Feeding tropical dairy cattle with local protein and energy sources for sustainable production

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ABSTRACT
The aim of this study was to investigate the effect of high protein feed (Hipro-feed) formulated with carbohydrate source in concentrate mixture on feed intake, rumen fermentation, and milk performance of lactating cows fed Ruzi grass. Sixty cross-bred dairy cows (75% Holstein–Friesian and 25% Thai cows) in mid-lactation, 390 ± 50.0 kg body weight, 85 ± 5 days in milk with daily milk production of 10 ± 2.0 kg/day, were selected from 15 smallholder dairy farms and assigned according to a randomized complete block design. Four cows per farm were subjected to two groups to receive dietary treatments: Formulation I = control formula used by farmers and Formulation II = Mixed carbohydrate source + Hipro-feed (48% crude protein). The results showed that cows that received Formulation II had higher total feed intake and nutrient digestibility ($P < .05$). However, ammonia nitrogen, total volatile fatty acids, and propionic acid were increased in cows that consumed Formulation II, while acetic acid and butyric acid, ruminal pH, temperature, and blood urea nitrogen were similar between groups. Milk yield and economic return were increased in cows receiving Formulation II. In conclusion, Hipro-feed could usefully be incorporated with carbohydrate source in concentrate formulation for the improvement of dairy performance of smallholder dairy farming in the northeastern region of Thailand.

1. Introduction
Feed quantity and quality are the major factors contributing to efficient and profitable dairy farming, especially on smallholder farms. Dairy cattle are becoming the major ruminant distributed in the north-east of Thailand. Due to the low quality of roughage feedstuffs in this area, supplementation with a concentrate diet containing a high density of energy and nitrogen would be potentially useful and could be mixed on farm (Wanapat 1999). Modern feeding strategies have changed from primarily forage-based to progressively more readily fermentable carbohydrate feedstuffs in dairy rations to meet the increasing milk production of high-producing animals. These practices favour the use of silages, low-fibre diets, and high concentrate levels (Marden et al. 2007; Wanapat et al. 2014). It is well known that increasing concentrate supplies increase milk yield (Morand-Fehr et al. 2007).

Feed costs are about 70% of total operating costs, the largest being expenditure on concentrates (65–80%), resulting in increasing production cost (Wanapat et al. 2013c). With the present trend of rising feedstuff prices and global inflation, livestock production is increasingly constrained by feed scarcity and the high cost of feeds (Ayantunde et al. 2005). Therefore, the reduction of feed costs by using the available biomass from the forage resources, crop residues as well as agro-industrial by-products, and other non-conventional feed resources, and improvement of productivity are important in obtaining higher profits in livestock production (Devendra & Leng 2011). It is reported that by-products from vegetable oil extraction such as coconut meal, palm kernel meal, cotton seed meal, and kapok seed meal, and brewery’s grain meal are locally available protein sources (Wanapat & Rowlinson 2007). Some of the vegetable oil industries, including coconut oil and palm oil, produce millions of tonnes of by-products a year; these products could be local feedstuffs available for ruminant diets. These local feeds have been used in several ruminant studies (Khampa et al. 2006; Wora-anu et al. 2007; Wanapat et al. 2009).

According to previous work of Wanapat et al. (2013a, 2013b, 2013c), who studied the effect of carbohydrate and protein sources in concentrate diet (high protein feed; Hipro-feed) in milking cows, young dairy bulls, beef cattle, and buffalo, Hipro-feed incorporated with carbohydrate source (cassava chip) could improve feed intake, rumen fermentation, and milk production. However, these data have been limited for on-farm practice of smallholder farmers. Therefore, the

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objective of this experiment was to study the effect of Hipro-feed formulated with carbohydrate source (cassava chip) in concentrate mixture on the feed intake, nutrient digestibility, rumen fermentation efficiency, and milk performance of lactating dairy cows fed Ruzi grass as basal diet.

2. Materials and methods

2.1. Animals, diets, and experimental design

The experiment was conducted on 15 small-scale dairy farms from 3 milk collection centres (Ubonrat, Nampong, and Kranuan in Khon Kaen Province) under the administration and supervision of the Dairy Promotion Organization of Thailand (DPO) in the northeastern region of Thailand. Sixty cross-bred dairy cows (75% Holstein–Friesian and 25% Thai cows) in midlactation, 390 ± 50.0 kg of body weight and 85 ± 5 days in milk with daily milk production of 10 ± 2.0 kg/day, were selected and assigned according to a randomized complete block design. All cows were categorized into two groups to receive dietary treatments as follows: Formulation I = control formula used by farmers; Formulation II = formula mixed with local energy source (cassava chip) and high protein concentrate (48% CP). All formulation contained CP at 18.0% and were fed at 1:2 ratio of concentrate to milk production, while Ruzi grass was fed as a roughage source ad libitum. Hipro-feed was formulated using available local protein sources to contain 49% CP and 72.9% total digestible nutrient as shown in Table 1. Formulations I and II of the dietary treatments are shown in Table 2. The cows were housed in individual pens and individually fed with dietary treatments twice daily at 06:00 and 16:00 hours after milking. Clean fresh water and mineral blocks were available at all times.

2.2. Sampling procedure, data collection, and data analysis

The experiment lasted for a period of 45 days, and feed intake was measured in the first 40 days. Feed offered and refusals were recorded daily before morning feeding. Samples of concentrate and Ruzi grass were collected daily, bulked for each animal, and stored at –20°C for chemical analysis. Faecal samples were collected daily during the last 5 days of the experiment at 09:00 or 12:00 hours by rectal sampling. When faecal samples were taken at 3-h intervals, two successive samples were combined and used as one sample. Bulked samples were dried at 60°C, ground (1-mm screen using Cyclotech Mill, Tecator), and analysed for dry matter (DM), CP, and ash content according to the methods of AOAC (1995), while neutral detergent fibre (aNDF) and acid detergent fibre (ADF) were determined according to the methods of Van Soest et al. (1991) with residual ash included. Faecal samples were also analysed for acid-insoluble ash to estimate the digestibility of nutrients according to the methods of Van Keulen and Young (1977).

At the last day of the experiment, approximately 200 ml of rumen fluid was taken using a stomach tube connected with a vacuum pump. Rumen fluid was immediately measured for pH and temperature using a portable pH metre (HANNA instrument HI 8424 microcomputer, Singapore) and then filtered through four layers of cheesecloth. About 45 ml was transferred to a plastic bottle to which 5 ml of 1 M H2SO4 was added to stop microbial fermentation and then centrifuged at 3000 × g for 10 min. About 20–30 ml of supernatant was collected and analysed for ammonia nitrogen (NH3–N) using Kjeltec Auto 1030 Analyser (AOAC 1995) and volatile fatty acid (VFA) by high-pressure liquid chromatography (HPLC; instruments by Waters: Nova-Pak model 600E; water mode i484 UV detector; Nova-PakC18 column, column size 3.9 × 300 mm; mobile phase, 10 mM H2PO4 (pH 2.5)) according to Samuel et al. (1997). The HPLC system consisted of a Shimadzu VP SERIES with SpD10A detector and WINCHROM software. A 3.9 × 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 mM H2PO4 (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 standard volatile acids (Merck, India) as control.

A 10-ml blood sample was drawn from the jugular vein at the same time as the rumen fluid was collected. Blood samples

| Table 1. Ingredients and chemical compositions of high protein concentrate. |
|-----------------------------|-----------------|
| Items                       | High protein concentrate |
| Ingredients (%)             |                  |
| Cottonseed meal             | 28.9             |
| Palm kernel meal            | 30.8             |
| Coconut meal                | 26.6             |
| Urea                        | 8.9              |
| Molasses                    | 3.0              |
| Salt                        | 0.6              |
| Sulphur                     | 0.6              |
| Mineral premix              | 0.6              |
| Chemical composition, % of dry matter |         |
| Organic matter              | 92.7             |
| Crude protein               | 49.0             |
| Neutral detergent fibre     | 26.6             |
| Acid detergent fibre        | 18.7             |
| Total digestible nutrient   | 72.9             |

| By calculation. |

| Table 2. Feed formulation and chemical compositions of dietary treatments. |
|---------------------------------|-------------------|
| Items                           | Formulation I     | Formulation II    |
| Ingredients (%)                 |                  |
| Cassava chip                    | 55.2              | 66.5              |
| High protein concentrate        | 10.0              | 33.5              |
| Rice bran                       | 10.2              | –                 |
| Soybean meal                    | 12.4              | –                 |
| Brewers’ grain                  | 7.2               | –                 |
| Palm kernel meal                | 5.8               | –                 |
| Coconut meal                    | 4.4               | –                 |
| Urea                            | 1.5               | –                 |
| Molasses                        | 1.5               | –                 |
| Salt                            | 0.5               | –                 |
| Sulphur                         | 0.3               | –                 |
| Mineral premix                  | 1.0               | –                 |
| Chemical composition            |                   |
| Organic matter                  | 95.7              | 95.6              |
| Crude protein                   | 18.1              | 18.2              |
| Neutral detergent fibre         | 15.1              | 16.3              |
| Acid detergent fibre            | 7.3               | 7.7               |
| Total digestible nutrient       | 75.1              | 77.3              |

*By calculation; Formulation I = control formula used by farmers; Formulation II = formula mixed with local energy source (cassava chip) and high protein concentrate (48% CP).
were immediately placed on ice and transported to the laboratory to separate plasma from the whole blood after refrigeration for 1 h at 4°C and then centrifuged at 3500 × g for 20 min. Plasma was collected and stored at −20°C for later blood urea N (BUN) analysis according to Crocker (1967).

The cows were milked twice daily by a bucket milking machine and milk yield was recorded during the 45-day period, and samples were collected during the last 5 days for milk composition analysis. Milk samples were collected at morning and afternoon milking times. The two successive samples were combined according to the proportion of milk yield at each milking time, preserved with 2-bromo-2-nitropropane-1, 3-dial, and stored at 4°C until analysis for fat, protein, lactose, total solids, and solids-not-fat content by infrared methods using Milko-Scan 33 (Foss Electric, Hillerod, Demark). Milk urea nitrogen (MUN) was determined using Sigma kit #640 (Sigma Diagnostics, St. Louis, MO). Milk production costs, income, and profit were evaluated using the real-time existing costs of feed ingredients and milk sale.

2.3. Statistical analysis

The means of all parameters measured were statistically analysed by analysis of variance procedure and the means were statistically compared between Formulations I and II by T-test (SAS 1996). Differences between means with P < .05 were accepted as representing statistically significant differences.

3. Results and discussion

Results of feed intake and nutrient digestibility affected by Hipro-feed incorporated with carbohydrate source are shown in Table 3. Concentrate and total feed intake were increased in cows that consumed Formulation II, while the intake of Ruzi grass was similar between groups (P < .05). Consistent with the present result, Wanapat et al. (2013c) found that cows fed with Hipro-feed diet had a higher total feed intake. However, Wanapat et al. (2012, 2013a, 2013b) did not show any difference on voluntary feed intake of beef cattle, young dairy bulls, and buffaloes by Hipro-feed feeding. The different results could be due to the difference in animal type, feeding programme, and environmental factors. Higher feed intake could be due to the cottonseed meal present in the Hipro-feed. It is reported that cottonseed meal contains a high level of rumen-undegradable protein which provides amino acids to the host ruminant via small intestine absorption (Broderick et al. 2010). Cows receiving Formulation II may obtain a better balance of amino acids than those on the Formulation I diet, leading to a higher feed intake. Moreover, cows fed with Formulation II had higher nutrient digestibility, which may be a partial explanation. Moreover, cows that received Formulation II had higher nutrient digestibility in terms of organic matter, CP, aNDF, and ADF compared to those that received Formulation I diet (P < .05). These findings could be due to the presence of cottonseed meal in Formulation II which contains a high level of rumen-undegradable protein (Wanapat et al. 2012; 2013a, 2013b, 2013c). Moreover, the rumen-undegradable protein and non-structural carbohydrate intakes could also affect nutrient digestibility. Bruckental et al. (2002) found that the digestibility of CP and non-structural carbohydrate increased when the proportion of undegradable protein was increased.

Table 3. Effect of high protein concentrate on voluntary daily feed intake and nutrient digestibility in lactating dairy cross-breeds.

| Items                          | Formulation I | Formulation II | SEM  |
|-------------------------------|---------------|----------------|------|
| Feed intake (kg/ head/day)    | 7.1           | 7.2            | 0.33 |
| Concentrate                   | 6.6           | 8.0           | 0.67 |
| Total                         | 13.7          | 15.2          | 0.64 |
| Digestion coefficients (%)    |               |                |      |
| Dry matter                    | 57.2          | 59.9           | 2.15 |
| Organic matter                | 69.2          | 75.8           | 1.21 |
| Crude protein                 | 52.3          | 58.5           | 1.14 |
| Neutral detergent fibre       | 54.5          | 59.4           | 2.05 |
| Acid detergent fibre          | 50.8          | 53.1           | 1.02 |

\*Values within a row with different superscript letters are significantly different (P < .05); SEM, standard error of the means; Formulation I = control formula used by farmers; Formulation II = formula mixed with local energy source (cassava chip) and high protein concentrate (48% CP).

Table 4. Effect of high protein concentrate on ruminal fermentation in lactating dairy cross-breeds.

| Items                          | Formulation I | Formulation II | SEM  |
|-------------------------------|---------------|----------------|------|
| Ruminal pH                    | 6.6           | 6.5            | 0.08 |
| Ruminal temperature (°C)      | 38.8          | 39.0           | 0.09 |
| Ammonia nitrogen (mg/dl)      | 12.5          | 13.9           | 0.30 |
| Blood urea nitrogen (mg/dl)   | 9.2           | 11.7           | 1.12 |
| Milk urea nitrogen (mg/dl)    | 8.2           | 10.3           | 0.96 |
| Total volatile fatty acid (mmol/l) | 177.2       | 192.5          | 3.29 |
| Acetic acid                   | 64.1          | 63.3           | 0.69 |
| Propionic acid                | 24.4          | 26.2           | 0.46 |
| Butyric acid                  | 11.5          | 10.5           | 0.81 |
| Acet: propionic acid ratio    | 2.6           | 2.4            | 0.05 |

\*Values within a row with different superscript letters are significantly different (P < .05); SEM, standard error of the means; Formulation I = control formula used by farmers; Formulation II = formula mixed with local energy source (cassava chip) and high protein concentrate (48% CP).
those of Wanapat et al. (2013a, 2013c) that C3 and total VFA were increased while acetic acid (C2) to C3 ratio decreased when animals were fed Hipro-feed containing a high level of cottonseed meal. This may be also attributed to the higher digestibility in the Formulation II group. Bannink et al. (2006) estimated the stoichiometry of VFA production in the rumen of lactating cows and found many factors that affected the concentration and proportions of VFA, such as DM intake, dietary composition, digestibility, and the utilization rate of substrate by rumen microorganisms.

Milk composition in terms of fat, protein, lactose, total solids, and solids-not-fat was not significantly different between treatments (P > .05; Table 5), while milk yield and 3.5% fat-corrected milk yield increased in cows that received Formulation II (P < .05), which could be attributed to the cows having higher protein digestibility. Formulation II contained a high level of cottonseed meal which has been reported to contain a high proportion of rumen-undegradable protein which could provide amino acids to the host animals through small intestine digestion and absorption (Broderick et al. 2010; Ghanbari et al. 2012). Mikolayunas-Sandocek et al. (2009) stated that supplemental rumen-undegradable protein could increase the flow of amino acids, especially methionine and lysine, to the small intestine which was necessary for milk synthesis. In addition, Brito and Broderick (2007) also found that milk yield was increased by cottonseed meal supplementation. These findings indicated that using cottonseed meal as the main source to completely replace soybean meal in Formulation I was beneficial to milk production. Thus, using Hipro-feed containing cottonseed meal in Formulation II could be advantageous for milking cows, especially when fed on low-quality roughages. In addition, feed cost was similar between the two formulations (P > .05), whereas income from milk sale and profit were higher in cows fed with Formulation II (P < .05; Table 5). In the present study, similar feeding costs between the treatments were mainly justified by the use of amount of concentrate feed. These results imply that Hipro-feed enhances the nutrient utilization of dairy cows, particularly protein utilization, and improves rumen fermentation and milk production. Moreover, the use of Hipro-feed is easy to practise for smallholder dairy farmers who raise animals using available local feeds and low-quality roughages.

| Items                     | Formulation I | Formulation II | SEM  |
|---------------------------|--------------|---------------|------|
| Milk yield (kg/head/day)  | 13.3a        | 16.2b         | 0.92 |
| 3.5% FCM (kg/head/day)    | 13.9a        | 16.9b         | 0.60 |

In conclusion, using Hipro-feed with carbohydrate source in concentrate formulation could enhance feed intake, rumen fermentation efficiency, milk production, and economic return. This study suggested that Hipro-feed could usefully be incorporated with carbohydrate source in concentrate formulation for the improvement of dairy performance of smallholder dairy farming in the northeastern region of Thailand. Furthermore, the results obtained in this on-farm experiment should be extensively recommended for use in tropical areas where dairy farming has been implemented.

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### Disclosure statement

No potential conflict of interest was reported by the authors.

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