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ORIGINAL ARTICLE

Evaluating agro-industrial by-products as dietary roughage source on growth performance of fattening steers



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Abstract Silages from pineapple peel, sweet corn husk and cob mixed with bagasse and vinasse were evaluated to determine their chemical composition and fermentation characteristics as well as feeding performance in fattening steers. The experiment, which lasted 90 days, involved 48 fattening steers (264 ± 37.4 kg BW) randomly allocated to three diets. Treatments included: a control diet containing rice straw and molasses (T1); diet containing bagasse–vinasse mixture including sweet corn husk and cob silage (BS; T2); and diet containing bagasse–vinasse mixture including pineapple peel silage (BP; T3). All treatments included a commercial concentrate feed (13% CP) and *ad libitum* rice straw throughout the experiment. Results from chemical analysis showed that dry matter (DM) of BS was higher than BP ($P < 0.05$), whereas the protein content of BS and BP was similar ($P > 0.05$). For fermentation characteristics, pH in BP was lower than BS ($P < 0.05$); in addition, acetic and butyric acids in BS were higher than BP ($P < 0.05$). Findings from growth trial showed that total DM intake in steers fed T1 was higher compared to the other dietary treatments ($P < 0.05$), whereas the average BW gain was found to be greater in T3 steers ($P < 0.05$). As result from our findings, bagasse–vinasse mixture with pineapple peel silage appeared to be a viable feed ingredient in fattening steer diet and moreover it could become an economically feasible agro-industrial by-product for farmers.

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1. Introduction

Nowadays the shortage of conventional feeds and fodders in countries from the tropical and sub-tropical regions is well recognized. However, livestock development is taken up in these countries on a large scale in view of its potential as a source of income and employment. Ruminants species play an

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important role in the country economy, being able to digest fibrous material and by-products, these are well suited for recycling such material and providing an additional source of income (Vasta et al., 2008; Tufarelli and Laudadio, 2011). Recent growing interest in utilizing food industrial by-products as animal feed is due to enhanced environmental and economic concerns because most food by-products are environmental waste management problems (Tufarelli et al., 2013). Thus, there is need to explore the use of alternative sources that are more economical in formulating least-cost rations. A simple and low cost option which can preserve seasonally-dependent feeds is to ensile biomass. Total mixed ration silage made by mixing the wet by-products with roughage is in practice at farms in many countries because most food by-products have a high moisture content (Cazzato et al., 2011). This also helps to omit the time of mixing before feeding, minimizes the risk of effluent production and avoids self-selection of feeds by animals (Wang and Nishino, 2008). In addition, unpalatable by-products could possibly be incorporated into a total mixed ration if their odors and flavors were altered by silage fermentation (Xu et al., 2007b).

Ethanol industry which used molasses as raw material can produce vinasse by thermal concentration of dilute vinasse. Vinasse can be used for animal feed ingredient as a source of nutrients and minerals for pigs, poultry and ruminant species (Stemme et al., 2005; López-Campos et al., 2011). The weakness of vinasse is in its low dry matter which is difficult for transportation and storage. Sugarcane is one of the crops which has great potential for capturing solar energy and providing high biomass yield. An approach to utilize sugarcane as ruminants feed includes the use of by-products out of manufacture of sugar like the bagasse. Moreover, bagasse is highly produced from industry processing (Thai Sugar Mill, 2007), and if mixed with vinasse should increase the dry matter content and it could be easily supplied to animals in the form of bagasse–vinasse mixture. However, bagasse is the highly fibrous residue remaining after sugar cane is pressed to remove sucrose (Martin et al., 2007) and results in low protein and high in cellulose (Shelke et al., 2009; Kumari et al., 2013). Therefore, bagasse–vinasse mixture (BV) should increase the bagasse quality. The BV could be used to mix with another agro-industrial by products such as corn cob, corn husk and pineapple peel which can enhance other products in terms of nutritional composition and palatability. As a result, BV could be used as feed source to add in roughage in order to increase feed intake and performance of fattening steers. In spite of the fact that food industrial by-products are common in different countries (Ishida et al., 2012), there are limited published reports and many by-products cannot be quantified because of different equivalents available in the literature. In addition, the nutrient values of food industrial by-products vary widely depending on regions. Therefore, the objective of this study was to investigate the nutritional and fermentation quality of silage from agro-industrial by-products and to determine their effects on the growth performance using fattening steers.

2. Materials and methods

2.1. Animal and diets

Forty-eight Brahman × Thai steers were used in the present study. All steers were 18 months old with an average body

weight (BW) of 264 ± 37.4 kg. Animals were randomly allocated to three dietary treatments for 90 days after 14 days of adjustment period before data collection. Treatments included: a control diet containing rice straw and molasses (T1); diet containing bagasse–vinasse mixture including sweet corn husk and cob silage (BS; T2); and diet containing bagasse–vinasse mixture including pineapple peel silage (BP; T3).

For silage preparation, the bagasse and vinasse (BV) mixture was made using bagasse from sugar industry by-product and vinasse from the ethanol plant. The BV mixture was mixed at the ratio 70:30 of vinasse and bagasse, respectively. The BV was further mixed with sweet corn husk and cob silage or mixed with pineapple peel silage and considered, respectively. All dietary groups were opened and feed samples were weekly collected and analyzed for chemical composition and fermentation characteristics. Each group received also a commercial concentrate feed (13% CP) twice a day (2 kg at 6.00 a.m. and 3 kg at 16.00 p.m., respectively). Steers were fed *ad libitum* roughage and supplemented with rice straw and molasses (Table 1). The feed consumed by steers within each group were calculated based on nutrient requirements for maintenance and production (NRC, 2001). In addition, fresh water from individually automatic bowl and mineral block were available all the time. Body weight of each steer was recorded at the beginning of the trial period and after 90 days. Feed conversion ratio was calculated as the ratio of BW gain to DM intake. Feed refusals were collected, weighed and individually bulked for analysis. Samples of refusals and feeds offered were dried at 105 °C for 24 h to determine the intake.

2.2. Chemical analysis

Samples of feeds were ground in a hammer mill with a 1 mm screen and analyzed in triplicate for dry matter (DM, 945.15), ash (967.05), crude protein (CP, Kjeldahl N × 6.25, 990.03), crude fiber (962.09), ether extract (945.16) according to AOAC (1990). The neutral detergent fiber (NDF using heat-resistant α -amylase without sodium sulfite), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed according to Mertens (2002), AOAC (1990) (973.187), and Van Soest et al. (1991), respectively, using the sequential procedure and the filter bag system (Ankom Technology, New York). The NDF and ADF fractions include residual ash. N-free extract was calculated by difference. Hemicellulose and cellulose were also estimated as NDF (ash free) – ADF (ash free) and ADF (ash free) – ADL (ash free), respectively

Table 1 Chemical composition of the concentrate, rice straw and molasses used in the feeding trial (% on DM basis).

Items	Concentrate	Rice straw	Molasses
Dry matter	90.68	90.00	78.98
Crude protein	13.11	2.76	4.06
Ether extract	2.50	2.00	0.55
Ash	5.82	14.54	8.62
Crude fiber	14.56	38.13	0.01
Acid detergent fiber (ADF)	25.43	55.00	–
Neutral detergent fiber (NDF)	44.23	79.00	–
Calcium	1.01	0.40	–
Phosphorus	0.33	0.25	0.06
Gross energy (kcal/kg)	3729	3320	3683

(Tufarelli et al., 2010). The concentration of feed gross energy was estimated with the equation proposed by NRC (2001). The pH of silages was measured using a glass electrode pH-meter according to Bolsen et al. (1992). The volatile fatty acids (VFA; acetate, butyrate and lactate, respectively) were measured by HPLC according to Xu et al. (2007a).

2.3. Statistical analysis

Data from chemical analysis, fermentation parameters and growth performance were analyzed as a completely randomized design with three replicates per treatment. Data collected were subjected to analysis of variance (ANOVA) of SAS (1996). Duncan's new multiple range test was used to evaluate differences among means (Steel and Torrie, 1980). Significant differences were declared at $P < 0.05$ and a trend at $P < 0.10$.

3. Result and discussion

3.1. Chemical composition and fermentation characteristic of silages

The proximate composition of bagasse and silages used in the feeding trial is reported in Table 2. As result, the proximate composition of raw bagasse before mixing with vinasse resulted low in protein, but particularly high in crude fiber, NDF, ADF and cellulose. In fact, bagasse was found to contain appreciable content of fiber fractions as NDF and ADF (79.08% and 14.30% on DM basis, respectively) as well as cellulose and hemicellulose (44.19% and 20.59% on DM basis, respectively) levels. Moreover, the bagasse crude protein was on overall equal to 2% on DM basis. Our findings on bagasse nutritional composition were similar to those reported by Ibrahim and Pearce (1993) and Chullanandana (2000). Mixing bagasse with vinasse (BV) led to an enhancement of crude protein contents from 2.02% to 7.80%, whereas the DM of BS and BP was found to be 27.45% and 25.60%, respectively. In silage containing bagasse–vinasse mixture with sweet corn husk and cob (BS) the crude protein content of was 8.74%

and in silage containing bagasse–vinasse mixture with pineapple peel (BP) was 9.10%, respectively (Table 2). The BS in this study had higher crude protein than those found by Maneerat et al. (2013) who reported crude protein in pineapple and corn by-product silages of 3.80% and 6.90%, respectively. The notable protein content in silages in our study has nutritional significance, since moderate intake of these feeds will greatly increase the total dry matter intake. Hence, their utilization as an alternative roughage source in ruminant formulation will reduce over-dependence on conventional feeds.

The fermentation quality of bagasse–vinasse mixture and silages is reported in Table 3. From results, it was found that silages were well preserved, with low pH value and high lactic acid content. Propionic acid and butyric acid were found at low concentrations. These results could be attributed to water-soluble carbohydrates or some non water-soluble hemicelluloses in the total mixed ration materials (Winters et al., 1998). In particular, acetic and butyric acids in BS were significantly higher than BP ($P < 0.05$). Good quality silage is characterized by considerable lactic acid concentration (Zobell et al., 2004) and in our study it was found to be high. Moreover, as reported by McDonald et al. (2002), the pH value < 4.2 was well-preserved, 4.3–4.5 was intermediate range and

Table 3 Fermentation characteristics of silages used during the feeding trial.

Item	BV ^a	BS ^b	BP ^c	SEM
pH	4.10*	4.53*	3.96*	0.07
Volatile fatty acids				
Acetate, % of DM	1.90*	4.25*	4.02*	0.31
Butyrate, % of DM	0.53*	1.51*	1.40*	0.02
Lactate, % of DM	11.43*	5.54*	5.40*	0.03

* Means within the same row with different superscripts differ ($P < 0.05$).

^a Mixed bagasse and vinasse.

^b Bagasse–vinasse mixture with sweet corn husk and cob silage.

^c Bagasse–vinasse mixture with pineapple peel silage.

Table 2 Chemical composition of bagasse, vinasse and silages used in the feeding experiment (% on DM basis).

Item	Bagasse	Vinasse	BV ^a	BS ^b	BP ^c
Dry matter	91.64	32.85	24.00	27.45	25.60
Crude protein	2.02	12.63	7.80	8.74	9.10
Ether extract	0.79	2.01	0.89	1.11	0.60
Ash	11.31	17.58	15.54	10.44	6.40
Crude fiber	43.66	0.06	19.31	26.18	23.90
Nitrogen free extract (NFE)	42.22	66.54	39.28	47.56	65.89
Acid detergent fiber (ADF)	58.49	0.01	31.83	37.00	39.01
Neutral detergent fiber (NDF)	79.08	0.05	35.84	51.25	61.27
Acid detergent lignin (ADL)	14.30	–	8.02	8.49	5.82
Hemicellulose	20.59	–	4.01	14.25	22.26
Cellulose	44.19	–	23.81	28.51	33.19
Calcium	0.41	–	1.42	1.17	2.90
Phosphorus	0.02	–	0.09	0.10	0.10
Gross energy (kcal/kg)	3949	3316	3248	3765	4015

^a Mixed bagasse and vinasse.

^b Bagasse–vinasse mixture with sweet corn husk and cob silage.

^c Bagasse–vinasse mixture with pineapple peel silage.

Table 4 Growth performance and feed intake of fattening steers fed the different dietary treatments.

Item	Treatments ^a			SEM
	T1	T2	T3	
Initial body weight, kg	275.8	265.0	253.1	24.95
Final body weight, kg	298.8	271.3	288.8	15.74
Body weight gain, kg	25.0*	26.3*	35.7*	9.72
Average daily gain, kg/head/d	0.38*	0.40*	0.55*	0.09
Roughage DMI, kg/d ^b	5.39*	3.48*	4.33*	0.33
Concentrate DMI, kg/d	4.38*	3.52*	3.79*	0.11
Total DMI, kg/day	9.77*	7.00*	8.12*	0.41
Feed conversion ratio, kg/kg	10.55*	7.82*	6.89*	0.24

* Means within the same row with different superscripts differ ($P < 0.05$).

^a T1, dietary treatments including concentrate, rice straw and molasses (control); T2, dietary treatments including concentrate and bagasse–vinsasse mixture with sweet corn husk and cob silage; T3, dietary treatments including concentrate with bagasse–vinsasse mixture with pineapple peel silage.

^b DMI, dry matter intake.

for volatile basic nitrogen to total nitrogen ratio concentration $< 12.5\%$ was well preserved, which agreed to our findings.

3.2. Growth performance of fattening steers

The influence of dietary treatments on intake and growth traits of steers is reported in Table 4. The effects of including agro-industrial by-products on growth performance of fattening steers showed that the initial and final body weights (kg) did not differ significantly between groups ($P > 0.05$). However, the T3 group fed bagasse–vinsasse mixture with pineapple peel silage exhibited the highest average daily gain ($P < 0.05$), and body weight gains of T1 and T2 were comparable ($P > 0.05$). The total dry matter intake (DMI) of fattening steers in control diet (T1) was higher than those in BP and BS diets, respectively ($P < 0.05$). The part reason for the higher DMI of control treatment is the fast digestion rate of molasses included in the diet. As illustrated by McDonald et al. (2011), ruminant intake is actually more closely related to the rate of digestion of diets than to digestibility per se. The better palatability of molasses compared to other grains may be another factor enhancing the dietary intake. Feed conversion ratio (FCR) showed significant difference ($P < 0.05$) between all dietary groups, however steers in T3 were significantly lower ($P < 0.05$), indicating that feeding bagasse–vinsasse mixture with pineapple peel silage resulted in the best feed conversion efficiency. This result could be related to the higher gross energy and nitrogen free extract (NFE) of pineapple waste compared to sweet corn waste, especially for simple sugars such as glucose, fructose and sucrose (Muller, 1978). Thus, steers fed with BP received more nutrients for body utilization than BS, which had a positive effect on steers' average daily gain (Azevedo and Alves, 2000). In agreement with the findings of Shaker et al. (2003), the lower FCR observed in the T3 group resulted from a lower ($P > 0.05$) concentrate intake.

From our findings, it is suggested that the bagasse–vinsasse mixture (70:30) could be used with sweet corn husk, cob and pineapple peel to produce silage and it can be the most suitable one for replacing conventional ingredients as total mixed ration silage for fattening steers. The silages, including locally produced agro-industrially by-products mainly for replacing conventional concentrate, were well preserved with high

fermentation quality and the intake of steers was supported similar to conventional diet without any silage with by-products. However, further studies will be needed to evaluate an availability of the silage also for other ruminant species under different growth and physiological stages.

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