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Evaluation of Commercial Syrup as a Stimulant Additive to Improve Elephant Grass Silage Quality

Evaluasi Sirup Komersial Sebagai Aditif Stimulan untuk Meningkatkan Kualitas Silase Rumput Gajah

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ABSTRACT

Elephant grass is a common forage for livestock fodder, yet it is prone to damage and requires preservation through silage-making techniques. This study was investigating the potential usage of expired commercial syrup (ECS) as a source of glucose in elephant grass silage production. The research was using a Completely Randomized Design with five treatments and five replications. Treatments included a control group that consist of elephant grass (P1/control), and four supplemented grasses with ECS at levels of 2.50% (P2), 5% (P3), 7.50% (P4), and 10% (P5) based on dry matter (DM). After ensiling for 30 days at room temperature, various parameters were measured, i.e. aroma, texture, color, fungal growth, pH, dry matter, dry matter loss (DML), and fleigh value. Data were analysis using analysis of variance, followed by Duncan's test. The results revealed that ECS incorporation up to 10% DM had a significant influence on the evaluated parameters (p<0,05). The results showed P5 received the highest ratings from panellists for aroma (3.75; distinctive fermented acidity), texture (3.61; fine and non-clumping), and color (3.54; green). Additionally, P5 exhibited minimal fungal growth (1.57%), an optimal pH range (3.24-4.56), the highest dry matter content (31.4%), the lowest dry matter loss (2.27%), and the highest fleigh value (138). The findings suggested that expired commercial syrup could use as a stimulant additive in elephant grass ensiling, effectively.

Key words: elephant grass, expired commercial syrup, fungal growth, physical quality, silage

ABSTRAK

Rumput gajah merupakan pakan ternak yang umum dibudidayakan, namun rentan terhadap kerusakan dan membutuhkan pengawetan melalui teknik pembuatan silase. Penelitian ini menyelidiki potensi penggunaan sirup komersial kadaluarsa (SKA) sebagai sumber glukosa dalam produksi silase rumput gajah. Penelitian ini menggunakan Rancangan Acak Lengkap (RAL) dengan lima perlakuan dan lima kali ulangan. Perlakuan terdiri dari P1, yang terdiri dari rumput gajah (kontrol), P1 dengan penambahan SKA dengan persentase 2,50% (P2), 5% (P3), 7,50% (P4), dan 10% (P5) berdasarkan bahan kering (BK). Setelah difermentasi selama 30 hari pada suhu ruang, dilakukan pengukuran berbagai parameter, yaitu aroma, tekstur, warna, pertumbuhan jamur, pH, bahan kering, penyusutan bahan kering (KBK), dan nilai Fleigh. Analisis data menggunakan analisis varian dan uji lanjut Duncan. Hasil penelitian menunjukkan bahwa penambahan SKA hingga 10% BK secara signifikan mempengaruhi parameter yang diukur. Panelis menilai P5 paling tinggi dalam hal aroma (3,75; keasaman fermentasi yang khas), tekstur (3,61; halus dan tidak menggumpal), warna (3,54; hijau), pertumbuhan jamur minimal (1,57%), kisaran pH optimal (3,24-4,56), kandungan bahan kering tertinggi (31,4%), penyusutan bahan kering terendah (2,27%), dan nilai Fleigh tertinggi (138; sangat baik). Hasil ini menunjukkan bahwa sirup komersial kadaluarsa dapat secara efektif digunakan sebagai aditif stimulan dalam ensilase rumput gajah.

Kata kunci: kualitas fisik, pertumbuhan jamur, rumput gajah, silase, sirup komersial kadaluarsa

INTRODUCTION

Livestock production hinges on providing animals with high-quality forage that meets their nutritional demands (Thapa *et al*. 2022a; 2023b). Elephant grass (Pennisetum purpureum), a member of the Poaceae family, emerges as a promising candidate due to its exceptional nutrient profile (Liu *et al*. 2024b). Analysis of its composition reveals a wealth of essential nutrients, making it a highly preferred forage choice for various livestock species. Furthermore, elephant grass boasts impressive yields, ranging from 100 to 200 tons per hectare (Hedayatullah & Zaman 2019). However, this abundant production necessitates the implementation of effective preservation strategies to minimize losses and ensure year-round availability (Xie *et al*. 2023a). Silage technology, a well-established method for wet forage preservation, offers a viable solution for maintaining the quality and nutritional value of elephant grass (Olijhoek *et al.* 2023).

Silage, a product of anaerobic fermentation, is a high-moisture feed commonly fed to ruminant animals (Xie *et al*. 2023a). It's typically made from various grasses, including corn, sorghum, and other cereals, as well as agricultural, plantation, and forestry by-products, utilizing the entire plant, including seeds (Dryden, 2021; Xie *et al*. 2023b). Additionally, silage can also be derived from oil palm leaves, cassava, rice, hemp, and even organic market waste. Agro-industrial by-products like soybean pulp, tofu residue present further possibilities for sustainable biomass utilization (Sadarman *et al*. 2020) and spent grains. Accelerating the ensiling process often relies on providing microbial feed sources, such as expired commercial syrup (ECS) rich in glucose content, which stimulates anaerobic fermentation within silos (Sadarman *et al.* 2023c).

Syrup, a concentrated sugar solution comprising granulated sugar or sucrose, glucose, invert sugar, maltose, or fructose, is typically devoid of additional food ingredients (Ramle *et al*. 2024; Zaitoun *et al*. 2018). Alongside sugar, syrups may contain added coloring agents and preservatives (Rojas *et al*. 2019). Market offerings include sucrose syrup (granulated sugar), glucose syrup, maltose syrup, and fructose syrup, commonly known as high fructose syrup (HFS) (Ramle *et al*. 2024). Incorporating expired commercial syrup has shown promise in reducing pH levels, fungal growth, and dry matter loss in elephant grass and fresh tofu residue silage (Sadarman *et al*. 2023c). Sadarman *et al.* (2024) showed that adding expired commercial syrup up to 10% DM yields silage with low pH, minimal fungal growth, and improves physical quality including aroma, texture, and color of silage, owing to the syrup's high sugar content (50%-65%) and pH level (3.69-3.81), which fosters microbial energy and beneficial bacteria growth while lowering pH during ensiling.

Elephant grass, with its high dry matter production, presents a promising feedstock for silage production (Hedayatullah & Zaman 2019). However, the potential application of expired commercial syrup, a readily available resource in Indonesia, as a silage additive for elephant grass remains largely unexplored in the existing scientific literature. This knowledge gap offers a compelling research avenue to investigate the efficacy of expired commercial syrup in enhancing the ensiling process of elephant grass. Furthermore, determining the optimal level of syrup inclusion for elephant grass silage is crucial to ensure optimal fermentation and minimizing potential drawbacks. Exploring this approach could contribute significantly to optimizing silage production practices in Indonesia, particularly for resource-limited settings. This study was investigating the potential usage of expired commercial syrup (ECS) as a source of glucose in elephant grass silage production.

METHODS

This study was using materials of elephant grass, expired commercial syrup (ECS) with 30-70 grams of sugar per 100 mL, and distilled water (aquades). The equipments were a laboratory-scale silo with a 1.50 kg capacity, a digital pH meter, and plastic basins. Elephant grass was cut into 3-5 cm pieces and air-dried until its moisture content reached 65%. Subsequently, the grass weighed 1.50 kg, placed in a container, and the appropriate amount of expired commercial syrup was added based on its designated level of use. Distilled water was then added to each sample at 50 mL, followed by thorough mixing until homogeneous. All ensiled materials were then placed into airtight silos for anaerobic fermentation for 30 days, stored away from direct sunlight at a temperature of approximately 27-28°C (Olijhoek *et al*. 2023). Aroma, texture, and color of the silage were assessed through smelling, feeling, and visual examination during harvesting. Evaluation involved 50 untrained panelists, and their scores for each parameter, reflecting the silage characteristics (Table 1).

Silage pH was determined by blending the silage with distilled water at a ratio of 1:9 (w/v) using a blender and subsequent filtration (Bernardes *et al.* 2019). The digital pH meter was then immersed in the sample solution for

Table 1 Scores for each silage criterion

Criteria	Silage characteristic	Panelist score
Aroma	Lacking freshness	1-1.99
	Fresh	2-2.99
	Distinctive anaerobic fermentation scent	3-3.99
Texture	Fine, moist, and clumpy	1-1.99
	Moderate, moist, and slightly clumpy	2-2.99
	Fine and non-clumping	3-3.99
Color	Greenish brown	1-1.99
	Greenish yellow	2-2.99
	Green	3-3.99

Note: Adapted from Hynd (2019) modified by Sadarman *et al.* (2023c).

5 minutes, repeating the process three times (Xie *et al.* 2023a). Fungal growth was visually assessed, and the fungi were subsequently collected and weighed to ascertain the percentage of fungal growth on the top layer of the silo. This percentage was calculated by multiplying the weight of the ensiled material by 100 (Sadarman *et al.* 2023a), with contamination criteria based on the classification by Sofyan *et al.* (2017), ranging from no contamination (0%) to severe contamination (>15%). The dry weight of the sample at 60°C was determined by subtracting the weight after oven-drying at 60°C from the initial weight, then multiplying by 100 (Borreani *et al.* 2017). Dry matter loss was calculated as the difference between the initial dry weight and the weight after storage, divided by the initial weight and multiplied by 100 (McDonald *et al.* 2022). The Fleigh value (FV) was calculated following the equation FV = 220 + [(2 x %DM) - 15] - (40 x pH), where DM represents the dry matter weight of the silage (Kiliç 1984). Silage quality was categorized as excellent (score >85), good (score 60-85), fair (score 55-60), satisfactory (score 25-55), or poor (score <25) (Sofyan *et al.* 2017).

A Completely Randomized Design (CRD) with 5 treatments and 5 replications was utilized. The treatments included: P1: Elephant grass as a control; P2: P1 + ECS 2.50% DM; P3: P1 + ECS 5% DM; P4: P1 + ECS 7.50% DM; and P5: P1 + ECS 10% DM. Data were analyzed using Complete Randomized Design (CRD) analysis of variance as per Petrie & Watson (2013), employing Statistical Package for the Social Sciences (SPSS) version 27.0. Differences between treatments were further assessed using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

The assessment of silage production success relies on objective criteria such as aroma, texture, and color of the final product. High-quality silage is characterized by a distinctive fermented acidity aroma, fine, non-clumping texture, and a color closely resembling the original before ensiling. Panelist ratings for the aroma, texture, and color of elephant grass silage, fermented with the addition of expired commercial syrup (ECS)(Table 2 and Figure 1).

The aroma of silage refers to its distinctive scent resulting from anaerobic fermentation. It can vary depending on the forage type, silage acidity (pH), and volatile compounds generated during anaerobic fermentation in the silo. This study revealed a significant effect (p<0.05) of ECS addition on the aroma of elephant grass silage. Panelists gave ratings for the aroma ranged from 2.94 to 3.75, indicated a pleasant to distinctly fermented aroma. There was no significant difference in aroma between P1 (control) and P2, thus ECS addition at 2.50% DM had a comparable effect on the control. Increasing ECS levels led to elephant grass silage with a distinctly fermented aroma, with panelist ratings ranging from approximately 3.17 to 3.75. This suggested that the high sugar content in ECS could fulfil the energy requirements for microbial activity, thereby maximizing fermentation rates.

Research by Sadarman *et al.* (2023a) found that combining molasses with ECS produces corn stover silage with a pleasant aroma. Sadarman *et al.* (2023b) observed that increased molasses addition correlates with higher panelist scores, averaging around 2.56-3.65, indicating a pleasant to distinctly fermented aroma, including typical fermentation aromas from organic market waste encapsulated using ECS (Sadarman *et al.* 2023c). Differences in silage aroma among treatments from third studies were attributed to the glucose content in ECS and molasses, serving as an energy source for lactic acid bacteria (LAB) growth and reproduction. Consequently, the increased LAB population accelerated fermentation rates, influenced the feedstock silage aroma and ensured high-quality silage production (Xie *et al.* 2023a).

The ensiling process involves preserving feed materials in a compressed and anaerobic environment. This condition allowed lactic acid bacteria (LAB) to produce organic acids that lowered pH and inhibited the growth of detrimental microbes, resulting in high-quality silage that characterized by a smooth, non-clumpy texture. The analysis of variance indicated a significant effect (p<0.05) of adding ECS on the texture of elephant grass silage. Panelists' scores for the texture of elephant grass silage ranged from 2.74 to 3.61 (smooth to fine and non-clumpy).

Table 2 Panelist ratings for aroma, texture, and color of elephant grass silage fermented with ECS

Treatments	Aroma	Criteria	Texture		Color	
P1	2.94±0.02[a]	Good	2.74±0.08[a]	Good	2.72±0.06[a]	Good
P2	3.01±0.08[a]	Very good	2.82±0.06[a]	Good	2.86±0.02[b]	Good
P3	3.17±0.06[b]	Very good	2.95±0.04[b]	Good	2.96±0.04[b]	Good
P4	3.48±0.14[c]	Very good	3.14±0.05[c]	Very good	3.15±0.04[c]	Very Good
P5	3.75±0.07[d]	Very good	3.61±0.11[d]	Very good	3.54±0.19[d]	Very Good

Note: P1 = Elephant grass silage, P2 = P1 + ECS 2.50% DM, P3 = P1 + ECS 5% DM, P4 = P1 + ECS 7.50% DM, P5 = P1 + ECS 10% DM. The data presented represent means ± standard deviation. Different superscripts within the same column indicate statistically significant differences (p <0.05).

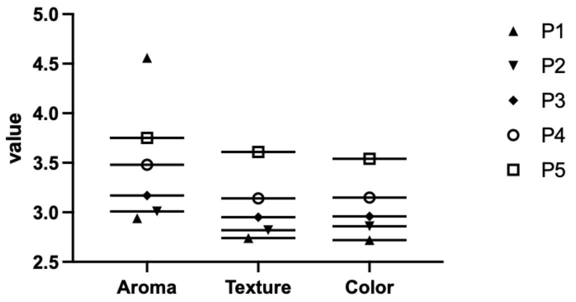

Figure 1 The illustration of panelist ratings for aroma, texture, and color of elephant grass silage fermented with ECS

There was no significant difference in texture of silage in P1 to P2, but different on P3, P4, and P5. The similarity in texture between P1 and P2 gave information that adding ECS at 2.50% DM provided a similar energy contribution to the control. However, increasing ECS levels up to 10% DM resulted in smooth, non-clumpy elephant grass silage. This was attributed to the sugar content in ECS, which can be utilized by beneficial microbes to accelerate fermentation through increased lactic acid production.

According to Sadarman *et al.* (2023a), the combination of molasses and ECS could enhance fermentation rates, resulting in high-quality corn stover silage based on its texture. Sadarman *et al.* (2023 b,c) stated that ECS addition can improve silage texture, making it smooth and reducing the risk of clumping. The result indicated that the sugar content in ECS can enhance silage texture by inhibiting the growth of undesirable microbes, allowing LAB to produce lactic acid optimally. Xie *et al.* (2023a) explained that optimization of lactic acid production leads to the breakdown of cell walls and disruption of plant fiber layers, resulting in smooth-textured silage. According to McDonald *et al.* (2022), high-quality fermentation is characterized by smooth, non-clumpy textured silage at harvest. Xie *et al.* (2023b) added that silage texture can also be influenced by the type of forage, silo conditions, and equipment and materials management before and after anaerobic fermentation.

The coloration of the final silage product served as a preliminary indicator of its condition and overall quality. There were significant effects ($p<0.05$) of adding ECS up to 10% DM on the color of elephant grass silage. Panelists' scores for silage color ranged from approximately 2.72 to 3.54, indicating silage with a greenish yellow to a green color resembling fresh elephant grass. The result showed that level showed that the color of elephant grass silage in P1 differed from P2 to P5. This difference was attributed to the lack of energy sources for beneficial microbes provided by P1. However, with ECS additions ranging from 2.50-10% DM, the color of elephant grass silage approached a fresh green color, indicating that ECS could have a positive effect on the resulting silage color.

Guamán *et al.* (2023) stated that use of molasses dissolved in tap water at concentrations of 20% and 6.50% can improve the anaerobic stability of silage and minimize dry matter (DM) loss. Research by Sadarman *et al.* (2023c) indicated that ECS can alter the color of market organic waste silage. Bakare *et al.* (2023) confirmed that adding high-sugar syrup to fermented organic market waste can change the waste colour due to the increased growth of pigment-producing microbes. The fermentation process altered the pH and triggers chemical reactions that produce coloring compounds like melanoidins (Xie *et al.* 2023b). This color changes was an indicator of active interactions between microorganisms, organic substrates, and fermentation conditions (Handriati *et al.* 2023). McDonald *et al.* (2022) stated that observing silage color helps assess the anaerobic fermentation activity in the silo, detect problems during ensiling, assess nutrient quality, and evaluate silage changes during storage.

According to Moore (2018), the changes in silage color occurred due to the presence of coloring agents, both organic and inorganic, in silage additives such as melanoidins, which impart characteristic colors to molasses, and coloring agents in ECS such as curcumin, riboflavin, carmine, cochineal extract, chlorophyll, caramel, beta-carotene, plant carbon, annatto extract, carotenoids, beetroot, anthocyanins, and titanium dioxide. McDonald *et al.* (2022) stated that the addition of these coloring compounds can mix with other components in the feed material and alter the resulting silage color. Molasses with a high melanoidin content could impart a more intense brown color to silage, while ECS with green coloring enhances the green effect on the feed material. Hynd (2019) stated that chemical reactions like the Maillard reaction between sugar and amino acids that produce melanoidin compounds can also change silage color.

Table 3 Percentage of fungal growth in elephant grass silage ensiled with ECS

Treatments	Fungal growth (%)
P1	2.77±0.02 ^{a}
P2	2.19±0.01 ^{b}
P3	2.03±0.02 ^{c}
P4	1.97±0.01 ^{c}
P5	1.57±0.18 ^{d}

P1= Elephant grass silage, P2= P1+ECS 2.50% DM, P3= P1+ECS 5% DM, P4= P1+ECS 7.50% DM, P5= P1+ECS 10% DM. The data presented represents the mean values ± standard deviation. Different superscripts in the same column indicate statistically significant differences ($p<0.05$).

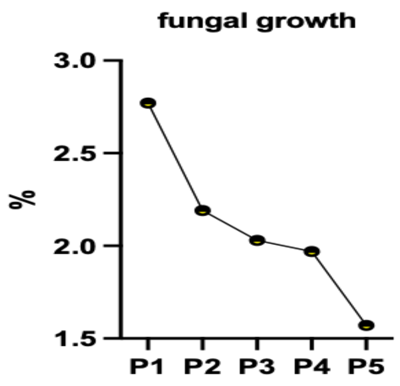

Figure 2 The influence of ensiled ECS on the percentage of fungal growth in elephant grass

Changes in fermentation conditions, such as increased lactic acid production or pH changes, could also influence the resulting silage color (Bakare *et al.* 2023). Preventing the proliferation of detrimental microorganisms during silage preparation was essential for ensuring high-quality silage. This was done to ensure that the produced silage is of good quality. The percentage of fungal growth in elephant grass silage could be observed in Table 3 and Figure 2.

There were significant decreases ($p<0.05$) in the percentage of fungal growth in the silage. Table 2 confirmed that the addition of ECS in P2, P3, P4, and P5 resulted in silage with significantly less fungal growth compared to P1. Fungal growth in elephant grass silage ranged from 1.57% to 2.19% (minimal fungal growth), which was lower than P1 at 2.77% (moderate). This showed that the glucose content in ECS can effectively inhibit fungal growth by accelerating the fermentation process, leading to silage with a pH tending towards acidity. Dryden (2021) notes that fungi typically thrive in conditions with a pH approaching neutral to alkaline (>7), while excessive fungal growth is often associated with excessively high moisture content in the ensiled material, resulting in silage with a putrid aroma or poor quality. McDonald *et al.* (2022) emphasize that optimal silage moisture content falls within the range of 65-70% for quality silage fermentation.

Quality fermentation is characterized by a surface free from mold (Liu *et al.* 2024a). McDonald *et al.* (2022) further explain that fungal growth in silage is primarily triggered by inadequate airtight conditions, allowing fungi to thrive aerobically and colonize the silage surface. Zang *et al.* (2023) suggests that high-quality silage should be devoid of any mold presence, with fungal growth often initiated by silo leaks, so efforts are needed to improve management practices during ensilage to minimize such occurrences (Adnane *et al.* 2024).

Xie *et al.* (2023) underscores the importance of management improvements in silage-making processes, such as using high-quality ensiled materials, ensuring silo integrity, and adjusting material moisture levels according to established standards. Minimal fungal growth in the silo results from the absence of oxygen, allowing only anaerobic bacteria to facilitate the ensiling process (Villa *et al.* 2020). Efforts to curtail fungal proliferation in silage are crucial for yielding high-quality silage with minimal dry matter losses, consistent with Bartosik *et al.* (2023) assertion that superior silage is devoid of mold and excessive moisture, exhibits acidity, high dry matter content, and low dry matter losses, thereby optimizing the fleigh value of the silage.

Chemical quality assessments of silage serve as pivotal indicators for gauging silage quality. Desirable silage exhibits pH levels nearing acidity, optimal dry matter content, minimal dry matter losses, and an optimal fermentation efficiency or fleigh value. The pH, DM, DML, and fleigh value of elephant grass silage were presented in Table 4 and Figure 3.

The analysis revealed a significant effect ($p<0.05$) of adding ECS up to 10% DM on the pH of elephant grass silage. Table 4 showed that adding ECS in P2, P3, P4, and P5 resulted in silage with lower pH compared to P1, with average pH values ranging from 3.24-3.75, notably lower than the control with a pH of 4.56. This pH reduction towards acidity is attributed to the presence of ECS carbohydrates, providing ample nutrition for microbes to grow and proliferate rapidly.

Table 4 pH, DM, DML, and fleigh value of elephant grass silage fermented with ECS

Treatments	pH	DM (%)	DML (%)	FV (%)
P1	4.56±0.02 ^{a}	25.6±0.59 ^{a}	6.28±0.96 ^{a}	73.7±0.90 ^{a}
P2	3.75±0.15 ^{b}	27.1±0.59 ^{b}	5.77±0.02 ^{b}	109±6.31 ^{a}
P3	3.52±0.04 ^{c}	29.1±0.23 ^{c}	4.66±0.05 ^{c}	122±1.56 ^{c}
P4	3.36±0.01 ^{d}	30.4±0.67 ^{d}	3.57±0.55 ^{d}	131±1.11 ^{d}
P5	3.24±0.01 ^{e}	31.4±0.53 ^{e}	2.27±0.02 ^{e}	138±1.23 ^{e}

P1= Elephant grass silage, P2= P1+ ECS 2.50% DM, P3= P1+ ECS 5% DM, P4= P1+ ECS 7.50% DM, P5= P1+ECS 10% DM. DM: dry matter; DML: dry matter losses; FV: fleigh value. The data presented are means ± standard deviations. Different superscripts in the same column indicate significant differences ($p<0.05$).

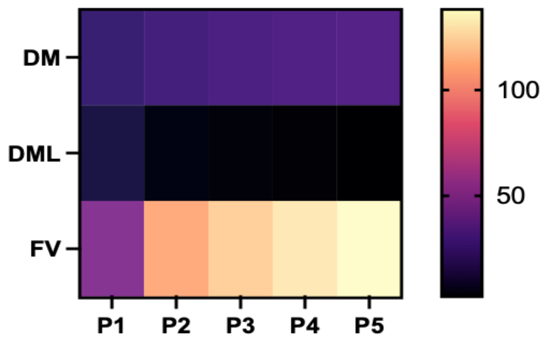

Figure 3 The heat map of percentage of dry matter, dry matter losses, and fleigh value in elephant grass silage

According to McDonald *et al*. (2022), additives can stimulate the growth and proliferation of lactic acid bacteria (LAB), predominant bacteria capable of lowering silage pH to 5 up to 3.80. Irawan *et al*. (2021) further explains that LAB absorbs carbohydrates and repeatedly ferments them to produce lactic acid, which is a byproduct of carbohydrate metabolism aiding in energy conversion (Xie *et al*. 2023b). The core principle of silage making involves fostering anaerobic conditions and an acidic environment inside the silo within a short duration (Esen *et al*. 2024). Achieving this necessitates promptly removing air, producing lactic acid to lower pH, preventing oxygen ingress, and inhibiting mold growth during storage (Ogunade *et al*. 2018).

Adding ECS in this study provided sufficient carbohydrates for LAB, accelerating their growth and proliferation. Consequently, anaerobic fermentation processes proceeded more swiftly, evidenced by the pH decline towards acidity. Xie *et al.* (2023) noted that silage pH could be influenced by ensiled material quality and silo damage, marked by mold growth, which could be affected silage dry matter content.

Silage dry matter (DM) refers to the total solid content remaining after water removal from the ensiled feed. The analysis indicated a significant effect ($p<0.05$) of adding ECS on the dry matter content of elephant grass silage. The study showed increased dry matter content with higher ECS levels. In Table 4 indicated P1 had a lower DM content (25.6%) ($p<0.05$) distinguishing it from other treatments. The highest DM content was in P5 (31.4%), indicating that adding 10% ECS DM produced elephant grass silage with optimal dry matter content.

Increasing the ECS dose is effective in maintaining dry matter (DM) and reducing dry matter loss (DML) because ECS provides readily fermentable sugars that enhance lactic acid bacteria activity, leading to rapid pH reduction, and improved silage preservation. This accelerated acidification inhibits spoilage microbes, minimizes nutrient degradation, and balances moisture content, resulting in better DM retention and lower DML (McDonald *et al.,* 2022).

Research by Sadarman *et al*. (2023b) reportes that molasses addition can enhance elephant grass silage dry matter content, given molasses' high sugar content, similar to ECS. Thus, ECS use in this study positively affected elephant grass silage dry matter content. Xie *et al*. (2023) noted that silage dry matter content can vary based on feed type, feed damage during ensiling, and feed handling management before and after ensiling. Sadarman *et al.* (2023a) highlighted that high dry matter content indicates lower dry matter loss in resulting silage.

The quality of silage could be estimated by its dry matter loss rate. The analysis revealed a significant effect ($p<0.05$) of adding ECS up to 10% DM on the dry matter loss of elephant grass silage. Table 4 showed that adding ECS in P2, P3, P4, and P5 resulted in elephant grass silage with lower dry matter loss compared to P1. The average dry matter loss in this study ranged from 2.77% - 6.28%. The minimal dry matter loss in treatments supplemented with ECS is attributed to the glucose content in ECS, which fulfills microbial requirements during ensiling.

According to Sadarman *et al.* (2022; 2023a), adding ECS up to 10% DM could reduce dry matter loss in elephant grass silage with or without the addition of fresh tofu pulp. Xie *et al.* (2023b) stated that materials with high glucose content can be fermented to produce organic acids. Highlighted the importance of organic acid production in silage, such as extending silage shelf life initiated by high lactic acid production (Ahmadi *et al*. 2019), preserving nutrient content stability through inhibiting enzymes damaging nutrient content (Xie *et al*. 2023b), aiding in feed digestibility by breaking cell walls and damaging plant fiber layers (Liu *et al*. 2024), and enhancing digestibility through improving silage aroma, thus favored by livestock (Liu *et al*. 2023).

The final silage color offered a preliminary indication of its condition and quality, a more comprehensive evaluation necessitates further analyses. Recent research suggested a promising avenue for exploration: the application of high-glucose products (e.g., commercial syrup residues) as fermentation stimulants during elephant grass ensiling (Bai *et al*. 2022; Sadarman *et al.* 2023). These additives could potentially lead to several beneficial outcomes, including lower silage pH (Sadarman *et al.* 2023), increased levels of soluble carbohydrates (McDonald *et al.* 2022), and enhanced lactic acid production (Irawan *et al*. 2021). This translates to reduced dry matter loss, a critical factor for optimal silage quality. According to McDonald *et al.* (2022), the ideal dry matter content for ensiled feed falls within the range of 30% - 40%. Therefore, investigating high-glucose additives presented a potentially sustainable approach to optimizing silage production, improving its nutritional value, and minimizing dry matter losses.

The fleigh value or fermentation efficiency value represented the level of fermentation efficiency during silage making. This value could be used as a measure to evaluate how digestible and available the nutrients in the feed or silage are after ensiling. The analysis showed that the fleigh value of elephant grass silage can be influenced ($p<0.05$) by adding ECS. The fermentation efficiency value in this study increased with increasing levels of ECS supplementation. FV in P1 (73.7) was lower than treatments P2 to P5, which added ECS at 2.50-10% DM, respectively. The increase in FV in this study was attributed to the sugar content in ECS, supporting LAB to produce lactic acid, thus resulting in a rapid pH decrease. An acidic silo condition could suppress detrimental microbial growth, minimizing dry matter loss, that optimize silage FV.

Sofyan *et al*. (2017) stated that using Lactobacillus plantarum-Saccharomyces cerevisiae and adding rice bran can produce king grass silage with optimal FV. The fleigh value of king grass silage in this study ranged from 76.9-81.4, categorizing it as high-quality silage. Research by Sadarman *et al*. (2023b) stated that using molasses to ensile elephant grass can increase the FV of the resulting silage, with FV ranging around 73.7-138. According to Kiliç (1984), the higher the fleigh value would increase the fermentation efficiency and nutrient changes in silage, overall indicated that the ensiling process successfully converts feed into silage with minimal nutrient loss, thus producing high-quality silage.

According to Ozturk *et al*. (2006), the fleigh value was obtained through calculation using the FV equation $= 220 + [(2 \times \%DM) - 15] - (40 \times pH)$, meaning to obtain an optimal fleigh value, a high DM content and a pH approaching acidity are required. McDonald *et al*. (2022) stated that high-quality silage was characterized by a pH not exceeding 4.50 with a DM content of around 35-40%. Kiliç (1984) mentioned that good silage fleigh values could be achieved by controlling critical factors in the ensiling process, such as optimal DM content, appropriate pH, good silo density, tight packing, and effective preservation.

CONCLUSION

The commercial syrup residue had potential as a silage additive for elephant grass at levels up to 10% of dry matter. Its use supported the goal of improving silage quality. Further research is needed to evaluate its effect on fermentation characteristics, such as ammonia levels, total volatile fatty acids, and in vitro digestibility.

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