



## Original Research Article

# Effect of ground corn cobs as a fiber source in total mixed ration on feed intake, milk yield and milk composition in tropical lactating crossbred Holstein cows



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## ABSTRACT

The aim of this study was to evaluate the effect of ground corn cobs (GCC) as a sole fiber source in total mixed ration (TMR) on feed intake, milk yield and milk composition in tropical lactating crossbred Holstein cows. Four multiparous crossbreds Holstein Friesian dairy cows with an initial body weight (BW) of  $415.5 \pm 26.20$  kg were used in a  $4 \times 4$  Latin square design. The dietary treatments of TMR contained a roughage-to-concentrate ratio of 40:60. The roughage source was used at different ratios of GCC to rice straw (RS) at 100:0, 82.5:17.5, 67.5:32.5, and 50:50 for TMR1 to TMR4, respectively. The results revealed significant improvements in intake of dry matter, protein, neutral detergent fiber (NDF) and metabolizable energy (ME) for TMR1 and TMR2 ( $P < 0.05$ ), while the digestibility of nutrients was not altered by the treatments ( $P \geq 0.05$ ). Ground corn cobs was used for up to 100% of the total roughage without affecting milk production. Moreover, ruminal pH, temperature, ammonia-nitrogen ( $\text{NH}_3\text{-N}$ ) and volatile fatty acid (VFA) concentrations were not impacted by the treatments ( $P > 0.05$ ). However, milk yield was significantly different among the GCC:RS ratios ( $P < 0.05$ ) and was the highest in TMR1 and TMR2 (13.1 kg/d), while the milk compositions were not changed ( $P > 0.05$ ). The results imply that using GCC as a whole roughage source significantly improved nutrients intake and milk yield in dairy cows raised in tropical areas.

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## 1. Introduction

Crossbred dairy cows raised in the tropics are normally fed low quality roughages, principally agricultural crop-residues such as rice straw (RS) (Devendra and Chantalakhana, 2002; Wanapat et al.,

2015). However, RS is low in nutritive value with low protein (2% to 5% DM), high fiber, with neutral detergent fiber (NDF) > 70%, and DM digestibility < 50%, resulting in low voluntary feed intake (1.5% to 2.0% of BW) (Wanapat and Cherdthong, 2009; Wanapat et al., 2009b). Corn cobs (CC) is a by-product of a major cereal grown worldwide. Since the ratio between corn grain and CC may reach 100:18, a large quantity of CC can be generated (Cao et al., 2004). Corn cobs is a prominent cereal crop by-product in Thailand, and currently most of these materials are wasted natural resources and also are sources of environmental pollution. Legal steps are already being taken in several countries to ban the burning of CC. Corn cobs are high in cellulose and hemicelluloses, and are potentially valuable sources of roughage for ruminants (Avila-Segura et al., 2011; Van Eylen et al., 2011; Liu et al., 2011). Ground corn cobs (GCC) are a good source of fiber, and when enriched with urea (15 g/kg)

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and fed to swamp buffaloes, they can be efficiently utilized in the rumen and provide good fermentation end-products (Wanapat et al., 2009a). Emery et al. (1964) reported that dairy cows fed GCC as a roughage source could have improved feed intake and milk yield compared with those fed ground hay. However, no data have been reported on replacing RS by GCC in total mixed ration (TMR) in tropical area. The aim of this study is to evaluate GCC as whole fiber source in TMR on feed intake, milk yield and milk composition in tropical lactating crossbred Holstein cows.

## 2. Materials and methods

### 2.1. Animals, experimental design and diets

Four multiparous crossbreds Holstein Friesian (75%) dairy cows with an initial body weight of  $415.5 \pm 26.20$  kg and day-in-milk of  $131.8 \pm 39.40$  d (average milk yield 12.75 kg/d) were used in a  $4 \times 4$  Latin square design with four treatments. The TMR consisted of roughage and concentrate at a ratio of 40:60. The roughage source used in TMR had different ratios of GCC to RS which were 100:0, 82.5:17.5, 67.5:32.5 and 50:50 in TMR1 to 4, respectively. The GCC and RS were obtained from a local market, and ground to pass through a 1-cm screen using a chopper machine. The roughage was then mixed with concentrate at the ratio of 40:60 using a horizontal feed mixer and fed as a TMR. The composition of dietary treatments, GCC and RS are shown in Table 1.

Cows were housed in individual pens and individually fed TMR at 06:00, 11:00, and 16:00. All cows were fed *ad libitum*. Clean fresh water and mineral blocks were available during the experiment. The experiment was run in 4 periods. Each period lasted for 21 d, in

which the first 14 d was for treatment adaptation, and the last 7 d were used for feed intake measurements and sample collections. Refusals were collected every day, and sampled (10% of refusal weight), and feed offered adjusted 3 times per week to ensure 5% to 10% refusal of the total feed offered. Individual voluntary feed intake was calculated by the difference between offered feed and refusals. Feed samples from offered diet were collected from each experimental period. Body weights were measured at the first and last day of samplings. Milk yield was recorded during the 21 d which data reported at the last 7 d of each period.

### 2.2. Data collection and sampling procedures

The TMR, GCC and RS were sampled daily during the collection period and were composited by period prior to chemical analyses. Feed and fecal samples were collected during the last 7 days of each period. For the last 7 days, fecal samples were collected twice a day by rectal sampling. Fecal sample pools were created by combining samples from last 7 days of each animal. Composited samples were dried at 60°C, ground (1-mm screen using Cyclo-tech Mill, Tecator), and then analyzed for DM, ash, organic matter (OM), ether extract (EE), crude protein (CP) content (AOAC, 2000), and NDF and acid detergent fiber (ADF) (Van Soest et al., 1991), and acid-insoluble ash (AIA). Acid-insoluble ash was used as internal marker to estimate digestibility of nutrients (Van Keulen and Young, 1977). Metabolizable energy (ME) was calculated according to the equation described by Robinson et al. (2004):  $ME \text{ (MJ/kg DM)} = 0.82 \times [2.4 \times CP + 3.9 \times EE + 1.8 \times \text{the rest of the OM}] \times \text{in vitro organic matter digestibility (ivOMD)}$ , where CP, EE and OM are in gram per kilogram DM and ivOMD values obtained from our previous *in vitro* study with mean values of 530 g/kg DM.

Milk samples were composited during the last 7 days of each experimental period, according to yield, for both the morning and afternoon milking, preserved with 2-bromo-2 nitropropane-1, 3-dial, and stored at 4°C until analysis for fat, protein, lactose, totals solids, and solids-not-fat content by infrared methods using Milko-Scan 33 (Foss Electric, Hillerod, Demark).

At the end of each period, jugular blood and rumen fluid samples were collected at 0, 2 and 4 h after feeding. A blood sample (about 10 mL) was collected from the jugular vein (at the same time as rumen fluid sampling) into tubes containing 12 mg of ethylene diamine tetra-acetic acid (EDTA), and plasma was separated by centrifugation at  $500 \times g$  for 10 min and stored at  $-20^\circ\text{C}$  until analysis of blood urea N according to the method of Crocker (1967). Approximately 200 mL of rumen fluid was taken from the rumen by a stomach tube connected with a vacuum pump at each time at the end of each period. Rumen fluid was immediately measured for pH and temperature using (Hanna Instruments HI 8424 microcomputer, Singapore) after withdrawal. Rumen fluid samples were then filtered through 4 layers of cheesecloth. Fluid sample was taken into bottle containing 5 mL of 1 mol/L  $\text{H}_2\text{SO}_4$  added to 45 mL of rumen fluid. The mixture was centrifuged at  $16,000 \times g$  for 15 min, and the supernatant was stored at  $-20^\circ\text{C}$  before  $\text{NH}_3\text{-N}$  analysis using the Kjeltach Auto 1030 Analyzer and volatile fatty acid (VFA) analysis using high performance liquid chromatography (HPLC). The HPLC-system consisted of a Shimadzu VP SERIES with SpD10A detector and WINCHROM software. A 3.9 mm  $\times$  300 mm stainless-steel column, packed with ReproGel H and a pre-column, packed with the same material were used. The mobile phase consisted of 10 mmol/L  $\text{H}_2\text{SO}_4$  (pH 2.5) and the flow rate was 0.8 mL/min. The UV detector (at 210 nm) was employed for quantification. The UV-Visible spectra were recorded at the peak maxima and were corrected for the solvent background. The results were determined, using the standard volatile acids (Merck, India) as control.

**Table 1**

Ingredients and chemical compositions of total mixed rations (TMR), ground corn cobs (GCC) and rice straw (RS) used in the experiment (DM basis).<sup>1</sup>

Item	TMR1	TMR2	TMR3	TMR4	RS	GCC
Ingredient, %						
GCC	40.0	33.0	27.0	20.0		
RS	0.0	7.0	13.0	20.0		
Cassava chip	17.8	17.8	17.9	18.0		
Corn meal	2.4	2.4	2.4	2.4		
Rice bran	4.7	4.7	4.7	4.7		
Soybean meal	16.1	16.1	15.8	15.6		
Whole cotton seed	7.3	7.3	7.3	7.3		
Palm kernel cake	4.7	4.7	4.7	4.8		
Molasses	5.0	5.0	5.0	5.0		
Urea	0.4	0.4	0.4	0.5		
Limestone	0.5	0.5	0.5	0.5		
Dicalcium phosphate	0.5	0.5	0.5	0.5		
Salt	0.3	0.3	0.3	0.3		
Mineral premix <sup>2</sup>	0.5	0.5	0.5	0.5		
Chemical composition, %						
Dry matter	97.1	97.0	96.7	96.7	94.6	90.5
Ash	6.7	7.0	7.8	8.2	8.2	2.5
Organic matter	93.3	93.0	92.2	91.7	91.8	97.5
Crud protein	13.2	13.0	12.9	12.8	3.0	2.3
Ether extract	3.2	3.2	3.3	3.2	3.4	0.8
Neutral detergent fiber	53.7	54.1	53.5	54.0	80.4	87.7
Acid detergent fiber	22.4	23.6	22.9	24.5	53.2	47.7
Hemicelluloses <sup>3</sup>	31.9	30.5	30.6	29.6	27.2	40.0
Cellulose <sup>3</sup>	16.5	19.1	17.8	18.6	41.2	36.7
Lignin <sup>3</sup>	5.3	4.5	5.1	5.8	12.0	11.0
ME <sup>4</sup> , MJ/kg DM	11.3	10.5	10.9	10.0	6.3	6.7

<sup>1</sup> The roughage source used different ratios of GCC to RS: TMR1, 100:0; TMR2, 82.5:17.5; TMR3, 67.5:32.5 and TMR4, 50:50.

<sup>2</sup> The mineral premix per each kilogram provided vitamin A, 10,000,000 IU; vitamin E, 70,000 IU; vitamin D, 1,600,000 IU; Fe, 50 g; Zn, 40 g; Mn, 40 g; Co, 0.1 g; Cu, 10 g; Se, 0.1 g; I, 0.5 g.

<sup>3</sup> These are calculated values. Hemicellulose is NDF-ADF; Cellulose is ADF-lignin.

<sup>4</sup> Metabolizable energy (ME) was calculated according to the equation described by Robinson et al. (2004).

### 2.3. Statistical analysis

All data from the experiment were analyzed according to a  $4 \times 4$  Latin square design using the GLM procedure (SAS, 1998) according to the model:  $Y_{ijk} = \mu + M_i + A_j + P_k + \varepsilon_{ijk}$ , where  $Y_{ijk}$ , observation from cow  $j$ , receiving TMR  $i$ , in period  $k$ ;  $\mu$ , the overall mean,  $M_i$ , effect of GCC to rice straw ratios ( $i = 1, 2, 3, 4$ ),  $A_j$ , the effect of cows ( $j = 1, 2, 3, 4$ ),  $P_k$ , the effect of period ( $k = 1, 2, 3, 4$ ), and  $\varepsilon_{ijk}$ , residual effect. Significant differences between individual means were evaluated using the Duncan's multiple comparison tests when a significant ( $P < 0.05$ ) effect was detected (Steel and Torrie, 1980). Standard errors of means were calculated from the residual mean squares in the analysis of variance.

## 3. Results and discussion

### 3.1. Chemical composition of feeds

The TMR diets contained concentrations of 12.9% to 13.2% CP and 10.0 to 11.3 MJ/kg DM of ME, sufficient for supporting the requirement of dairy cows yielding 10 to 15 kg/d milk with 4% milk fat (NRC, 2001). These values were expected to support the level of performance of the cows in our study. Furthermore, GCC was established as high-quality roughage and RS as having poor quality when comparing the chemical composition of hemicelluloses and cellulose (Avila-Segura et al., 2011; Van Eylen et al., 2011; Liu et al., 2011). The hemicellulose content in GCC is higher than in RS at 13.02% (see Table 1), while cellulose is lower, at 4.5% DM. Hemicellulose likely has an even higher digestion fraction than cellulose (Van Eylen et al., 2011). Lignin were ranged from 4.5% to 5.8% DM, while RS had higher lignin content than GCC. Therefore, GCC contains high hemicellulose, low in cellulose and lignin, which tends to increase digestibility and result in enhanced dry matter feed intake.

### 3.2. Effect on feed intake, nutrient intake and digestibility

Cows fed higher proportions of GCC (TMR1 and TMR2) consumed significantly more feed than those fed TMR3 and TMR4 ( $P < 0.05$ ). Dry matter intake (DMI) is fundamentally important in nutrition because it establishes the amount of nutrients available to an animal for health and production, including milk production. The data obtained in this study showed that CP, OM and ME intakes were significantly different ( $P < 0.05$ ) among the treatments, with the linearly greatest values for dairy cows fed TMR1 (Table 2). These results were in agreement with Emery et al. (1964), who showed that GCC was better roughage than ground hay and equal to chopped hay for maintaining feed intake in dairy cows. The difference in intake response is attributed to the higher-quality of the GCC ration compared to the lower-quality RS. It should be pointed out that a GCC could substitute for RS (Calabrò et al., 2012, 2014). This means that if a slightly poorer RS, which would probably be the quality of RS on most dairy farms, had been used for comparison, GCC would have compared even more favorably with RS than occurred in our study. Rice straw on most dairy farms is generally of lower quality than used here (Wachirapakorn et al., 2014) and GCC could be expected to compare even more favorably than in this study. The apparent digestibility of nutrients was not altered by the GCC:RS ratio ( $P > 0.05$ ). Moreover, there was a trend for digestion coefficients of DM and OM to increase as GCC proportion was increased due to the higher DM degradation of GCC as compared to RS. No significant differences existed in fiber digestibility among the rations, which was probably due to the comparable intake of fiber in the rations (Wanapat and Kang, 2015; Wanapat et al., 2015). In addition, the digestibility values for all of the rations were lower than expected from most published values for ration components.

**Table 2**

Effect of various total mixed rations (TMR) on body weight (BW) change, dry matter intake (DMI), nutrient intake and nutrient digestibility in crossbred lactating dairy cows.<sup>1</sup>

Item	TMR1	TMR2	TMR3	TMR4	SE
BW, kg	436.6	437.5	429.3	434.5	2.65
BW change, kg/d	0.5	0.6	0.4	0.2	0.19
DMI, kg/d	15.3 <sup>a</sup>	15.2 <sup>a</sup>	13.9 <sup>b</sup>	13.4 <sup>b</sup>	0.48
DMI, % BW	3.5 <sup>a</sup>	3.5 <sup>a</sup>	3.2 <sup>b</sup>	3.2 <sup>b</sup>	0.12
DMI, g/kg BW <sup>0.75</sup>	160.5 <sup>a</sup>	158.8 <sup>a</sup>	147.5 <sup>b</sup>	140.9 <sup>b</sup>	4.67
Digestion coefficient, %					
Dry matter	73.4	72.4	68.0	65.6	3.44
Organic matter	75.5	74.3	69.8	68.8	3.44
Crude protein	82.9	81.5	80.5	76.4	3.32
Neutral detergent fiber	63.7	63.4	58.2	58.1	5.14
Acid detergent fiber	52.4	52.6	45.6	44.5	4.70
Nutrient intake, kg/d					
Crude protein	2.1 <sup>a</sup>	2.0 <sup>a</sup>	1.8 <sup>ab</sup>	1.7 <sup>b</sup>	0.08
DOM <sup>2</sup>	10.9 <sup>a</sup>	10.5 <sup>a</sup>	9.0 <sup>ab</sup>	8.5 <sup>b</sup>	0.81
Neutral detergent fiber	8.2	8.2	7.4	7.1	0.30
Acid detergent fiber	3.4	3.6	3.2	3.4	0.09
ME, MJ/d	169.5 <sup>a</sup>	166.5 <sup>a</sup>	136.8 <sup>b</sup>	128.4 <sup>b</sup>	7.11
ME, MJ/kg DM	11.3	10.9	10.0	10.0	1.23

SE = standard error of means; DOM = digestible of organic matter; ME = metabolizable energy.

<sup>a,b</sup> Within a same row, means with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup> The roughage source used different ratios of ground corn cobs (GCC) to rice straw (RS): TMR1, 100:0; TMR2, 82.5:17.5; TMR3, 67.25:32.75 and TMR4, 50:50.

<sup>2</sup> One kg DOM, 15.9 MJ ME/kg (Kearl, 1982).

However, the digestibilities were similar but slightly lower than those reported by Wanapat and Cherdthong (2009) and Wachirapakorn et al. (2014) in a similar experiment involving GCC. The limitation of power in the current experimental design may also affect the digestibility data considerably.

### 3.3. Milk production and composition

Milk yields increased ( $P > 0.05$ ) with incremental ratios of GCC in TMR diets at 13% and 20% (13.1, 13.1, 12.4 and 12.4 kg/d for TMR1, TMR2, TMR3 and TMR4, respectively). Feed efficiency was similar for all diets ( $P > 0.05$ ). More feed (DM, CP, OM, and ME) was consumed and milk yield was higher with the inclusion of GCC in the ration to replace RS. The kg of milk per kg of DMI and 4% FCM per kg of DMI were quite low which indicated that dietary treatments could have potential for improving milk production in cows. However, it has been debated whether milk production is driven by intake or whether intake is driven by milk production. On the basis of ME intake regulation theory and others theories, cows appear to consume feed to meet energy needs, suggesting that intake is driven by milk production (NRC, 2001; Calabrò et al., 2012). Numerous lactation studies with bovine somatotropin (27 mg/d) have clearly shown this increase in ME intake in response to energy expenditure, in which DMI follows milk production (Etherton and Bauman, 1998). In addition, the ratio of GCC in the TMR had no significant negative effects ( $P > 0.05$ ) on milk compositions. Milk fat content and energy corrected milk were also not affected ( $P > 0.05$ ) by the increase in cobs but tended to be higher for the high GCC ration (Table 3).

### 3.4. Characteristics of ruminal fermentation and blood metabolites

The rumen parameters measured were pH, temperature,  $\text{NH}_3\text{-N}$ , and VFA. Blood urea N (BUN) was also determined to investigate the relationship with rumen  $\text{NH}_3\text{-N}$  and protein utilization. Rumen fluid pH was not altered among the treatments, and the values were stable at pH 6.8 to 6.9. Ruminal pH ranges from 6.8 to 6.9, according to Wanapat and Cherdthong (2009), who

**Table 3**Effect of various total mixed rations (TMR) on milk yield and composition in crossbred lactating dairy cows.<sup>1</sup>

Item	TMR1	TMR2	TMR3	TMR4	SE
Milk yield, kg/d	13.1 <sup>a</sup>	13.1 <sup>a</sup>	12.4 <sup>b</sup>	12.4 <sup>b</sup>	0.25
4% FCM, kg/d	13.2	13.5	12.4	12.5	0.36
Protein, kg/d	0.4	0.4	0.4	0.4	0.01
Fat, kg/d	0.5	0.6	0.5	0.5	0.01
Efficiency					
Milk:DMI, kg/kg	0.9	0.9	0.9	0.9	0.09
4% FCM:DMI, kg/kg	0.9	0.9	0.9	0.9	0.07
ECM milk <sup>2</sup> , kg	13.5	13.7	12.7	13.1	1.26
Milk composition, %					
Fat	4.1	4.2	4.0	4.0	0.09
Protein	3.4	3.5	3.4	3.4	0.07
Lactose	4.6	4.7	4.7	4.8	0.06
Solids not fat	8.7	8.8	8.8	8.9	0.09
Total solids	12.9	13.0	12.9	12.9	0.19

SE = standard error of means; FCM = fat-corrected milk; DMI = dry mater intake; ECM = energy-corrected milk.

<sup>a,b</sup> Within a same row, means with different superscripts differ ( $P < 0.05$ ).<sup>1</sup> The roughage source used different ratios of ground corn cobs (GCC) to rice straw (RS): TMR1, 100:0; TMR2, 82.5:17.5; TMR3, 67.25:32.75 and TMR4, 50:50.<sup>2</sup> Energy-corrected milk = Milk production  $\times$  (0.383  $\times$  % fat + 0.242  $\times$  % protein + 0.7832)/3.1138.

suggested that the optimum level of pH in the rumen for microbial digestion of fiber and protein should be 6.5 to 7.0 when fed mostly on roughages. Ruminal NH<sub>3</sub>-N and BUN ranged from 13.8 to 16.4 mg/dL and 9.3 to 9.7 mg/dL, respectively (Table 4). The NH<sub>3</sub>-N and BUN values tended to be higher in cows fed the highest ratio of GCC and were in good ranges for rumen fermentation. Ruminal NH<sub>3</sub>-N is an important nutrient in supporting efficient rumen fermentation (Satter and Slyter, 1974; Cherdthong et al., 2011a, b). Ruminal NH<sub>3</sub>-N concentrations in this study ranged from 13.8 to 16.4 mg/dL, which agreed with the report of Wanapat and Pimpa (1999) (13.6 to 17.6 mg/dL).

The total VFA, acetic acid, propionic acid, butyric acid proportions, and acetic acid:propionic acid ratio are shown in Table 4. There were no significant differences in VFA concentrations or molar proportions of VFA ( $P > 0.05$ ). The total VFA concentrations in all of the treatments ranged from 133.1 to 139.8 mmol/L and were similar to those reported by Wanapat et al. (2008, 2009a) also, the proportions of acetate, propionate and butyrate in this study were in accordance with Wanapat et al. (2008, 2009a). The proportions of volatile fatty acids (acetate, propionate and butyrate) were not affected by GCC, which agreed with Wanapat et al. (2009a), who found that acetate, propionate and butyrate concentrations in swamp buffaloes were not affected by GCC and urea at 15 g/kg.

**Table 4**Ruminal pH, temperature, concentrations of ammonia-nitrogen (NH<sub>3</sub>-N) and volatile fatty acid (VFA) and concentration of blood urea N by feeding various diets to crossbred lactating dairy cows.<sup>1</sup>

Item	TMR1	TMR2	TMR3	TMR4	SE
Ruminal pH	6.8	6.9	6.9	6.8	0.07
Ruminal temperature, °C	38.9	39.0	39.0	38.9	0.11
Ruminal NH <sub>3</sub> -N, mg/dL	16.4	14.8	15.6	13.8	1.03
BUN, mg/dL	9.7	9.2	9.5	9.3	0.91
Total VFA, mmol/L	137.3	133.1	139.8	134.6	1.48
VFA, mol/100 mol					
Acetic acid (C2)	65.6	64.1	64.5	65.2	0.22
Propionic acid (C3)	27.2	27.5	27.2	26.5	0.21
Butyric acid (C4)	8.2	8.4	8.0	8.3	0.09
C2:C3 ratio	2.4	2.3	2.4	2.5	0.03

BUN = blood urea-nitrogen; TMR = total mixed ration; SE = standard error of means.

<sup>a,b</sup> Within a same row, means with different superscripts differ ( $P < 0.05$ ).<sup>1</sup> The roughage source used different ratios ground corn cobs (GCC) to rice straw (RS): TMR1, 100:0; TMR2, 82.5:17.5; TMR3, 67.25:32.75 and TMR4, 50:50.

## 4. Conclusions

It was concluded that ground corn cobs used as the whole roughage source in TMR containing 60% concentrate significantly improve nutrient intake and milk yield in lactating dairy crossbred cows. These findings should be applied further in practical dairy feeding in the tropics to increase production efficiency.

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