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Research article

Effect of storage time on the quality of fermented total mixedration (FTMR) from sweet potato by-products

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Abstract

The experiment was carried out to establish diet formulations for beef cattle, with the main ingredients being sweet potato vines (SPV) and sweet potato tubers (type 3) (SPT). The experiment was arranged in a completely randomized design with three treatments and three replications with seven evaluation time points. The formulations with the same ratio of SPV and SPT (according to DM) were mixed with other ingredients such as rice straw, copra meal, extracted soybean, corn kernel, rice bran, salt, mineral premix, and urea. Treatments were evaluated for sensory and chemical composition at 1, 14, 28, 42, 56, 70, and 84 days after ensiling. The parameters to assess the nutritional content such as dry matter (DM), ash, crude protein (CP), crude fiber (CF), acid detergent fiber (ADF), neutral detergent fiber (NDF), and ether extract (EE). The pH values starting from 14 to 84 days of storage were all satisfactory for silage since there is a pH in the range of 4-4.5. The NH_3 content in the same formulation over the fermentation times was not statistically significant ($P>0.05$). The assessment results of changes in nutritional content and sensory evaluation over time showed little change in the formulation; all three formulations met the standards of Fermented Total Mixed Ration (FTMR).

Keywords: Beef cattle, Fermented Total Mixed Ration (FTMR), Silage, Sweet potato by-products, Sweet potato vines

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INTRODUCTION

Faced with the fact that residential areas are growing more and more, the farming area is increasingly narrow, the land for grazing ruminants is limited, especially the drought and salinity are occurring on a large scale, lack of green grass will be a matter of concern. Cultivation by-products such as rice straw, sugar cane tops, corn stalks, and other available green foods can also be used as feed for ruminants and cows at low cost. Meanwhile, according to preliminary data in 2020, the sweet potato growing area across the country is 109.3 thousand hectares with an output of 1,372.2 thousand tons. Particularly in the Mekong Delta region, Vinh Long province is the leading province in terms of planting area (12.8 thousand hectares) as well as sweet potato production (358.1 thousand tons) (General Statistics Office, 2021). Therefore, the problem is to take advantage of the available source of sweet potatoes, including sweet potato vines (SPV) and sweet potato tubers (SPT), to make fodder for livestock in combination with other feeds sources such as corn kernel, rice bran, copra meal, and rice straw, and extracted soybean to increase economic efficiency for farmers should be given due attention. Moreover, Kanjak et al. (2023) indicated that dietary fiber was used to reduce feed costs in local animal production.

However, fresh sweet potato vines and tubers will be challenging to store long after harvest. Currently, forage silage is a traditional method to preserve and improve the nutrients of forages, widely used in many countries worldwide. Forage with high water content (70-80%) in an anaerobic environment used to raise dairy cattle is very effective (Thu, 2008). This method not only solves the problem of storage to prevent spoilage after harvest but also promotes the effect of beneficial fermentation by lowering the pH during the fermentation period. Silage has a relatively high digestibility, especially indigestible substances such as cellulose, broken down into simple sugars that are easy to digest and absorb (Giang et al., 2008). Based on the above requirement, the study was carried out to evaluate the quality of silage formulations from SPV and SPT through different storage times.

MATERIALS AND METHODS

Object and site

The sweet potato vines (SPV) and sweet potato tubers (SPT) (type 3) were collected at households in Binh Tan district, Vinh Long province. SPV (type 3) is characterized by a weight less than 50g, broken or scratched. SPV and SPT were combined with other ingredients (rice straw, corn kernel, rice bran, extracted soybean, copra meal, urea, mineral premix, salt) to mix into three Fermented Total Mixed Ration (FTMR) formulations. The experiment was conducted from February 2022 to May 2022 at the Faculty of Animal Sciences, College of Agriculture, Can Tho University.

Experimental layout

The sweet potato vines were cut into pieces about 2-3 cm, and sun-dried for 4-6 hours under sunlight. The sweet potato tubers, after washing the mud, were sliced by a chopper with a 0.3-0.5 cm thickness. The mixture was weighed with the corresponding ratio according to the treatments so that the mass reached 2 kg/formulation. The mixture was well mixed into a plastic bag with a capacity of 4 liters, tightly compressed, attached to the one-way valve to the bag and tied tightly, marked with the corresponding formulation symbol, and stored at room temperature in a dry place. The check valve allows air from the pack to go only in one direction.

Figure 1 Sweet potato tubers after cutting.

Figure 2 Sweet potato vines after cutting.

The experiment was arranged in a completely randomized design with 3 treatments (FTMR) and 3 replicates and 7 sampling time points of 1, 14, 28, 42, 56, 70, and 84 days after ensiling. The sample in each bag was mixed well at each sampling time, and then a representative sample was taken to determine the parameters. The proportions of ingredients were calculated in %DM (Table 1). The formulas were mixed to meet the nutritional requirements of beef cattle with a Metabolisable energy (ME) requirement of 2.400 KCal/kg DM and a Crude protein (CP) requirement of 14% (Kearl, 1982).

Table 1 FTMR formulations (%DM)

Formulation	FTMR I	FTMR II	FTMR III
Rice straw	3.0	4.0	5.0
Sweet potato vines	30.0	30.0	30.0
Sweet potato tubers (type 3)	20.0	20.0	20.0
Corn kernel	14.52	17.3	20.09
Rice bran	13.41	9.78	6.14
Copra meal	5.67	6.52	10.0
Extracted soybean	12.0	11.0	7.38
Urea	0.5	0.5	0.5
Mineral premix	0.4	0.4	0,4
Salt	0.5	0.5	0.5
ME (Kcal/kg DM)	2,400	2,400	2,400
CP (%)	14.0	14.0	14.0

FTMR: Fermented Total Mixed Ration; ME: Metabolisable energy; CP: Crude protein; DM: Dry matter

Evaluation criteria and analytical methods

Sensory evaluation: Sensory criteria such as color, odor, and appearance of the mold of the batch. The mold formation was directly observed over storage time after opening the bag. Colors were observed with the naked eye, and each formula's odors were smelled.

Quality evaluation: Analysis of chemical composition and nutritional value of the silage at 7 times 1, 14, 28, 42, 56, 70, and 84 days after ensiling, the analytical parameters include: pH, Ammonia nitrogen (NH_3-N), Dry matter (DM), Ash, Crude protein (CP), Crude fiber (CF) and Ether extract (EE) according to the method of AOAC (2002). Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) was analyzed by the method of Van Soest et al. (1991).

Statistical analysis

The data were analyzed by the General Linear Model (GLM) option in the ANOVA program of the Minitab Software (Minitab 2021). When there is a difference between the mean values of the treatments, the Tukey test will be used to evaluate the difference between each treatment pair ($P<0.05$).

RESULTS

Sensory evaluation

The sensory quality of FTMR after 14, 56, and 84 days of ensiling is shown in Figure 3. At 14 days, all 3 treatments had the light yellow color of SPV and a slightly sour smell, while SPV was still characteristic purple color. At 56 days, all 3 treatments were fragrant, and the bag ingredients were closely linked. At 84 days after fermentation, all 3 treatments showed slight mold on the surface but no mold inside the sample, and had a strong sour smell. The results of the sensory evaluation showed that all 3 FTMR treatments were suitable to preserve SPV and SPT for a period of 14-84 days.

pH changes with different storage times

The pH value between fermentation times of the treatments was statistically significant ($P<0.05$). However, the pH values of the treatments were only statistically significant on days 1 and 84 ($P<0.05$). Compared with the 1-day time point of FTMR I (pH value of 5.00), starting from 14 days after fermentation, there was a decrease in pH value, decreasing from 4.24 (at day 14) to 4.09 (at day 84).

Evaluation time	Treatment FTMR I	FTMR II	FTMR III
14 day			
56 day			
84 day			

Figure 3 Sensory evaluation of the treatments with different storage time

Table 2 pH content of the treatments

Day	Treatment			SEM	P
	FTMR I	FTMR II	FTMR III		
1	$^{a}5.00^{B}$	$^{a}5.24^{A}$	$^{a}5.19^{AB}$	0.04	0.02
14	$^{b}4.24$	$^{b}4.28$	$^{b}4.24$	0.08	0.92
28	$^{c}4.08$	$^{b}4.12$	$^{c}4.07$	0.04	0.58
42	$^{c}4.10$	$^{b}4.19$	$^{c}4.15$	0.04	0.25
56	$^{c}4.10$	$^{b}4.16$	$^{c}4.15$	0.03	0.39
70	$^{c}4.03$	$^{b}4.07$	$^{c}4.07$	0.02	0.28
84	$^{c}4.09^{B}$	$^{b}4.16^{A}$	$^{c}4.07^{B}$	0.01	0.01
SEM	0.02	0.07	0.02		
P	0.001	0.001	0.001		

Values with different letters in the same row (right) or column (left) were statistically significant (P<0.05)

DM changes with different storage times

Table 3 DM content of the treatments (%)

Day	Treatments			SEM	P
	FTMR I	FTMR II	FTMR III		
1	36.04	36.32	38.12	1.07	0.39
14	41.69	39.81	39.06	2.49	0.75
28	41.58	38.99	40.41	2.09	0.70
42	39.52	35.50	35.60	1.65	0.23
56	39.06	37.14	38.08	0.89	0.37
70	38.92	38.37	36.57	1.06	0.33
84	38.35	37.86	35.66	1.76	0.55
SEM	1.94	1.04	1.86		
P	0.46	0.12	0.51		

The DM content between treatments and the fermentation time of each treatment was not statistically significant (P>0.05). From Table 3, we also saw that the DM content after 14 and 28 days of fermentation, the dry matter content increased and then tended to decrease gradually with the fermentation time of the treatment.

CP changes with different storage time

The CP content of the treatments over the fermentation times did not change significantly, and the difference was not statistically significant (P>0.05). CP content was highest in FTMR III at day 84 (17.68%), and the lowest FTMR II on day 1 was 15.45%.

The NH_3 content in the same treatment over the storage times had no statistical difference (P>0.05), except for FTMR I. In the same fermentation time, the NH_3 content of the treatments also had no statistical difference (P>0.05).

Table 4 Change in CP and NH_3 contents (%)

Day	Treatments			SEM	P
	FTMR I	FTMR II	FTMR III		
CP content					
1	16.97	15.45	17.36	0.65	0.17
14	17.51	15.78	17.55	0.58	0.12
28	17.40	16.10	16.01	1.08	0.62
42	16.63	15.37	15.90	0.98	0.68
56	16.73	16.03	15.69	1.38	0.87
70	16.76	17.27	16.87	0.33	0.56
84	17.27	16.81	17.68	1.04	0.84
SEM	0.99	1.06	0.68		
P	0.99	0.84	0.24		
NH_3 content					
1	^{ab}0.68	0.69	0.62	0.03	0.30
14	^{ab}0.63	0.57	0.60	0.06	0.78
28	^{b}0.49	0.46	0.46	0.06	0.91
42	^{a}0.70	0.71	0.65	0.47	0.62
56	^{ab}0.58	0.63	0.65	0.07	0.76
70	^{ab}0.61	0.60	0.63	0.05	0.90
84	^{ab}0.62	0.61	0.64	0.04	0.90
SEM	0.04	0.06	0.50		
P	0.08	0.15	0.17		

Values with different letters in the same column (left) were statistically significant (P<0.05).

Ash changes with different storage time

Table 5 Ash content of the treatments (%)

Day	Treatments			SEM	P
	FTMR I	FTMR II	FTMR III		
1	11.27	9.88	9.86	0.46	0.12
14	10.01	9.51	9.96	0.41	0.65
28	9.94	9.87	9.91	0.36	0.99
42	9,54	11.32	10.84	0.60	0.18
56	9.65	9.57	10.45	0.53	0. 47
70	10.51	10.19	11.20	0.42	0.31
84	10.65	10.50	10.70	0.51	0.96
SEM	0.44	0.48	0.51		
P	0.14	0.19	0.43		

The total mineral content over time of each treatment was not statistically significant (*P*>0.05). Similarly, the total mineral content between treatments by fermentation time was also not different.

CF, ADF, and NDF changes with different storage time

The CF content of the formulas over the fermentation times did not have statistical significance (*P*>0.05), except at day 84, the CF content was different (P <0.05). Meanwhile, in the same treatment, the CF content over the storage times decreased and the difference was statistically significant (P<0.05).

The ADF composition between treatments in the same fermentation period was not statistically significant (*P*>0.05). The ADF content in the same treatment over the storage times was not different (*P*>0.05).

The NDF content through the fermentation times of each treatment and between the FTMR treatments at each time was statistically significant (*P*<0.05), except in the FTMRII treatment. The NDF concentration between treatments at the same time was not statistically significant (*P*<0.05), except for day 1. The highest NDF concentration was in the FTMR III treatment on day 1 (63.30%), on days 14 to 84, the NDF content also ranged from 49.94 to 54.05%.

Table 6 CF, ADF, and NDF contents of the treatments (%)

Day	Treatments			SEM	P
	FTMR I	FTMR II	FTMR III		
CF content					
1	^{ab}18.21	^{a}19.02	^{abc}16.99	0.80	0.27
14	^{ab}17.72	^{a}17.14	^{ab}18.84	1.15	0.60
28	^{a}18.55	^{a}17.72	^{abc}15.93	1.34	0.43
42	^{abc}16.94	^{a}17.72	^{a}19.94	1.16	0.24
56	^{abc}16.62	^{a}19.64	^{abc}18.12	1.48	0.41
70	^{c}11.85	^{b}11.37	^{c}12.67	0.64	0.41
84	^{bc}13.02^{AB}	^{b}12.49^{B}	^{bc}13.91^{A}	0.22	0.01
SEM	1.08	0.84	1.20		
P	0.003	0.001	0.007		
ADF content					
1	19.76	18.37	17.82	0.77	0.26
14	18.22	18.14	19.41	1.19	0.71
28	18.61	17.37	17.61	1.05	0.69
42	18.77	20.65	20.54	1.08	0.44
56	19.26	20.48	19.79	0.92	0.66
70	20.04	19.30	22.10	0.79	0.11
84	21.49	21.06	22.21	0.77	0.60
SEM	0.94	0.85	1.05		
P	0.28	0.05	0.04		
NDF content					
1	^{a}48.20^{C}	56.85^{B}	^{a}63.30^{A}	0.44	0.001
14	^{a}54.05	55.62	^{b}55.80	1.01	0.45
28	^{a}53.79	57.48	^{b}56.51	1.07	0.11
42	^{a}49.94	52.45	^{b}53.57	1.07	0.12
56	^{a}53.57	52.30	^{b}53.67	1.29	0.72
70	^{a}51.22	52.86	^{b}53.28	1.47	0.60
84	^{a}51.69	54.,55	^{b}55.37	1.84	0.39
SEM	1.24	1.29	1.17		
P	0.04	0.06	0.001		

Values with different letters in the same row (right) or column (left) were statistically significant (P<0.05).

EE changes with different storage time

The EE content of the treatments over the storage times was significantly different (P<0.05). In the same storage time, the EE content between treatments was only statistically significant (P<0.05) at 14 days, 6.15; 4.76; 5.09% for FTMR I, II, and III, respectively.

Table 7 EE content of the treatments (%)

Day	Treatments			SEM	P
	FTMR I	FTMR II	FTMR III		
1	^{c}4.09	^{abc}4.29	^{c}3.55	0.18	0.07
14	^{a}6.15^{A}	^{ab}4.76^{B}	^{ab}5.09^{B}	0.20	0.007
28	^{ab}5.83	^{a}5.25	^{a}5.23	0.33	0.41
42	^{bc}4.68	^{bc}4.02	^{bc}3.66	0.26	0.08
56	^{abc}4.74	^{ab}4.66	^{abc}4.17	0.30	0.41
70	^{c}4.20	^{c}3.52	^{abc}4.00	0.26	0.24
84	^{c}3.83	^{c}3.68	^{abc}3.88	0.32	0.90
SEM	0.29	0.20	0.31		
P	0.001	0.001	0.008		

Values with different letters in the same row (right) or column (left) were statistically significant (P<0.05).

DISCUSSION

According to Hiep et al. (2020), the pH value of FTMR compound feed was the first important criterion to consider when evaluating the quality of fermented mixed feed. The pH value of the silage must be lowered to 3.8-4.2 for the feed to be preserved for a long time. These pH values help maintain feed quality (McDonald et al., 1991). This result is consistent with the study of Van et al. (2015) when the FTMR study from sugarcane tops, peanut vines, and corn stalks showed that the pH decreased in the first week, then gradually stabilized in the following weeks. This result showed that all three FTMR formulations could be preserved long. According to Hang (2008), silage with a pH in the range of 4.0-4.5 was considered good quality, but if the pH were higher than 4.5, the quality of the silage would decrease. This was relatively consistent with the results of Table 2, which shows that the silage times of the treatments were satisfactory for silage quality when the silage was from 1 day to 84 days and can use vines and sweet potato by-products in the FTMR compound feed. However, formulations at 84days pH tended to increase again compared to 70 days, so further consideration should be given to extending the fermentation period. When comparing the change of CP between treatments over time, it was found that this result is similar to the study of Tham (2017) when the CP content of corn stalks silage with rice straw, sugarcane molasses, corn kernels, rice bran, and copra meal changed insignificantly after 90 days of silage. This is a favorable condition to use as animal feed for a long time while feed quality is still stabilized. According to La (2012), the change of CP in the silage batch was the most concerning criterion in the fermentation process because the more CP decreases after fermentation, the worse the feed quality. Thereby, it was shown that the CP content did not change significantly over the fermentation time or through the treatments. The storage time did not affect the CP in the batch, which facilitated feed use for a long time while maintaining the feed quality (Tham, 2017). Although NH_3 content between different treatments was not statistically significant in the same fermentation time and in the same treatment with different fermentation times (except for FTMR I), all treatments had NH_3 values ranging from 0.46 to 0.71%. According to AOAC (2002), a qualified silage sample must have NH_3 content <5%. Therefore, it could be concluded that the silage quality of all three treatments met the standard of a batch of silage in terms of NH_3 content requirements.

According to the analysis results of Seglar (2003), when researching to evaluate the quality of silage, the high ash content in the silage batch after a period of fermentation was due to the soil clinging to the material or the fermentation of Clostridial bacteria when the environment was not guaranteed anaerobic conditions. On the other hand, at the end of the compression process, plant cells do not die immediately, creating an anaerobic environment. Still, they prolong their life for a short time and endogenous (anaerobic) respiration, so when cell death increases, the mineral content can also lead to this difference. This proves that the mixing ratio and fermentation time of the treatments have little effect on the total mineral content (Binh et al., 2005). Based on the above results, it was shown that the ash content did not change significantly after 84 days of storage, indicating that the materials were not mixed with soil before being mixed and the batch was incubated after 84 days of storage management still ensures anaerobic.

The CF content in the study did not change from day 1 to day 56, but it decreased sharply at day 70, probably due to the prolonged fermentation time, so the microflora inside the bag was active and decomposed some components of CF. The highest CF content in the FTMR II treatment on day 56 was 19.64%, which was lower than the results of Muoi et al. (2012) with the CF content of corn stalks being 29.89%. It could be concluded that the fermentation time significantly affects the CF content in each treatment, but the mixing ratio did not affect the CF content in the bags over the storage times.

The ADF content of the 3 treatments ranged from 17.37% to 22.21%. The ADF content of all 3 treatments on 84 days tended to decrease slightly. This result was consistent with the research results of Tham (2017) when the study of adding molasses with different rates (0, 2, 4, and 6%) on the quality of silage corn was carried out. It was found that, after 6 months of storage, the composition of ADF and NDF in the silage batch did not change significantly. The reason may be that the silage did not significantly change the ADF and NDF contents of the plant cell wall, so it could not reduce the ADF and NDF components. The ADF content was difficult to degrade in the green forage sample because it contains a lignin-hemicellulose linkage, so microorganisms could not completely cut off this linkage (Trach et al., 2006). Thus, different formulations and storage times did not affect the ADF content.

According to Ashbell and Donahaye (1984), the change in NDF content was due to the loss of water-soluble carbohydrates at the first stage of silage. This result was consistent with the study of Tham and Dat (2017), when silage of corn stalks with molasses (rate of 5%), NDF also decreased over time (120 days reduced by 1.79%). Cell wall carbohydrates (fiber) were an important nutritional component of ruminant diets and were a major component of forages such as forages, hay, silage, rice straw, and plant stalks. Dietary fiber often has a low digestibility due to the presence of lignin in plant cell walls. Lignin prevents microorganisms from entering the fiber component and is also a substance that creates stable bonds with the molecules hemicellulose and cellulose molecules (Giang et al., 2008). Thus, it can be concluded that the NDF content tended to decrease slightly, but the mixing ratio did not differ too much between the treatments and still ensured the quality requirements of the FTMR.

When comparing the EE content between treatments, the EE concentration increased on day 14, and then gradually decreased to day 42, on day 56 increased again and continued to decrease until day 84. EE was highest at day 14 in the FTMR I treatment (6.15%), and the lowest was 3.52% at day 70 (FTMR II). These results were higher than the results of the study by Chinh et al. (1995) with the EE content of silage by-products of sweet potato tubers being 0.9%. Therefore, the EE content depends on the silage time but was not affected by the mixing ratios of the ingredients.

CONCLUSION

It can be concluded that FTMR formulas for beef cattle meet the sensory requirements of fermentation. The pH values of the three formulations were all within the appropriate limits to ensure the quality of the batch. The results of evaluating the change in the nutritional content of the formulas over time showed little change. However, the formulas that were fermented for up to 84 days showed mold on the surface of the bags but did not affect the quality of the FTMR inside the bags. The research results are a basis for further studies on using FTMR in practical conditions.

AUTHOR CONTRIBUTIONS

Mai Truong Hong Hanh; Conceptualization and design of the experiment, investigation, methodology, formal analysis, manuscript preparation
Ho Thanh Tham; Supervision, editing, and finalization

CONFLICT OF INTEREST

We have no conflict of interest.

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