

Original Research Article

An Evaluation of Spraying Machine for Silage Production

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Abstract: Silage production requires a mixture of molasses, inoculum, and water to store forage. Inoculum or microbes are mixed into the forage to inhibit the reproduction of bacteria and organisms that could damage the silage. Silage processing requires workforces to manually prepare and measure liquid additives to formulate the solutions. In MARDI, a machine that accurately mixes an inoculum, water, and molasses has been developed. The machine eliminates the need for manual operation and can reduce the labour involved in preparing a liquid formulation. Besides, the machine enables agricultural input to be handled efficiently. This machine can increase silage productivity for ruminant feed preparation. The machine's accuracy is 99.63% for measuring water and inoculum and 98.58% for measuring molasses solution. The machine's capacity is 30 barrels/hour for preparing a mixture of additive materials into 25 litres of water while 60–120 barrels/hour for preparing a mixture of additive materials into a 30 kg silage barrel.

Keywords: Silage production; molasses; inoculum; spraying machine

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1. Introduction

According to statistical analysis from the Department of Veterinary Services Malaysia (DVS) in 2020, the ruminant livestock population, including buffaloes, cows, goats and sheep in Malaysia amounts to 1.88 million (DVS, 2020). Although the livestock population is decreasing in 2020 compared to the year before, ruminant feeds are still insufficient for this country's livestock supply. The most significant issue in the ruminant sector is feed scarcity. Feed sources are a crucial necessity that needs to be secured to ensure a continuous supply. Malaysia spent about RM 4.6 billion importing animal feed in 2020 (DOS, 2021). Due to the high cost of importing this formulated concentrate based on ruminant feed production, pasture

or forage grass variety is the best alternative to serve the ruminant (Ahmed *et al.*, 2012). Therefore, increasing the utilization of local feed resources is a crucial strategy to reduce feed imports. Nutrients vary according to ruminants' production stage, sex, weight and age (Ismail *et al.*, 2021). In general, protein function for ruminant livestock is vital for cell growth. It helps reproduction, while carbohydrates from fibre are the energy source for all activities. Napier grass is a crop that has high protein and crude as a substitute for higher-priced raw wheat.

Due to its yield, Napier, known as elephant grass, became the most profitable forage crop in many tropical countries. It spreads via roots, grows in bunches, and many fibrous roots propagate on the ground (Bharat *et al.*, 2013). Napier grass is the best option for ruminant feed, and it can produce a high content of dry-weight matter than other types of yield from forage grasses (Haryani *et al.*, 2018).

Apart from fresh Napier, processed grass or silage is an alternative for animal feed. Silage is a type of ruminant fodder that results from the fermentation process of forage in an airtight (anaerobic) condition. Silage can minimize nutrient loss of fodder through storage as well as improve feed handling efficiency for ruminants on the farm (Mahanna & Chase, 2003). Silage is stored in a silo and can supply the need for livestock feed despite any weather for harvesting now and again (Eddy, 2020). Silage production requires the input of additives that have been mixed, such as microbes (inoculum), molasses and water, into the stored forage. The purpose of microbes in the forage is to inhibit the reproduction of bacteria and organisms that cause current damage. Inoculants have been proven to preserve silage quality for a long duration (Muck *et al.*, 2018). Silage processing requires the workforce to measure and prepare additive mixture solutions manually.

In Malaysia, the method of mixing additives for silage processing is done manually by measuring and preparing the mixed solution before mixing it into silo barrels or bags filled with forage. Additive requirements differ depending on the type of crop and the weight of silage packaging. The manual method takes a long time to prepare the silage input.

The study was related to developing an additive spraying machine for silage preparation. The machine can mix inoculum, molasses and water to prepare silage additives with accurate and fast measurements. In addition, the machine can be used to spray the prepared additive solution into the forage in the silo before tightly closing. This machine can solve the problem of labour dependency for the manual operation used to measure the liquid formulation of the silage processing material. This machine also enables agricultural input applications to be handled efficiently. This machine can increase the productivity of silage for ruminant feed preparation. The Malaysian Agricultural Research and Development Institute (MARDI) developed the machine used in this study to assist farmers in preparing the Napier silage.

2. Materials and Methods

The idea of the project is to develop a spraying machine that dispenses molasses, inoculum, and water to prepare silages for a goat. The operator only needs to place raw additives without mixing them in beforehand and choose the size of the silo or container to store fodder. When the operator needs to dispense the additives, they only need to press the on button, and the additives will mix by pump and come out from the nozzle into the silo. So, the project can prevent the operator from manually measuring the additive input to prepare silage. The lab analysis has been done to determine the content of the silage by using a hand and machine.

2.1 Material and Apparatus

2.1.1 Napier

This experiment utilized a variety of Pak-Chong Napier for its fodder. The grass was harvested at six weeks and chopped by a chopping machine. The fresh Napier was chopped into 1 - 2 cm lengths and immediately processed into silages to avoid rotten forage.

2.1.2 Container

There are two types of containers used in this project. 30L bottles to store a mixing solution of molasses and water for silage additive. 200 L of barrel/drum to store Napier for silage production.

2.1.3 Liquid additive

Three types of liquids are used in the project: molasses, clean water (without chlorine), and bacterial inoculum. The inoculum is an effective Microorganism (EM), and it *is mixed into the forage to inhibit the reproduction of bacteria and organisms that could damage the silage*. The EM used in this project is from a component of the heterofermentative class that includes species such as Oenococci and Leuconostocs. This EM is developed in the MARDI lab.

2.1.4 Spraying machine

This project has developed a complete four-sided spraying machine on a trolley that weighs 50 kilograms with an empty tank, as shown in Figure 1. Its design features a strong frame and a supporting structure. Two front wheels are also proposed as freewheeling components. The frame is made of metal, which adds a modern and aesthetic look to the trolley. Its height, width, and length are also in proportion to its overall design to carry all accessories needed to spray an additive into silages. Its base front segment comprises a hollow channel

that facilitates pump maintenance. The machine has two pumps, a valve, a nozzle generator, and a controller. The molasses and EM were placed in the tank without mixing. A pump is needed to measure and mix the additive inputs to prepare silage.

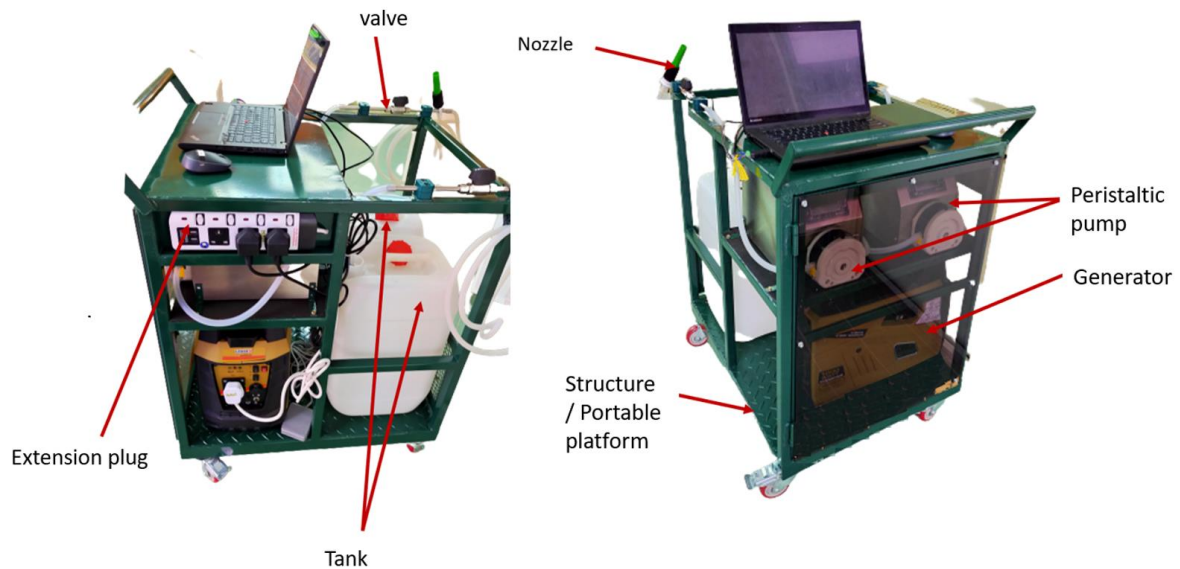


Figure 1. The spraying machine (a) front view; (b) isometric view

2.1.4.1 Pump selection

A peristaltic pump is used as the main part of the sprayer. This pump is selected since it is food grade and utilized to clean fluids since it is used to prepare the animal feed. Some of the common applications of this type of pump are for pumping high-solids slurries such as molasses with high viscosity. The parameters of the liquids used to prepare silage are shown in Table 1. Besides, the pump's pressure was also an essential criterion for selecting a pump. The calculation of the pressure is as follows.

$$\begin{aligned}
 & \text{Pressure, } P_{\text{molasses}} \\
 &= \text{Liquid density } \left(\frac{\text{kg}}{\text{m}^3} \right) \times \text{gravitational acceleration } (\text{m/s}^2) \times \text{height } (\text{m}) \\
 &= 1400 \times 9.81 \times 2 \text{ (Liquid depth in the 200L barrel placed on the lorry)} \\
 &= 27,468 \text{ Pa} = 0.27 \text{ bar}
 \end{aligned} \tag{1}$$

$$\text{Flow rate} = 50 \text{ L/min} = 8.33 \times 10^{-4} \text{ m}^3/\text{s} \tag{2}$$

$$\begin{aligned}
 & \text{Power (watt)} \\
 &= \text{Flow rate } (\text{m}^3/\text{s}) \times \text{Pressure } (\text{Pa}) \\
 &= 8.33 \times 10^{-4} (\text{m}^3/\text{s}) \times 27,468 \text{ Pa} \\
 &= 23 \text{ watt}
 \end{aligned} \tag{3}$$

Table 1. The parameter of liquids used to prepare silage

Factor	Parameter / Measurement	
Fluid type	Water	Viscosity: 0.8 centistoke
	Molasses	Viscosity: 5.019 centistoke
	EM	Viscosity: 0.8 centistoke
Flow rate	50L/min (plain water), 1.2L/min (Molasses)	
Operational temperature (ambient)	20°C–40°C	
Pressure	0.27 bars	
Power (output)	23 watts	

2.2 Machine Performance Evaluation

Machine performance is evaluated based on the suction of three liquids used for silage production. The time the machine transfers 500 ml of each fluid from 20 L into a new 1 L bottle is recorded. The ability of the pump to suck the fluid is evaluated.

2.3 Mixing Solution for Preparing Additive Solution

The machine is used to prepare the mixing solution for an additive solution. Molasses and EM are sucked from the original container and put into a 30L barrel filled with 25 L clean water without chlorine. The work capacity of the machine is determined and recorded. The solution can be stored and sold to breeders or farmers directly on the farm. Table 2 shows the volume of solution needed to prepare the additive solution.

Table 2. The volume of solution for preparing the additive solution

Material	Quantity (L)
Molasses	0.5
Clean water without chlorine	25
Inoculum bacteria @ Effective Microorganism (EM)	1

2.4 Spraying Additive Solution for Silage Production

The additive solution prepared from the previous activity is sprayed into chopped Napier stored in the 200 L barrel. The chopped Napier is put into the barrel, and the sprayer is operated simultaneously to dispense additive solution into the animal feed. 250 mL mixing solution is sprayed into the Napier. The pump is set to 500 mL/min and operated at 30 s.

2.5 Silage Sampling Analysis

The silage in the 200 L drum is opened on day 21, and 2 kg of silage is weighed and put in labelled paper bags. The samples are sent to the MARDI lab to determine energy content, crude fat, ash, crude fibre and dry matter. The fresh Napier is also sent to the lab as controlled data.

3. Results and Discussions

The data recorded and collected from all activities are analyzed.

3.1 Machine Performance

The machine is supposed to transfer 500 ml of liquid from the original container to a new barrel. The calibration is needed to ensure the suction and dispense are the same for a specified volume. The machine's calibration to transfer high-viscosity liquid takes more than 15 times to stabilize the measurement. In comparison, the lower viscosity liquid needs six times to stabilize the measurement. Figure 2 shows the flow rate vs. the number of calibrations required to achieve stability in the flow rate.

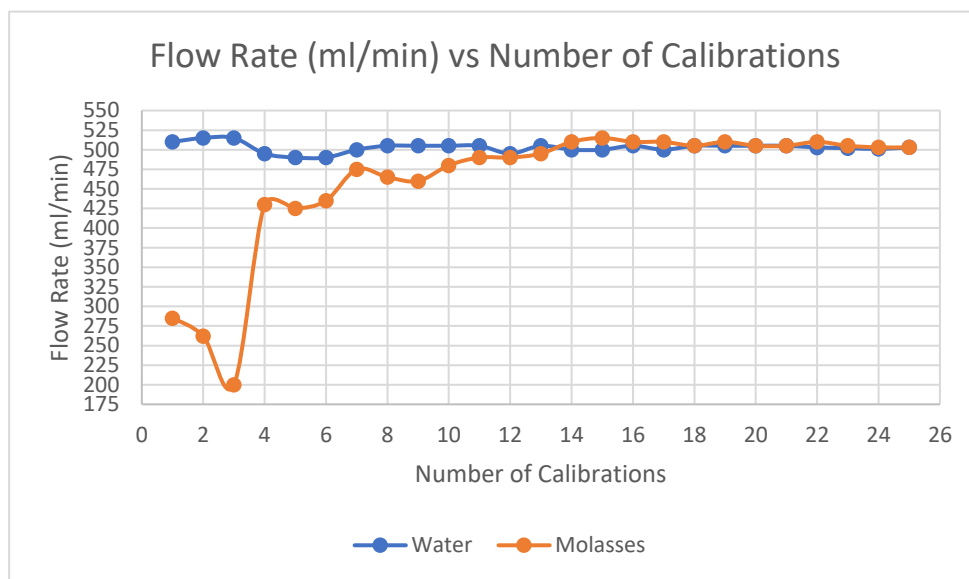


Figure 2. The Flow Rate vs. The Number of Calibrations to Achieve Stability in Flow Rate

3.2 Work Capacity for Preparing Additive Solution

The machine needs more time to fill in 500 ml Molasses into 25 L clean water. 2 min is sufficient to allow the high-viscosity liquid to transfer from the original container to the mixing bottle. The viscosity of EM is almost the same as water. Therefore, the time required for transferring liquid from its container to the mixing solution is quicker than for molasses. The measurement accuracy is 99.63% and 98.58% for EM and Molasses, as shown in Table 3.

Table 3. Machine capacity for preparing the additive solution

Duration	2 min/barrel	
Machine Capacity	30 barrels / h	
Accuracy of Measurement	EM	Molasses
	99.63%	98.58%

3.3 Work Capacity for Preparing Napier Silage

The machine requires 30–60 seconds to fill 250 ml of the additive into the chopped Napier barrel. The machine can prepare 60–120 barrels of silage/h with an accuracy of

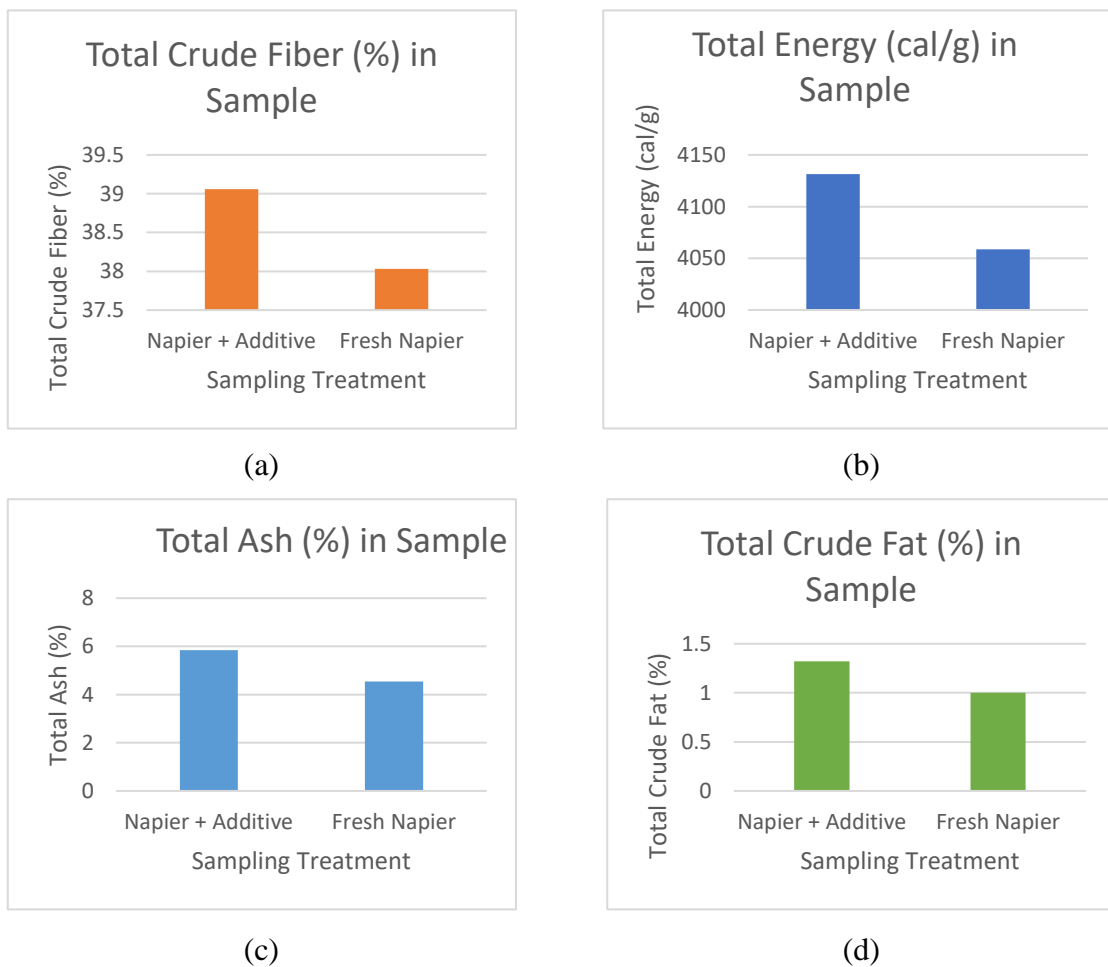
transferring an exact volume of 99.63% mixing solution. Table 4 shows the machine capacity for preparing Napier Silage.

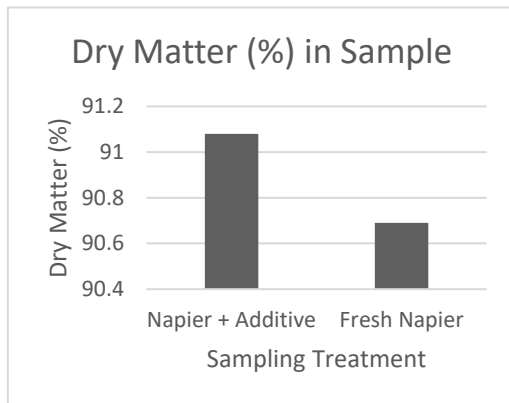
Table 4. Machine capacity for preparing Napier Silage

Duration	30–60 s/barrel
Machine Capacity	60–120 barrel / h
Accuracy of Measurement	99.63%

3.4 Determination of Content in Napier Silage.

The sample is taken 21 days after spraying an additive solution into the Napier barrel. The analysis results in a high content of total crude fibre, energy, ash, fat and dry matter compared to fresh Napier. From these results, using the machine can improve the quality of animal feed and make preparing silage easy for the farmer and breeder. Figure 3 compares Napier's content with additive and fresh Napier.





(e)

Figure 3. The comparison of content in Napier with additive and fresh Napier (a) Total crude fibre (b) Total energy (c) Total ash (d) Total crude fat (e) Dry matter

3.5 Machine Advantages

The machine is capable of measuring various types of liquids and viscosity. The peristaltic pump was selected as the primary tool for transferring liquid due to using Molasses with 5.019 Centistoke viscosity. Furthermore, the cleanliness of the solution is maintained, and there is no contamination between the pump components and the liquid because only the tube is in contact with the solution, and the aspirated solution will not go back into the original barrel. The measurement accuracy is high, up to 99.63% for water and EM and 98.58% for molasses solution. Besides, the machine is portable and can easily be used in the field for preparing silage. The comparison of using the spraying machines and manual operations is shown in Table 5.

Table 5. The comparison of using the spraying machines and manual operations

Parameter/condition	Machine	Manual
Contamination with additive solution	None	Yes
Work capacity (Preparing silage/h)	30 barrels / h	12 barrels / h
Work capacity (Preparing silage/month)	4200 barrels/month	1680 barrels/month

4. Conclusions

This research concludes that the machine can increase silage production's productivity for ruminant feed preparation. The machine's accuracy is up to 99.63% for measuring water and inoculum and 98.58% for measuring molasses solution. The machine's capacity is 30 barrels/hour for preparing a mixture of additive materials into 25 litres of water while 60 – 120 barrels/hour for preparing a mixture of additive materials into a 30kg silage barrel. The analysis results of sampling silage show that Napier sprayed with additives in silage drums has a high content of total crude fibre, energy, ash, fat, and dry matter compared to fresh Napier.

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Conflicts of Interest: The authors declare no conflict of interest.

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