Accredited by Kemendikbudristek Dirjendiktiristek No 225/E/KPT/2022. E-ISSN 2541-5875

The Quality of Organic Waste Market Ensiled Using Rejected Commercial Syrup as An Alternative Ruminant Livestock Feed

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Abstract. Organic Waste Market (OWM) refers to the residual organic matter generated from market trading, including leftover vegetables, fruits, and other organic food items. If not managed properly, this waste can pose environmental issues due to potential decomposition and the emission of unpleasant odours. However, when managed appropriately, it can serve as an alternative feed for livestock. This research aims to assess the quality of OWM silage using rejected commercial syrup (RCS) as a silage additive. The entire process, including production, harvesting, drying, and ensiling, took place at the Laboratory of Nutrition and Feed Technology, Faculty of Agriculture and Animal Science, Universitas Islam Negeri Sultan Syarif Kasim Riau, while the fermentation quality test is conducted at the Dairy Cattle Laboratory, Faculty of Animal Science, IPB University Bogor. The experimental design utilized a Completely Randomized Design with five treatments and five repetitions. The control treatment (P1) consisted of a combination of spinach (33.3%), cabbage (33.3%), and water spinach (33.3%). For treatments P2, P3, P4, and P5, RCS was added at 1%, 2%, 3%, and 4%, respectively, based on dry matter. Subsequently, ensilage occurred for 30 days at room temperature. Measured parameters included silage physical quality, temperature, humidity, mold growth, silage fermentation quality, as well as dry matter loss and Fleigh silage value. Data were analyzed using analysis of variance, and the difference in parameter values between treatments was further examined with a DMRT at a 5% significance level. The results showed that the use of RCS had a significant effect ($P<0.05$) on texture, colour, temperature, humidity, mold growth, pH, ammonia, total VFA, dry matter loss, and silage Fleigh value, while silage smell was not influenced by the addition of RCS ($P>0.05$). The use of RCS can produce silage with a range of respondents' values for smell 2.64-2.98 (fresh), texture 2.79-3.85 (Moderately slightly clumping- Smooth non-clumping), color 2.97-3.73 (Greenish to Green). Silage temperature at harvest 29.7-30.3°C, humidity 70.3-83.7%, average mushroom growth 2.35-3.40%, silage pH 3.34-4.49 according to good quality silage pH standard; ammonia 3.47-5.04 mM, total VFA 54.1-72.3 mM, dry matter loss 10.5-14.3%, and Fleigh value 54-95. Conclusion: the addition of RCS can improve the silage quality of the organic waste market by optimizing temperature, humidity, pH, mold growth, ammonia, total VFA, and Fleigh value so that dry matter loss can be minimized.

Keywords: Anaerobic fermentation, fungal growth, OWM, Quality of silage, RCS.

Abstrak. Limbah organik pasar (LOP) adalah residu organik yang dihasilkan dari kegiatan perdagangan pasar seperti sisa sayuran, buah, dan bahan makanan organik lainnya. Limbah ini dapat menjadi sumber masalah lingkungan jika tidak dikelola dengan baik karena dapat membusuk dan menimbulkan bau tidak sedap. Namun, jika dikelola dengan baik, residu organik tersebut dapat digunakan sebagai pakan alternatif bagi ternak. Penelitian ini bertujuan untuk mengevaluasi kualitas silase limbah organik pasar menggunakan sirup komersial afkir (SKA) sebagai aditif silase. Pembuatan, pemanenan, pengeringan, dan penyilasean dilakukan di Laboratorium Nutrisi dan Teknologi Pakan, Fakultas Pertanian dan Peternakan, Universitas Islam Negeri Sultan Syarif Kasim Riau, sedangkan uji kualitas fermentasi dilakukan di Laboratorium Ternak Perah Fakultas Peternakan IPB University Bogor. Metode eksperimen dengan Rancangan Acak Lengkap terdiri atas 5 perlakuan dan lima ulangan. Perlakuan P1 terdiri dari bayam 33,3% + kol 33,3% + kangkung 33,3% sebagai kontrol. Untuk P2, P3, P4, dan P5, SKA ditambahkan masing-masing sebanyak 1%, 2%, 3%, dan 4%, berdasarkan bahan kering, kemudian diensilase selama 30 hari pada suhu ruang. Parameter yang diukur meliputi kualitas fisik silase, suhu, kelembaban, pertumbuhan jamur, kualitas fermentasi silase, serta kehilangan bahan kering dan nilai *Fleigh* silase. Data dianalisis menggunakan analisis ragam, dan perbedaan nilai parameter antar perlakuan diuji lebih lanjut dengan DMRT pada taraf signifikansi 5%. Hasil analisis ragam menunjukkan bahwa penggunaan SKA memberikan pengaruh yang signifikan (P<0,05) terhadap tekstur, warna, suhu, kelembaban, pertumbuhan jamur, pH, amonia, total VFA, kehilangan bahan kering, dan nilai *Fleigh* silase, sedangkan aroma silase tidak dipengaruhi oleh penambahan sirup afkir (P>0,05). Penggunaan sirup afkir dapat menghasilkan silase dengan rentang nilai responden untuk aroma 2,64-2,98 (fresh), tekstur 2,79-3,85 (Moderately slightly clumping- Smooth non-clumping), colour 2,97-3,73 (Greenish to Green). Suhu silase pada saat dipanen 29,7-30,3°C, kelembaban 70,3-83,7%, pertumbuhan jamur rata-rata 2,35-3,40%, pH silase 3,34-4,49 sesuai stardar pH silase berkualitas baik; amonia 3,47-5,04 mM, total VFA 54,1-72,3 mM, kehilangan bahan kering 10,5-14,3%, dan nilai *Fleigh* 54-95. Kesimpulan: penambahan SKA dapat meningkatkan kualitas silase limbah organik pasar dengan mengoptimalkan suhu, kelembaban, pH, pertumbuhan jamur, amonia, total VFA, dan nilai *Fleigh* sehingga kehilangan bahan kering dapat diminimalkan.

Kata kunci: Fermentasi anaerob, kualitas silase, limbah organik pasar, pertumbuhan jamur, SKA.

Introduction

Department of Environment and Sanitation of Pekanbaru City (2021) presented data obtained from the National Waste Management Information System (NWMIS) stating that in 2019, the amount of waste generated by the residents of Pekanbaru City was 378,324.91 tons, with daily waste generation of 1,036.51 tons. Meanwhile, in 2020, there was an increase in waste generation to 400,461.54 tons, with a daily waste generation of 1,097.15 tons. The waste generation for Pekanbaru City in 2021 was 323,032.45 tons, with a daily generation of 885.02 tons, resulting in the accumulation of both inorganic and organic waste.

Improperly processed vegetable waste can lead to various problems, ranging from environmental issues like unpleasant odors, wastage of resources related to production efficiency that can reduce profits for farmers, health problems due to the proliferation of microbial pathogens that can harm livestock and consumers consuming animal products, as well as the loss of potential nutrients contained in the vegetable waste (Baruna et al. 2021). Dariati et al. (2017) stated that to address the issue of abundant vegetable waste production, it is important to implement sustainable waste management practices. This includes waste reduction through production control and inventory management, converting waste into valuable resources such as compost or bioenergy, developing sustainable farming practices to minimize resource waste, and optimizing the use of vegetable waste as feed for ruminant livestock by processing it through ensilage processes (Kondo et al., 2016).

Ensilage is the process of preserving forage materials, including agricultural and plantation biomass, through anaerobic fermentation (Dryden, 2021; McDonald et al., 2022). According to Collins and Moore (2018), in the ensilage process, fresh forage materials like grass, corn, straw, or sorghum are chopped into small pieces and then placed into an airtight storage container, such as a silo. Borreani et al. (2017) state that the feed materials undergo anaerobic fermentation by microorganisms, especially lactic acid bacteria, inside the silo. During this anaerobic fermentation, lactic acid microorganisms convert carbohydrates in the feed materials into organic acids, primarily lactic acid. According to McDonald et al. (2022), this process creates an acidic environment with a low pH, which prevents the growth of harmful microorganisms and the spoilage of ensiled feed materials, thus helping to preserve the nutritional quality of the feed materials.

Moore (2018) outlines the benefits of feed ensilage. First, ensilage enables the utilization of forage materials that cannot be directly consumed by livestock, turning them into easily digestible and highly nutritious feed. The ensilage process improves the digestibility of crude fiber in feed materials, allowing animals to digest nutrients more efficiently. Second, ensilage allows for longer-term storage of animal feed, making it a year-round feed source, especially when the supply of fresh forage is limited. Third, ensilage can enhance feed stability, reduce nutrient loss during storage and transportation, and mitigate the risk of contamination by harmful microorganisms (Hynd, 2019). According to Irawan et al. (2021), ensilage is commonly used in animal husbandry as an effective and practical method of preserving forage feed, enabling farmers to have a consistent supply of high-quality feed available throughout the year. Sadarman et al. (2020) suggest that the ensilage process can be accelerated by providing a suitable energy source for beneficial microorganisms, and one such energy source is rejected commercial syrup (RCS) (Sadarman et al., 2023).

RCS can be used as a preservative in the ensilage process (Sadarman et al., 2023a,b). The additive contains organic acids and sugars that are essential for lactic acid bacteria to ferment feed materials (Sutrisno et al., 2018). According to Wu (2017), organic acids and sugars play a crucial role in the ensilage process within the silo. Organic acids, such as lactic acid, can convert sugars in the feed into lactic acid. Lactic acid plays a vital role in lowering the pH of the silage to an acidic level that inhibits the growth of harmful microorganisms like pathogenic bacteria and fungi. Additionally, acetic acid can contribute to preserving silage by hindering the growth of harmful microorganisms through its impact on enzyme activity within the silage. As a result, these organic acids help maintain nutrient stability within the silage. According to McDonald et al. (2022), alongside organic acids, sugars present in the feed materials serve as an energy source for microorganisms involved in anaerobic fermentation. Microorganisms, especially lactic acid bacteria, consume the sugars in the forage materials and convert them into organic acids, such as lactic acid.

Research related to the processing of organic waste market (OWM) into animal feed has been reported by Superianto et al. (2018). They found that providing a substrate of 35% rice bran from vegetable waste can increase the content of dry matter, crude fiber, crude fat, and ash, but the content of crude protein and NNFE (Non-Nitrogen Free Extract) decreases. Falahudin and Imanudin (2018) stated feeding 60% forage and 40% vegetable waste silage resulted in a dry matter consumption of 720 g/head/day, followed by an increase in daily weight gain of about 88.2 g/head/day. Muktiani et al. (2013) utilized vegetable waste silage supplemented with alginate minerals in sheep diets, and results improved feed conversion and efficiency, as indicated by increased sheep body weight gain.

Up to this point, the utilization of RCS for the ensilage Organic Waste Market (OWM) has not been published, so this research is aimed at evaluating the quality of ensiled organic market waste using leftover commercial syrup in terms of temperature, humidity, fungal growth, and silage pH of potentially utilize it as animal feed.

Materials and Methods

Research location

The production, harvesting, pH testing, and physical quality testing were conducted at the Nutrition and Feed Technology Laboratory of the Faculty of Agriculture and Animal Science, Universitas Islam Negeri Sultan Syarif Kasim Riau, while the fermentation quality test is conducted at the Dairy Cattle Laboratory, Faculty of Animal Science, IPB University Bogor.

Research materials

Research material involved organic market waste, which comprised water spinach, spinach, and cabbage. Other materials used included rejected commercial syrup (RCS) and distilled water. The equipment employed included silage-making tools like a silo, as well as instruments for measuring variables related to temperature, pH, and silage quality.

Table 1. Score values of vegetable market waste silage criteria

Criteria	Silage Characteristics	Score
Smell	Not fresh	1-1,99
	Fresh	2-2,99
	Distinct aroma of silage	3-3,99
Texture	Fine clumping	1-1,99
	Moderately slightly clumping	2-2,99
	Smooth non-clumping	3-3,99
Colour	Brownish green	1-1,99
	Greenish	2-2,99
	Green	3-3,99

Source: Hynd (2019) modified by Sadarman et al. (2023)

Research Designs

This study employed an experimental method using a Completely Randomized Design with 5 treatments and 5 replications. The treatments involved the addition of RCS in the production of organic market waste silage. The treatments were as follows: P1: Spinach 33.3% + Cabbage 33.3% + Water spinach 33.3% (control), P2: P1 + 1% RCS based on dry matter (DM), P3: P1 + 2% RCS based on DM, P4: P1 + 3% RSC based on DM, and P5: P1 + 4% RSC based on DM.

Research Procedure

Water spinach, spinach, and cabbage were cut into small pieces with 1 to 3 cm size. They were wilted until the moisture content reached 65%. A 350 g was placed into a 15 L plastic container added 50 mL of diluted RCS for each treatment. The mixture was thoroughly stirred until it was uniform and homogeneous. All silage materials were placed into white plastic silos for anaerobic fermentation. After 30 days, the silos were opened, and their quality was analyzed.

Measured variables

The physical quality of the silage was assessed by observing 60 untrained respondents which had no impairments in vision, smell, or touch (Sadarman et al., 2023b). The observation scores are presented in Table 1.

Temperature measurements were conducted by inserting a cleaned thermometer with tissue into the silo, covering it with cloth for 1 minute (Sadarman et al., 2023b), and then recording the temperature indicated by the thermometer. Humidity was measured by subtracting the dry weight of the silage from the wet weight, dividing the result by the wet weight, and then multiple with 100% (Moore, 2018). Fungal growth was observed, and the fungi were weighed to determine the percentage of fungal growth on the top of the silo, calculated by multiplying the weight of the ensiled material by 100% (Sadarman et al., 2023b). The acidity of the silage was measured by blending the silage with distilled water in a 1:9 (w/v) ratio using a blender, then immersing a digital pH meter into the sample solution for 5 minutes and repeating the process three times (Bernardes et al., 2019). The total VFA concentration was measured using the steam distillation method (Krooman, 1967), with the formula as follows: Total VFA = (mL titrant blank – mL titrant sample) x N HCl x (1000/5)) mM. The NH_3 concentration was measured using the microdiffusion Conway technique (1940), with the calculation formula as follows: Total NH_3 = (mL titrant x N H_2SO_4 x (1000/1)) mM. The value of dry matter loss is calculated based on the difference between the dry matter of OWM before ensiling and the dry matter of OWM after ensiling for 30 days. The Fleigh value (NF) for OWM silage was determined using the formula by Kiliç (1984): NF = 220 + [(2 x %DM) - 15] – (40 x pH), where %DM represents the silage's dry matter content. Silage quality is classified as excellent when the value is greater than 80, good when it falls between 60-80, and poor when it is less than 60.

Table 2. Physical quality of organic waste market silage

Treatments	Smell	Texture	Colour
P1: organic waste market (control)	2.64±0.46	2.79a±0.40	2.97a±0.03
P2: P1 + RSC 1% DM	2.69±0.06	3.49b±0.14	3.15a±0.01
P3: P1 + RSC 2% DM	2.76±0.02	3.59b±0.12	3.42b±0.12
P4: P1 + RSC 3% DM	2.79±0.01	3.72c±0.13	3.63c±0.06
P5: P1 + RSC 4% DM	2.98±0.14	3.85c±0.11	3.73c±0.31

DM: Dry Matter. The presented data are mean values ± standard deviation. Different superscripts in the same column indicate significant differences (P<0.05) in silage aroma, texture, and color among treatments

Data analysis

The data was processed using the Statistical Package for the Social Sciences (SPSS) version 26.0. If significant differences were found through analysis of variance, further testing was conducted using Duncan's Multiple Range Test (DMRT) at a 5% significance level (Petrie and Watson, 2013).

Results and Discussion

The Physical Quality of Organic Waste Market (OWM) Silage

The physical quality of Organic Waste Market (OWM) silage can be assessed based on smell, fungal growth, texture, and colour. The panellist scores for each variable are presented in Table 2.

The Smell of Organic Waste Market Silage

The quality of silage can be identified by its smell, colour, and consistency. Good forage has an aromatic scent without the presence of unpleasant odors such as butyric acid, vinegar, or other undesirable smells. Generally, the smell of silage is acidic due to the fermentation process. The addition of rejected commercial syrup (RCS) in treatments P2, P3, P4, and P5 resulted in silage with the same smell as in P1 (Table 2). Based on the organoleptic test results for OWM silage, the distinct smell of silage/slightly acidic was evident in treatments P2, P3, P4, and P5, while treatment P1 showed slightly higher results, indicating a slightly distinct silage/slightly acidic aroma. The addition of rejected commercial syrup (RCS) during the production of OWM silage led to a change in smell towards a more acidic profile (Table 2). This is supported by the pH measurements (Table 5), which decreased with the addition of RCS in OWM silage production. The trend of increasing acidity in aroma aligns with the decreasing pH of the silage. The addition of RCS as an additive is intended to improve the nutritional composition of silage, reduce storage losses, limit fermentation losses by controlling the level of fermentation, and extend the shelf life of silage (enhancing aerobic stability) (Yitbarek and Tamir, 2014). Treatments with RCS supplementation exhibit the distinct smell of silage, signifying a successful ensilage process. This is evident through the alteration of smell, where the produced aromas in each treatment approach the typical silage or slightly acidic aroma.

Texture of Organic Waste Market (OWM)

High-quality silage is characterized by a texture that is smooth and non-clumpy. The addition of rejected commercial syrup (RCS) results in good-quality OWM silage. The textures of silage produced with varying levels of rejected commercial syrup (RCS) supplementation show scores ranging from 2.79 to 3.85, indicating a slightly soft to firm texture. Generally, the textures produced during OWM silage production are relatively similar, showing no significant impact and can be categorized as well-made complete silage. According to various reports, good silage has clear textures resembling natural solid materials and has a natural green color (Siregar, 1996).

Factors that contribute to a smooth and non-clumpy silage texture include sufficient energy sources for lactic acid bacteria, moisture content, and the material itself. The research by Sadarman et al. (2022) mentions that the addition of leftover commercial syrup can result in smooth and non-clumpy silage made from elephant grass and fresh tofu residue. This is due to the sugar content in the commercial syrup that lactic acid bacteria can utilize as an energy source to accelerate the ensilage process. Similarly to molasses, rejected commercial syrup is an additive for silage that contains high glucose content, allowing its use in this study to produce smooth and non-clumpy OWM silage. According to Dryden (2021), smooth-textured silage is achieved from materials rich in carbohydrate content or soluble sugars dissolved in water.

Colour of Organic Waste Market (OWM)

The color of silage can provide insight into the processes occurring within the silo during ensilage. Statistical test results indicate an influence of the base material Organic Waste Market (OWM) used in silage production on the color of the resulting silage ($P<0.05$). The average color scores from panellists range from approximately 2.97 to 3.73, depicting silage with a light brownish-green to dark brownish-green color after 30 days of fermentation. The production of complete silage also affects the color characteristics of the silage. Generally, the use of natural grass, sorghum, and king grass results in relatively high color quality. According to Wati et al. (2018), a bright green or greenish-brown color is considered normal for silage derived from grasses. The produced silage, based on its color, is of good quality due to its brownish-green color. On the other hand, abnormal silage color is dark due to prolonged respiration caused by the ingress of oxygen, leading to non-anaerobic fermentation. Prolonged respiration is usually caused by trapped oxygen within the silo. As a result, the temperature within the silo increases due to the breakdown of carboxylates and proteins (Utomo et al., 2013). When respiration extends, the silo temperature rises, leading to the deterioration of silage color (McDonald, 1991). The research by Sadarman et al. (2022) highlights that the sugar content in rejected commercial syrup can support microbial activity, accelerating the fermentation rate, leading to a faster ensilage process, and resulting in dark green silage to match the color of the used rejected commercial syrup as a stimulant additive.

Temperature and Humidity of Organic Waste Market (OWM)

The temperature of silage during harvesting can vary depending on several factors, including the type of plants used for silage, weather conditions during harvesting & the silage storage method employed. Temperature and humidity for (OWM) silage can be seen in Table 3.

The analysis of variance in Table 3 indicates that the addition of rejected commercial syrup (RCS) has a significant effect ($P < 0.05$) on the temperature of OWM-based silage. The average silage temperature at harvesting time ranges from approximately 30.3 to 29.7°C. The Duncan's Multiple Range Test (DMRT) at 5% significance level demonstrates that the silage temperature in P1 is not different from P2 and P3 but differs from P4 and P5. This is due to the sugar content in RCS in P2 and P3 being relatively similar to P1 (control), which can slow down the temperature increase during the initial fermentation. The temperature in P4 is not different from P5, but the silage temperature in both treatments tends to decrease compared to P1, P2, and P3. The trend of temperature decrease in P4 and P5 is attributed to the sugar in RCS providing an additional energy source for microbes involved in fermentation, thus reducing the heat production during the ensilage process. Consequently, the silage temperature can be better controlled and does not significantly rise.

Table 3. Temperature and Humidity of Organic Waste Market (OWM)

Treatments	Silage Temperature (°C)	Silage Humidity (%)
P1: organic waste market (control)	30.3a±0.10	83.7a±0.10
P2: P1 + RCS 1% DM	30.2a±0.13	81.8b±0.13
P3: P1 + RCS 2% DM	30.2a±0.08	76.1c±0.08
P4: P1 + RCS 3% DM	29.8b±0.54	73.2d±0.54
P5: P1 + RCS 4% DM	29.7b±0.42	70.3e±0.42

DM: Dry Matter. The presented data are mean values ± standard deviation. Different superscripts in the same column indicate significant differences (P<0.05) in silage temperature and humidity among treatments

The findings from the study by Sadarman et al. (2022) indicate that the addition of RCS did not have a significant effect on the temperature of elephant grass and fresh tofu residue silage, with average silage temperatures ranging from 28.7 to 29.6°C. This suggests that the addition of RCS resulted in relatively similar silage temperatures for elephant grass and fresh tofu residue, and these temperatures remained within the favourable silage temperature range of 25-37°C (Okine et al., 2005). According to McDonald et al. (2022), the silage temperature at harvesting can provide insights into the initial fermentation activity within the silo. However, it does not provide a complete picture of overall silage quality or success. Dryden (2021) explains that factors contributing to changes in silage temperature include the size of the silo used, the density of the ensiled feed material, and the humidity within the silo during ensilage.

The moisture content within the silo during the ensilage process of feed materials refers to the water content or relative humidity in silo when the plant material is chopped and stored as silage. This moisture content plays a crucial role in the success of ensilage and the quality of the resulting silage. Moisture data for OWM silage can be observed in Table 3. The analysis of variance indicates that the addition of RCS has a significant effect ($P < 0.05$) on the moisture content of OWM silage. The produced silage in this study has an average moisture content ranging from 70.3% to 83.7%, which tends to decrease with increasing levels of RCS usage. DMRT at 5% significance level confirms that the moisture content of silage differs between treatments.

Hynd (2019) state the appropriate moisture content in ensiled forage is crucial to microbial activities during anaerobic fermentation. Optimal moisture facilitates the growth of fermentative microbes, such as LAB, which are responsible for the fermentation and preservation of the feed material into silage. Improper moisture levels can hinder or disrupt microbial activities, potentially leading to a decline in silage quality.

The use of RCS up to 10% of DM can result in silage with optimal pH values and reduced fungal growth, thereby minimizing dry matter losses (Sadarman et al., 2022). McDonald et al. (2022) state minimal fungal growth in silage is initiated by silo conditions with optimal humidity levels. Dryden (2021) state grass ensilage, a humidity level of around 60-70% is considered ideal, while for corn ensilage, a humidity level of around 65-70% is considered optimal. Achieving the optimal humidity value within the silo is supported by selecting appropriate feed materials for ensilage, measuring feed material humidity before ensilage, ensuring uniform chopping of feed material and controlling water additions to avoid excessive humidity On the other hand, Hynd (2019) states that excessively low humidity can inhibit the activity of microbes necessary for effective silage fermentation. This can disrupt the optimal fermentation process and result in poor-quality silage due to its fungal.

Table 4. Fungal Growth in Organic Waste Market (OWM)

Treatments	Fungi in Silage (%)
P1: organic waste market (control)	3.40a±0.04
P2: P1 + RCS 1% DM	3.11b±0.04
P3: P1 + RCS 2% DM	2.93c±0.05
P4: P1 + RCS 3% DM	2.53d±0.06
P5: P1 + RCS 4% DM	2.35e±0.09

DM: Dry Matter. The presented data are mean values ± standard deviation. Different superscripts in the same column indicate significant differences (P<0.05) fungi in silage among treatments.

Fungal Growth in Organic Waste Market

Fungal growth in silage can be detrimental issue due to fungi can produce potentially toxic metabolic products & can pose a threat to health of livestock consuming silage. Fungal growth percentage of silage can be observed in Table 4.

The analysis of variance in Table 4 indicates that the use of RCS for ensilaging OWM significantly affects ($P < 0.05$) the percentage of fungal growth in silage observed at harvest. The average fungal growth in OWM silage is approximately 2.35-3.40%. The DMRT 5% test explains that the fungal growth in P1 is greater than in P2, P3, P4, and P5, distinguishing it from other treatments. The addition of RCS up to 4% of DM can minimize fungal growth in OWM silage. This is due to the role of RCS's sugars in providing a source of energy for beneficial microorganisms, thus reducing the activity of pathogenic microorganisms, including fungi. In contrast, OWM, as in P1, is vegetable waste with low sugar content, resulting in relatively high fungal growth in that treatment

The addition of rejected commercial syrups supports the activity of beneficial microorganisms, thereby minimizing fungal growth through the mechanism of increased lactic acid production (Sadarman et al., 2022; 2023 a, b). According to McDonald et al. (2022), high lactic acid production can contribute to lowering the pH of the silage towards acidity. This decrease in pH has a negative impact on the growth and development of unfavourable microorganisms, including fungi, that can produce toxins. Consequently, livestock consuming silage with extensive fungal growth can have their health affected due to the presence of these toxins.

Fungal growth in silage can be initiated by high humidity within the silo, low levels of acidity and sugars in the feed material, the presence of spores in the feed, and inadequate storage conditions such as loosely packed silos, silo leaks, and excessive exposure that can introduce fungal spores, increase humidity, and hinder the anaerobic fermentation process within the silo (Hynd 2009). McDonald et al. (2022) state that to control fungal growth in silage, it is important to ensure appropriate humidity levels during the ensiling process, promote good lactic acid bacteria activity, and provide proper storage conditions. Regular monitoring of silage quality, including visual inspection for signs of fungal growth, is also crucial to detect and take necessary measures if undesired fungal growth occurs. Dryden (2021) adds that fungal growth can also serve as an indicator of the pH level of the ensiled feed material.

Quality of Organic Waste Market (OWM) Fermentation

The quality of organic waste market fermentation can be assessed based on pH, ammonia, and VFA total; the data for each variable are presented in Table 5.

Table 5. Fermentation Quality of Organic Waste Market (OWM)

Treatments	pH Silage	Ammonia (mM)	VFA Total (mM)
P1: organic waste market (control)	4,49a±0,22	4,73d±0,08	63,3b±0,16
P2: P1 + RCS 1% BK	3,67a±0,02	3,47a±0,21	54,1a±0,37
P3: P1 + RCS 2% BK	3,43a±0,11	5,04e±0,07	63,3b±0,16
P4: P1 + RCS 3% BK	3,42b±0,05	4,41c±0,11	72,3c±055
P5: P1 + RCS 4% BK	3,34c±0,17	4,10b±0,02	63,3b±0,16

DM: Dry Matter. The data presented are mean values ± standard deviation. Different superscripts in the same column indicate significant differences (P<0.05) in pH, ammonia, and total VFA among treatments

pH of Organic Waste Market (OWM) Silage

The pH of silage is crucial to know as it plays a significant role in the ensilage process and can provide essential information about the quality and stability of the silage. The analysis in Table 5 indicates that the addition of rejected commercial syrups up to 4% has a significant effect (P<0.05) on the pH of silage. The pH values of organic waste market silage in this study ranged from approximately 4.49 to 3.34. The results of the DMRT 5% test demonstrate that the pH of silage in P1 is not different from P2 and P3 treatment. The similarity in pH values across these three treatments is attributed to the similar microbial activity required during ensilage. Adding 1-2% DM of rejected commercial syrups corresponds to the same sugar intake as in P1 treatment, thus maintaining relatively consistent microbial activity for producing lactic acid. However, the increase in rejected commercial syrups usage at 3% and 4% DM results in varying pH levels. This difference is due to the varying sugar content in rejected commercial syrups, which acts as a source of energy for microbial growth, subsequently influencing lactic acid production. Optimal lactic acid production leads to a strongly acidic pH in the silage, demonstrating that the use of rejected commercial syrups up to 4% BK can yield high-quality silage.

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A slightly acidic pH characterizes the good-quality silage. Silage with an acidic pH can hinder the growth of beneficial microbes as long as the ensiled feed remains stored in the silo (McDonald et al., 2022). The research by Sadarman et al. (2022; 2023a,b) states that the addition of RCS can lower the pH of silage. The pH reduction is a result of the rapid fermentation process carried out by beneficial microbes, supported by the availability of sugar as their energy source.

Several factors contribute to lowering the pH towards acidity (low pH) during ensilage within the silo, including high activity of lactic acid bacteria, sufficient sugar supply as an energy source for beneficial microbes, and the suppression of harmful microbial activity during ensilage. Rejected commercial syrup, being a high-sugar beverage product, serves as a modifier that can enhance silage quality, characterized by minimal mold growth in OWM silage (Dryden 2021).

Ammonia content of silage

The concentration of ammonia (NH_3) in OWM silage ranges from 3.47 to 5.04 mM during the 30-day storage period, and these values remain within the normal range of < 10 mM (McDonald et al., 2022). The highest concentration of NH_3 was observed in treatment P3 (P<0.05), while the lowest was in treatment P2 (P<0.05). Elevated ammonia production indicates significant protein degradation during the ensilage process, which is reflective of successful silage production (Hundal et al., 2016). Additionally, ammonia levels depict the extent of protein breakdown by microorganisms during ensilage (McDonald et al., 2022). Extensive protein degradation can result in silage of poor quality, leading to a decrease in the protein content of the feed material or ensiled feed (Lozano, 2015; McDonald et al., 2022).

Factors contributing to high ammonia content in silage include feed materials with high protein content, such as legumes (Dryden, 2021), silo leakage leading to the proliferation of undesirable bacteria (Hundal et al., 2016), and insufficient energy sources for beneficial microbes, which can slow down the fermentation rate (Lozano, 2015). A delay in the ensilage process can have adverse effects on the ensiled material (McDonald et al., 2022). This includes a decrease in substrate content due to the increased energy demand of microbes during the fermentation of the feed material (Hynd, 2019; Dryden, 2021).

VFA Production in Silage

The highest concentration of Volatile Fatty Acids (VFA) was observed in treatment P4, reaching 72.3 mM, and this difference was statistically significant (P<0.05) compared to the Control treatment (Table 5). The addition of 1% rejected commercial syrup resulted in the lowest VFA content. Volatile Fatty Acids (VFAs) consist of acetate, propionate, and butyrate and are the main products of microbial carbohydrate fermentation in the rumen (McDonald et al., 2022). These volatile fatty acids are essential as a source of energy and carbon for the growth of rumen microbes. Volatile Fatty Acids are the end products of carbohydrate fermentation, both within the silo and within the rumen. The content of acetate, propionate, and butyrate can serve as a basis to determine the quality of the resulting silage. According to Dryden (2021), good quality silage has proportions of acetate <25%, butyrate <5%, lactate >60%, and propionate around 35%.

The functions of each volatile fatty acid within the body of ruminant animals. Acetate serves as a precursor for milk production; propionate supports meat production, while the other two volatile fatty acids, like butyrate, can lead to decreased silage quality (Saha and Pathak 2021). Optimal production of lactic acid can quickly lower the pH of silage towards acidity, resulting in well-made silage (McDonald et al., 2022).

Dry matter loss and Fleigh value of Organic Waste Market (OWM)

Dry matter loss refers to the amount of dry weight lost from the silage during the fermentation process. On the other hand, the fleigh value is a number generated from the calculation of dry weight and pH of the silage, typically used to assess the quality of the silage. DM loss and fleigh values in OWM silage are presented in Table 6.

Tabel 6. DM loss and fleigh value OWM silage

Treatments	DM Loss (%)	Fleigh Value
P1: organic waste market (control)	14.3a±2.08	54.0a±8.83
P2: P1 + RCS 1% DM	10.5a±2.43	79.1b±5.20
P3: P1 + RCS 2% DM	11.9a±1.93	91.7c±5.09
P4: P1 + RCS 3% DM	12.5b±1.39	93.2d±2.53
P5: P1 + RCS 4% DM	11.8b±1.17	95.0e±7.03

DM: Dry Matter. The data presented are mean values ± standard deviation. Different superscripts in the same column indicate significant differences (P<0.05) in dry matter loss and fleigh value among treatments in the silage.

Dry matter loss in OWM silage

Dry matter loss commonly occurs during the ensilage process. Sequentially, dry matter losses in silage, starting from the addition of 1%, 2%, 3%, and 4% DM of RCS, were 10.5%, 11.9%, 12.5%, and 11.8% respectively, which were lower than the control (P1) that resulted in silage with a dry matter loss of about 14.3% (Table 6). The percentage of dry matter loss is a measurement method that calculates the loss of dry weight, and in reality, there is no change in the fresh weight of the sample. However, when calculating the dry weight content, it results in the reported dry matter loss figure (Ridwan et al., 2005). The research findings indicate a reduction in dry matter content as the RCS

Furthermore, the high dry matter loss in the control (P1) treatment is due to the absence of a carbohydrate source used in the ensilage process. The low dry matter losses in treatments P2 to P5 are due to the addition of OWM as a glucose source. According to Dryden (2021), sufficient glucose availability during ensilage can be utilized by microbes as their energy source. It is emphasized by McDonald et al. (2022) that microbes require adequate energy sources to grow and multiply. The increase in the population of lactic acid bacteria corresponds with the increase in lactic acid production. This can accelerate the pH reduction within the silo, thus expediting the ensilage process. Accelerating the ensilage process directly leads to reduced dry matter losses in silage, resulting in well-made silage.

Dry matter loss in silage is also influenced by the respiration and fermentation processes that

content in the silage increases. This is suspected to be due to the addition of RCS contributing to the dry matter content for each treatment, resulting in a decreasing trend of dry matter loss with increasing RCS in the silage. The potential for dry matter loss during the silage-making process can be minimized through the application of good management practices during silage production, avoiding field preservation of forage, minimizing respiration and fermentation of the feed by accelerating the silage-making process, reducing fermentation respiration in the silo, and avoiding silage spoilage (Borreani et al., 1999; Bichert et al., 2000; Rankin & Undersander, 2000; Jones, 2001; Muck et al., 2003; Rotz, 2005).

occur during ensilage. The impact of respiration can alter the nutrient content of the feed by degrading it, leading to a decrease in dry matter, including organic matter in the silage. This is due to the production of lactic acid and water during the fermentation process. Dry matter loss can also be linked to the content of non-structural carbohydrates, especially from the non-structural carbohydrates originating from the ensiled material. According to Surono et al. (2006), an increase in non-structural carbohydrate content will also increase the production of lactic acid bacteria, which can affect the dry matter loss of the ensiled material. Sufficient availability of water-soluble carbohydrates as an energy source for microbes can accelerate the fermentation rate, thus expediting the ensilage process within the silo and minimizing dry matter losses.

Fleigh value of Organic Waste Market (OWM) Silage

The Fleigh value is a numerical outcome obtained from the calculation of pH and dry matter of silage to determine its quality (Sariçiçek et al., 2016). Table 6 reveals that the addition of 1% to 4% DM of RCS results in OWM with higher Fleigh values compared to the control ($p<0.05$). The Fleigh value in P1, approximately 54.0, is significantly lower ($p<0.05$) than the Fleigh values in P2, P3, P4, and P5, which are approximately 79.1, 91.7, 93.2, and 95, respectively. Consequently, the produced OWM silage can be categorized as good to excellent. The increase in the Fleigh value could be attributed to the presence of sugar content in the silage, which acts as an energy source for microbes.

The Fleigh value is a chemical property of silage derived from pH and dry matter content (McDonald et al., 2022). Low or high Fleigh values are a result of pH and silage dry matter. In this study, the pH of OWM silage is around 3.34-4.49, which can be categorized as good, indicating that the addition of RCS can lower the pH towards acidity. Kilic (2015) adds that the Fleigh value depends on the dry matter level of the silage material and pH changes during fermentation. Additionally, as per Dryden (2021), a decrease in pH towards acidity negatively impacts harmful microbes as their growth and development are inhibited by beneficial microbes such as lactic acid bacteria.

Conclusions

The addition of RCS up to 4% DM can optimize temperature and humidity, lower pH, and minimize fungal growth in silage. Therefore, overall, RCS can enhance the quality of organic market waste silage, offering a potential solution to minimize waste generation in the future.

Acknowledgment

This study was fully funded by the Ministry of Education and Culture, the Republic of Indonesia.

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