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Effect of Fermented By-Product and Rice Straw on Milk Yield and Fatty Acid Composition in Dairy Cows

Thaintip Kraiprom[1], Somkiert Prasanpanich[1], Phongthorn Kungmun[1], Sour Sivijchai[2] and Sornthep Tumwasorn[1,*]

ABSTRACT

This experiment used by-products from agro-industry waste as a roughage source for dairy cows. Bagasse, pineapple peel, corn cob, corn stover and vinasse were used to produce fermented by-product (FBP). The objective of this study was to determine the effects of FBP with rice straw on the milk yield, milk composition and fatty acid profile in dairy cows. Fifteen dairy cows with 75–87.5% Holstein Friesian blood were used with an average initial body weight (± SD) of 407.33 ± 53.48 kg in mid-lactation and 111.25 ± 25.12 days in milk. Cows were randomly allocated to three treatments (T1 = five dairy cows fed rice straw *ad libitum*; T2 = five dairy cows fed FBP with rice straw at the ratio 50:50 (dry basis) *ad libitum*; T3 = five dairy cows fed sweet corn waste silage with rice straw at the ratio 50:50 (dry basis) *ad libitum*) using a completely randomized design. Data were adjusted with parity and initial body weight as covariates. The results revealed that the milk yield and 4% fat-corrected milk from cows fed FBP with rice straw were found to be the highest ($P < 0.05$) among all treatments. The caproic acid (C6:0) and palmitoleic acid levels (C16:1) from cows fed FBP with rice straw were the highest ($P < 0.05$) among all treatments. Moreover, short chain fatty acids (SCFAs), long chain fatty acids (LCFAs) and polyunsaturated fatty acids composed of γ-linolenic (C18:3n6c), α-linolenic (C18:3n3c), eicosatrienoic acid (C20:3n6) and arachidonic acid (C20:4n6) were significantly highest in cows fed FBP with rice straw. The body weight change and average daily gain obtained from cows fed with FBP and rice straw were found to be the highest among all treatments. It was concluded that dairy cows fed FBP with rice straw at the ratio of 50:50 on a dry matter basis increased the milk yield and the SCFA and LCFA contents. The present study showed great benefit from feeding FBP and rice straw as a ready-to-feed practice producing higher milk yield and quality.

Keywords: fermented by-products, dairy cows, milk yield, fatty acid composition

INTRODUCTION

Dairy farmers in Thailand are forced to feed their cows in the dry season when natural pasture supplies dry up with low quality roughage such as rice straw together with an expensive concentrate (Suksombat and Mernkrathoke, 2005). The majority of roughage in the tropics consists of fiber which is low in digestibility and nutrient contents (Leng and Brumby, 1986) and commonly farmers use silage or hay as roughage sources in the dry season. Fermented by-products (FBP) are

1 Department of Animal Science, Faculty of Agriculture, Kasetsart University, 10900, Thailand.
2 Dairy Farming Promotion Organization of Thailand (DPO), Saraburi 18180, Thailand.
* Corresponding author, e -mail: sornthep13@hotmail.com

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composed of the by-products from agro-industrial waste and in conjunction with agricultural by-products can be used as a roughage source for dairy cows (Suwannasin, 2009). Rice straw is a normal agricultural waste fed to dairy cows in Asia and many techniques have been applied to increase the feed intake and digestibility of untreated rice straw (Wanapat, 2009). The supplementation of FBP with rice straw can be used as another choice of roughage source for dairy cows.

Jensen (1995) reported that the synthesis of milk fatty acids are derived almost equally from two sources, the feed and the microbial activity in the rumen of the cow. The fatty acid synthesis in the mammary gland of the cow produces fatty acids with the number of carbons being 4–16 in length. The *de novo* synthesis in the mammary gland is 4:0–14:0 acids together with about half of the 16:0 from acetate and β-hydroxybutyrate. Acetate and butyrate are generated in the rumen by the fermentation of feed components. The butyric acid is converted to β-hydroxybutyrate during absorption through the rumen epithelium. Jensen (2002) reported that milk fat is composed of 69% saturated fatty acids (SFAs), 27% monounsaturated fatty acids (MUFAs) and 4% polyunsaturated fatty acids (PUFAs). MUFAs and PUFAs are beneficial constituents of the human diet (Banni and Martin, 1998) and may have positive effects on health (Simopoulos, 2002). Conjugated linoleic acid (CLA) is a mixture of geometric and positional isomers of linoleic acid with a conjugated double bond. Linoleic acid and α-linolenic acid are both precursors of the CLA isomer *cis*-9, *trans*-11 (Aii *et al*., 1999) which is the major isomer of CLA in milk fat. The role of CLA is as an inhibitor of the growth of cancer cells and it is also antiatherogenic, antidiabetic and immudulating (Parodi, 2002). The objective of the current study was to evaluate the effects of a diet composed of different roughage sources (rice straw, FBP with rice straw, and sweet corn waste silage with rice straw) on the milk yield, milk composition and fatty acid composition in mid-lactation of dairy cows and on their body condition score.

MATERIALS AND METHODS

Animals, diets and management

Fifteen healthy, vaccinated, multiparous 75–87.5% Holstein Friesian lactating dairy cows in the second lactation were used in this experiment. The cows had mean (± SD) days in milk of 111.25 ± 25.12, were aged 5–6 yr with an average body weight (± SD) of 407.33 ± 53.48 kg. The dairy cows were randomly allocated to pens and adjusted using the response variables of parity and covariance of the initial body weight into three groups. Group 1 consisted of five dairy cows fed *ad libitum* with rice straw. Group 2 consisted of five dairy cows fed FBP with rice straw in the ratio 50:50 (on a dry basis). Group 3 contained five dairy cows fed sweet corn waste silage (SCW) with rice straw in the ratio 50:50 (on a dry basis). All cows were housed in individual pens and were fed *ad libitum* with roughage allowing not more than 10% refusals. A commercial concentrate (87.90% dry matter, 18.29% crude protein) was provided to all dairy cows. The feeding level of the dairy cows in each group was calculated based on the requirements for maintenance and production (National Research Council, 2001) with twice daily feeding at 0600 hours and 1500 hours before milking. In addition, fresh cool water from individual automatic supply bowls and mineral blocks were available at all times.

Fermented by-product and sweet corn waste silage management

The FBP was composed of pineapple peel, corn stover, corn cob, bagasse and vinasse. Pineapple peel, corn stover and corn cob were obtained from canning factories. Bagasse was sourced as a by-product from the sugar industry. These by-products were collected and chopped into 3–4 cm lengths before use. Vinasse was obtained from an ethanol plant. The ratio of the by-

products and vinasse was 93:7 (on a fresh basis). The different treatments were all thoroughly mixed and fermented in two layers of plastic bags. Each bag was made up to 35 kg 30 d after fermentation. The SCW was composed of husk leaves, cobs, discarded kernels and small amounts of stalk which were all chopped into 2–3 cm pieces. SCW treatment mixtures were fermented in two layers of plastic bags for 30 d. Each bag was made up to 30 kg. Then, after 30 d of fermentation, the FBP and SCW bags were opened and samples were collected and analyzed for chemical composition and fermentation characteristics. The chemical compositions of ingredient are shown in Table 1.

Measurements

Feed intake was obtained through the difference between the amount of feed offered and the refusals collected daily. Feed samples were obtained and analyzed in all treatments. These feed samples were analyzed for dry matter (DM), crude protein, ether extract, ash and gross energy according to Association of Official Analytical Chemists (1990), for neutral detergent fiber, acid detergent fiber and acid detergent lignin according to Goering and Van Soest (1970), for pH according to Bolsen *et al*. (1992) and for water soluble carbohydrate (WSC) according to Dubois *et al*. (1956). The concentrations of volatile fatty acids (lactic acid, acetic acid, butyric acid and propionic acid) in the samples of FBP and SCW silage were measured by high performance liquid chromatography (Rooke *et al*., 1990). Cows were weighed at the beginning and at the end of the experiment and the body weight was calculated for live weight change. The milk yield was individually recorded at each milking time. The milk compositions were analyzed for fat, protein and lactose percentage by infrared spectroscopy (MilkoScan 133; Foss Electric; Hillerød, Denmark) and 4% FCM was calculated as described by Walker *et al*. (2001).

Milk samples were taken for free fatty acids and CLA analyses (gas chromatography; Hewlett Packard GCD system HP 6890; Hewlett Packard; Palo Alto, CA, USA). Fatty acid analysis was carried out as described by Hara and Radin (1978). In brief, milk fat was extracted from the milk sample using hexane and isopropanol (3:2, volume per volume per gram of fat cake),

Table 1 Chemical composition (% of dry matter) of diets used in the experiment.

Item	Concentrate	Rice straw	FBP	SCW
Dry matter	87.90	88.27	24.01	22.62
Crude protein	18.29	3.60	7.80	7.11
Ether extract	3.30	0.56	1.25	1.87
Crude fiber	20.50	34.27	30.21	26.18
Ash	8.20	13.18	6.40	3.81
Acid detergent fiber	34.50	48.58	43.77	41.34
Neutral detergent fiber	38.90	76.48	75.54	83.47
Acid detergent lignin	9.40	17.40	7.85	4.05
Gross energy (kcal.kg^{-1})	3,889.00	3,399.50	4,041.34	4,121.35
Water soluble carbohydrate	-	-	5.19	2.48
pH	-	-	3.58	3.51
Lactic (% of dry matter)	-	-	6.07	0.68
Acetic (% of dry matter)	-	-	8.69	10.60
Butyric (% of dry matter)	-	-	0.00	2.71
Propionic (% of dry matter)	-	-	1.59	0.00

FBP = Fermented by-products, SCW = Sweet corn waste silage.

modified from Kelly *et al*. (1998). Heptadecanoic acid (17:0) was added as an internal standard. The fatty acid methyl esters (FAME) were analyzed by gas chromatography (GC). The GC conditions were: injected temperature, 240 ºC; detector temperature, 260 ºC; carrier gas, He; split ratio, 1:30; temperature program, 70 ºC for 4 min, followed by an increase of 13 ºC.min^{-1} to 175 ºC, then 4 ºC. min^{-1} to 215 ºC. Peaks were identified by comparison of retention times with those of the corresponding standards (SupelcoTM37 component FAME Mix; Sigma-Aldrich Co.; St. Louis, MO, USA). Identification of peaks included two fatty acids between 14:0 and 22:6 and CLA isomers, that is, *c*9, *t*11; 3 *t*10, *c*12. The fatty acid compositions of the concentrate, rice straw, FBP, SCW and milk are presented in Tables 2 and 5.

Statistical analysis

All data obtained from the experiment were analyzed by analysis of variance using a completely randomized design and adjusting data with parity and initial body weight as covariates using the procedure of the Statistical Analysis System Institute software (Statistical Analysis System Institute, 1996). Differences between treatment means were determined by Duncan´s new multiple range test according to Steel and Torrie (1980).

RESULTS AND DISCUSSION

Chemical composition of feed

The chemical composition of the concentrate, rice straw, FBP and SCW on a dry matter basis are presented in Table 1. The dry matter of the SCW and FBP were found to be similar to those reported by Mustafa *et al*. (2004) who stated that the dry matter of sweet corn residue ensilaged was 22.62%. The pH and lactic acid levels of the FBP were at optimum levels (4.2 and 3–13% on a dry matter basis) according to Catchpoole and Henzell (1971). Good quality silage is characterized by its lactic acid concentration (Zobell *et al*., 2004) which is desired in silage-making, and thus has been developed to improve the conservation of silage (Rotz and Muck, 1994). Lactic acid inhibits the growth of microorganisms (Weinberg and Muck, 1996). The concentration of butyric acid from FBP was less than 0.1 g.kg^{-1} DM which is indicative of well preserved silages (Kung and Shaver, 2001). The FBP had higher amounts of water soluble carbohydrate (WSC) than the SCW. WSC or NC (sugar and starch) is used as the energy source for microbes in the rumen to produce volatile fatty

Table 2 Fatty acid composition of concentrate and different fiber sources.

Items	Concentrate	Rice straw	FBP	SCW
	grams per 100 g of total fatty acid			
C8:0	0.67	0.04	0.08	0.07
C12:0	11.93	0.87	1.15	0.09
C14:0	4.06	1.42	0.58	0.38
C16:0	17.83	35.23	19.50	27.43
C18:0	3.11	4.82	3.33	3.98
C18:1n9c	26.98	10.11	16.82	24.11
C18:2n6c	30.36	23.66	25.90	34.32
C18:3n6	0.00	0.26	0.21	0.07
C20:0	0.48	2.88	0.89	0.98
C20:1	0.21	0.05	0.12	0.38
C22:0	0.27	2.06	0.59	0.97

FBP = Fermented by-products, SCW = Sweet corn waste silage.

acid (VFAs) such as acetic, propionic and butyric acids. The optimum level of WSC was reported to be 6-12% (Aminah *et al*. 2004). The SCW silage had higher levels of linoleic acid (C18:2) than FBP and rice straw (Table 2). However, the SCW contained the lowest concentration of linolenic acid (C18:3). Both linoleic acid and linolenic acid are converted to CLA in the rumen (Kelly *et al*., 1998).

Feed intakes

The DM consumption is presented in Table 3. There were no significant differences in roughage (kilogram per day, percent body weight and gram per kilogram based on the metabolic body weight, $BW^{0.75}$) and concentrate DM intake (percent body weight). The concentrate DM intake in terms of kilograms per day and grams per kilogram $BW^{0.75}$ were highest in cows fed only rice straw ($P < 0.05$). Cows fed solely on rice straw in terms of kilograms per day had higher ($P < 0.05$) total DM intake than cows fed FBP with rice straw. However, the total DM intake in terms of percent body weight and grams per kilogram $BW^{0.75}$ were not different among cows fed different fiber sources. Huhtanen *et al.* (2003) reported that the fermentation quality of silages had a major effect on the feed intake, nutrient utilization and milk production in ruminants. The FBP used in this study had no detectable odor of butyric acid (0% DM) and thus, this had no effect on the feed intake. Erdman (1993) reported that final fermentation products (lactic, acetic and butyric acids) were present in high concentrations in high moisture forages which were likely to have a negative effect on the intake of silage.

Milk production and fatty acid composition

The milk yield and 4% fat-corrected milk content (4% FCM) were significantly ($P < 0.05$) different among treatments. Cows fed FBP with rice straw had higher milk and 4% FCM yields ($P < 0.05$) than cows fed SCW with rice straw and rice straw only (Table 4). This result was similar to the report by Phipps *et al*. (1995) who found that diets based on maize silage (MS) increased the milk yield and milk protein content. Wanapat *et al*. (2009) reported that feeding only rice straw to dairy cows could decrease the milk yield to as low as 10.80 $kg.d^{-1}$. The milk protein, milk fat, solid not fat (SNF) and total solid (TS) contents were not significantly ($P > 0.05$) different

Table 3 Dry matter intake of lactating dairy cows receiving different fiber sources.

Item	RS	FBP +RS	SCW+RS	SEM
Roughage DM intake				
($kg.d^{-1}$)	4.94±0.18	5.18±0.52	5.38±0.45	0.11
(percent body weight)	1.23±0.18	1.25±0.09	1.37±1.18	0.03
($g.kg^{-1}$ $BW^{0.75}$)	55.02±6.60	56.09±2.17	60.86±3.39	1.15
Concentrate DM intake				
($kg.d^{-1}$)	7.33±0.00^{a}	6.41±0.00^{b}	6.41±0.00^{b}	0.00
(percent body weight)	1.83±0.20	1.57±0.27	1.66±0.23	0.06
($g.kg^{-1}$ $BW^{0.75}$)	81.46±6.72^{a}	70.13±8.81^{ab}	73.08±7.80^{a}	2.02
Total DM intake				
($kg.d^{-1}$)	12.26±0.18^{a}	11.59±0.52^{b}	11.79±0.45^{ab}	0.50
(percent body weight)	3.06±0.38	2.80±0.35	3.03±2.45	0.71
($g.kg^{-1}$ $BW^{0.75}$)	136.46±5.11	126.21±10.22	133.92±10.48	0.00

^{a,b} = Means within the same row with different superscripts are significantly different ($P < 0.05$).

RS = Rice straw, FBP = Fermented by-products, SCW = Sweet corn waste silage, SEM = Standard error of the mean, DM = Dry matter, $BW^{0.75}$ = metabolic body weight.

among treatments. Lock and Shingfield (2004) found feeding cows MS had no effect on the milk fat content. The milk lactose contents from cows fed FBP with rice straw and rice straw only was higher than those from cows fed SCW with rice straw ($P < 0.05$). Mansson (2001) reported that bovine milk contains approximately 4.60% lactose, 3.4% protein and 4.2% fat which was consistent with the ranges reported in the current study. Cows fed FBP had the significantly ($P < 0.05$) highest milk yield in association with milk protein, SNF and TS. Gibson (1987) stated that the high positive correlation between milk yield and total solids, fat and protein contents indicates that adequate feeding of dairy cows will lead to corresponding increased milk yield constituents. Such high milk production and 4%FCM were highest in the group of cows fed FBP because FBP is a high quality forage. FBP had the highest crude protein and is low in fiber content, so when fed to dairy cows, this could improve the milk yield and milk composition. Sandovol-Castro *et al.* (2000) reported that the availability and quality of roughage feed under a tropical dairy system could influence the level of milk output as well as its components.

The fatty acid composition in the milk fat samples are presented in Table 5, which shows that caproic acid (C6:0) and palmitoleic (C16:1) acid from cows fed FBP with rice straw had the highest ($P < 0.05$) values. Furthermore, cows fed FBP with rice straw and rice straw only had higher lauric acid (C12:0), tridecylic acid (C13:0) and myristoleic acid (C14:1) than cows fed SCW with rice straw. Moreover, the short chain fatty acid (SCFA) levels of cows fed FBP with rice straw were found to be the highest ($P < 0.05$). The isomer *trans*-10, *cis*-12 C18:2 CLA was higher ($P < 0.05$) in cows fed FBP with rice straw and rice straw only. Cows fed FBP with rice straw had a higher level of *cis*-9, *trans*-11 C18:2 CLA than cows fed SCW with rice straw and rice straw only, as this isomer of CLA was the major isomer in ruminant milk fat representing 80–90% of the total CLA in the milk fat. The milk fat content of CLA is affected by the intake of unsaturated fatty acid (Griinari *et al*., 1998). Viviani (1970) presented a schematic diagram showing that CLA was formed as an intermediate product in the biohydrogenation pathway of linolenic acid. However, the linolenic pathway did not involve CLA as an intermediate. The isomer *cis*-9, *trans*-11 may be produced endogenously from *trans*-11-octadenoic acid by Δ-9-desaturase in the body tissue (Griinari *et al*., 1997). Other factors may affect CLA production in the rumen. The type and source of dietary carbohydrate may influence the rates of microbial fermentation in a way that alters the rate of CLA production or utilization by rumen microbes and ultimately the concentration of CLA in the milk fat. The total CLA of cows fed FBP with rice straw was higher than for cows fed SCW with rice

Table 4 Milk yield and milk composition in lactating dairy cows receiving different fiber sources.

Item	RS	FBP +RS	SCW+RS	SEM
4% FCM (kg.d^{-1})	11.22±0.43^{b}	15.69±2.24^{a}	12.50±1.09^{b}	0.38
Milk composition				
Protein (%)	3.09±0.20	2.99±0.65	2.95±0.65	0.04
Fat (%)	4.35±0.50	4.37±0.62	4.32±0.56	0.15
Lactose (%)	4.84±0.08^{a}	4.60±0.29^{a}	4.91±0.06^{b}	0.05
Solids-not-fat (%)	8.89±0.61	8.52±0.60	8.55±0.19	0.13
Total solids (%)	13.24±0.14	12.90±0.73	12.88±0.67	0.21

^{a,b} = Means within the same row with different superscripts are significantly different ($P < 0.05$).

RS = Rice straw, FBP = Fermented by-products, SCW = Sweet corn waste silage, SEM = Standard error of the mean, FCM = 4% fat-corrected milk content.

Table 5 Fatty acid contents of milk fat in lactating dairy cows receiving different fiber sources.

Item	RS	FBP +RS	SCW +RS	SEM
	----------mg/g fat ----------			
C6:0	5.22±0.64[b]	6.12±0.64[a]	5.95±0.54[ab]	0.16
C8:0	5.62±1.34	6.99±0.91	5.79±0.71	0.26
C10:0	13.74±3.16	17.41±3.41	14.62±1.86	0.74
C12:0	39.66±3.38[a]	39.23±5.18[a]	29.26±2.09[b]	0.97
C13:0	0.81±0.05[a]	0.92±0.16[a]	0.57±0.08[b]	0.03
C14:0	109.43±5.45	106.03±13.50	103.81±1.83	2.19
C14:1	9.33±1.18[ab]	10.85±1.13[a]	7.81±1.54[b]	0.34
C15:0	10.46±0.75[a]	9.51±0.60[b]	9.57±0.65[b]	0.17
C16:0	351.13±25.07	344.35±22.14	383.64±46.73	8.57
C16:1	14.53±2.11[b]	22.32±0.40[a]	15.22±4.17[b]	0.70
C18:0	132.69±6.35[a]	106.75±2.68[b]	118.68±14.48[b]	2.39
C18:1n9t	5.04±0.33	5.66±1.21	5.36±0.91	0.22
C18:1n9c	2.15±0.33	2.27±0.19	2.09±0.45	0.17
C18:2n6c	16.48±3.99	19.92±0.24	15.16±3.91	0.83
C18:3n3	1.55±0.08[b]	1.82±0.15[a]	1.29±0.32[b]	0.05
C18:3n6c	0.51±0.10[ab]	1.49±1.20[a]	0.00±0.00[b]	0.18
C20:0	2.52±0.17[a]	2.02±0.08b	2.16±0.14[b]	0.03
c9t11CLA (C18:2)	10.41±1.73	12.68±0.93	10.49±0.63	0.49
t10c12CLA(C18:2)	0.59±0.04[a]	0.84±0.22[a]	0.15±0.21b	0.05
c9c11CLA (C18:2)	0.48±0.27	0.40±0.37	0.15±0.21	0.07
Total CLA	11.81±1.74[ab]	14.20±0.85[a]	11.22±2.58[b]	0.48
C20:2	1.96±1.13[a]	0.70±0.12[a]	0.58±0.11[b]	0.15
C22:0	1.03±0.11[a]	0.69±0.10[b]	0.77±0.50[b]	0.02
C20:3n6	0.58±0.05[b]	0.79±0.15[a]	0.00±0.00[b]	0.03
C20:4n6	1.21±0.09[b]	1.55±0.04[a]	1.26±0.24[b]	0.04
C23:0	0.46±0.05[a]	0.23±0.15[b]	0.37±0.05[a]	0.03
C20:5n3	1.26±0.34[a]	0.74±0.30[b]	0.84±0.03[b]	0.07
C20:1	1.74±0.34	1.66±0.20	1.52±0.26	0.07
Short chain FA (C4:0-C13:0)	66.85±8.78[b]	72.93±10.22[a]	57.66±3.50[b]	2.07
Medium chain FA (C14:0-C17:0)	492.10±25.88	495.65±34.72	520.02±47.98	9.64
Long chain FA (≥C18:0)	430.46±31.01	431.31±44.77	423.03±47.85	10.81
Saturated FA	585.15±187.73	572.60±159.84	676.65±38.29	37.22
Monounsaturated FA	269.73±21.41	311.99±45.02	297.57±31.94	8.99
Polyunsaturated FA	37.98±3.88[b]	44.43±2.41[a]	32.50±6.34[b]	1.17

[a,b] = Means within the same row with different superscripts are significantly different ($P < 0.05$).

RS = Rice straw, FBP = Fermented by-products, SCW = Sweet corn waste silage, SEM = Standard error of the mean, FA = Fatty acid, CLA = Conjugated linoleic acid.

straw. Lock and Garnsworthy (2003) reported that CLA in dairy cows ranged between 0.8 and 1.9 g per 100 g fat (8–19 mg.g^{-1} fat). Long chain fatty acids (LCFAs) such as γ-linolenic (C18:3n6c), α-linolenic (C18:3n3c), eicosatrienoic acid (C20:3n6) and arachidonic acid (C20:4n6) were at their highest levels in cows fed FBP with rice straw ($P < 0.05$). The PUFA level in cows fed FBP with rice straw was the highest (4.78%) which was higher than reported by Walstra *et al*. (1999) who found that PUFA was 2.3% of the total fatty acids with linoleic and α-linolenic being the main PUFA constituents. Linoleic and α-linolenic are referred to as essential FAs which cannot be synthesized by humans and need to be supplied in the diet.

Body weight gain and live weight change

The body weight change during the study period is presented in Table 6. Cows fed rice straw lost weight (-14.40 kg) while cows fed FBP and SCW with rice straw gained weight (11.40 and 0.80 kg, respectively). Moreover, cows fed FBP and SCW silage with rice straw had higher average dairy gain (ADG) (0.13 and 0.01 kg.d^{-1}) than those cows fed rice straw only (-0.16 kg.d^{-1}). Feeding FBP with rice straw to cows in the study yielded better results than the normal feeding option. FBP containing a high concentration of starch may become an important factor at high intake levels for dairy cows (Van Soest, 1994).

CONCLUSION

Dairy cows fed FBP with rice straw at the ratio of 50:50 on a dry matter basis increased milk and 4% FCM yields. Levels of SFA and LCFA including C18:3n6c, C18:3n3c, C20:3n6 and C20:4n6, and PUFA were found to be significantly highest in cows fed FBP with rice straw. The ADG and body weight change in cows fed FBP with rice straw were found to be the highest while those fed with rice straw lost weight. It was concluded that feeding FBP and rice straw as a roughage source for lactating dairy cows could improve significantly the milk yield and body weight gain including the milk fat composition.

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Table 6 Body weight change and average daily gain of lactating cows receiving different fiber sources.

Item	RS[1]	FBP+RS[2]	SCW+RS[3]	SEM
Live weight (kg)				
Initial (kg)	406.40±41.26	401.00±65.55	414.60±62.41	14.18
Final (kg)	392.00±26.19	412.40±59.67	415.40±38.38	10.72
Body weight change (kg)	-14.40±19.10	11.40±29.15	0.80±15.16	5.70
Average daily gain (kg.d^{-1} per head)	-0.16±0.21	0.13±0.17	0.01±0.32	0.06

RS = Rice straw, FBP = Fermented by-products, SCW = Sweet corn waste silage, SEM = Standard error of the mean.

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