mean score 10.66, whereas Texture scores were comparatively uniform ranging from 3.22 to 3.80 with mean score 3.52. The total DLG scores ranged between 13.18 to 17.57 with mean score of 15.63 which indicates that the silage quality varies from medium to very good.

In terms of DLG, the quality class showed that most treatment produced good quality of silage, while, treatment T₁, T₃ and T₉ were classified as very good and T₅ as medium. In all the treatments, T₉ was recorded as having the highest DLG score on basis of average score (17.57), whereas T₅ (13.18) had the lowest DLG score.

The results are similar to [6] reported the physical quality of score ranging from 1.30 to 2.00 in colour, 9.50 to 13.50 in odour and 3.50 to 4.00 in texture. [12] also reported the quality in which colour score is 2.00, Odour ranges from 12.75 to 14.00 and texture score is 4.00 points.

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