Effect of Tannin-rich *Mimosa pigra* Leaf Meal in Molasses-based Blocks on Feed Intake, Rumen Parameters, and Blood Metabolites of Dairy Heifers

SUNTORN WITTAYAKUN*, WEERA INNAREE, WORAWUT CHAINETR, NITTAYA THONGTIP

Department of Animal Science and Fishery, Faculty of Science and Agricultural Technology, Rajamangala University of Technology Lanna, Lampang Campus, Thailand.

Abstract | The study was aimed to evaluate the influence of condensed tannin in tannin-rich *Mimosa pigra* leaf meal (TMLM) as a nitrogen binder in molasses-based blocks (MBB) on feed intake, rumen parameters, and blood metabolites of dairy heifers. Four crossbred Holstein heifers with 328.12 ± 1.96 kg average body weight were assigned in a 4x4 Latin square design to dietary treatments with four different levels of TMLM in MBB at 0, 75, 150, and 300 g/kg dry matter, respectively. Heifers were fed green chopped guinea grass (*Panicum maximum* TD58) for ad libitum intake as the basal feed. The feeding trial lasted for 80-d. The results indicated that grass intake, total feed intake, neutral detergent fiber intake, and acid detergent fiber intake significantly increased in response to the advanced degree of TMLM inclusion MBB (P<0.05). However, none of the TMLM inclusions had a significant impact on rumen parameters, blood biochemical profiles, and complete blood counts (P>0.05), except the number of eosinophils (P<0.05). In conclusion, TMLM was beneficial for dairy heifers at 150 g/kg dry matter in MBB to improve feed intake and allow the development of dairy feeding strategies.

Keywords | Tannin-rich, *Mimosa pigra* Leaf Meal, Molasses-based Blocks, Heifer

Received | March 15, 2021; Accepted | May 09, 2021; Published | October 01, 2021

*Correspondence | Sunhorn Wittayakun, Department of Animal Science and Fishery, Faculty of Science and Agricultural Technology, Rajamangala University of Technology Lanna, Lampang Campus, Thailand; Email: w_suntorn@rmutl.ac.th

Citation | Wittayakun S, Innaree W, Chainetr W, Thongtip N (2021). Effect of tannin-rich *Mimosa pigra* leaf meal in molasses-based blocks on feed intake, rumen parameters, and blood metabolites of dairy heifers. J. Anim. Health Prod. 9(4): 463-470.

DOI | https://dx.doi.org/10.17582/journal.jahp/2021/9.4.463.470

ISSN | 2308-2801

Copyright © 2021 Wittayakun et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

The ideal goals of dairy feeding programs have been focused on how to increase the usages of available local feed resources to provide fermentable rumen carbohydrates, nitrogen, and minerals, particularly concerning smallholder dairy farms in the tropics, especially during the dry season. Supplementation of molasses-based blocks is a widely simple feeding technique that primarily aims to supply a small amount of nitrogen from urea together with non-structural carbohydrate in the form of molasses for rumen microbes to use as substrates for microbial protein synthesis (George Kunju, 1988; Katulski et al., 2017). Although supplementation of molasses-based blocks has shown several advantages, the rapid conversion of urea to ammonia in the rumen may cause potential problems such as poor feed intake and urea toxicity if excess urea is being absorbed rapidly post-feeding (Mirza et al., 2002). Giant sensitive tree (*Mimosa pigra* L.), a leguminous shrub, and a serious weed in the tropical regions have been referred to as a potential feed ingredient due to its availability, yield, and nutrient contents (Wittayakun et al., 2017). The leaf yield of giant sensitive tree accounts for 22.52 % of plant weight, which is high in crude protein (18.87 to 21.80%) and condensed tannins (3.11 to 9.89 %) (Hong et al., 2008). Many research results reported the benefits of condensed tannins...
as a potential substance to reduce nitrogen degradation in the rumen by forming strong complexes ruminants resulting in a balance of degradation rate and optimize microbial protein synthesis (Dey et al., 2006; Dey and De, 2014). We hypothesized that condensed tannins of tannin-rich Mimosa pigra leaf meal (TMLM) would reduce nitrogen degradation by forming strong complexes with urea nitrogen in molasses-based blocks (MBB), and have consequence positive effects in replacement dairy heifers particularly when feeding was based on guinea grass. Therefore, the objective of this study was to evaluate the effects of TMLM inclusion as a condensed tannin source in MBB and if this would affect feed intake, nutrient intake, rumen parameters, blood biochemical profiles, metabolites, or complete blood counts of dairy heifers.

MATERIALS AND METHODS

EXPERIMENTAL DESIGN AND MANAGEMENT

Four crossbred Holstein Friesian (93.75%) heifers, averaged 328.12±1.96 kg body weight, were assigned in a 4x4 Latin square design. The experimental periods consisted of four consecutive periods which overall trial lasted for 80 days. Each period consisted of 14-days as an adapt period and 6-days of sampling and measurements. Treatments were molasses-based block containing either tannin-rich Mimosa pigra leaf meal (TMLM) at 0, 75, 150, or 300 g/kg dry matter (Table 1). The Mimosa pigra L. leaves were collected in Lampang province (N18°17’32.35”, E 99°29’33.97”), northern Thailand. The molasses-based block (MBB) was prepared according to George Kunju (1988), then packed into molds, and allowed 10 to 14 days to become harden. Purple guinea grass or green panic grass (Panicum maximum TD58) was grown at Lampang campus, and harvested at approximately 60 days of regrowth age by tractor-combine double chop harvester; then fed twice at 08.00 and 16.00 h daily. Diets were expected to maintain the expected average daily gain at 0.60 kg/day of heifers based on the recommendation of NRC (2001). Heifers were individually kept in a corral of 1.5 x 4.0 m², each with free access to drinking water. Animal care and procedures were performed according to the guidelines of the Animal for Thai Scientific Purposes Acts, B.E. 2558 or A.D. 2015 (TGG, 2015).

SAMPLING AND MEASUREMENT

Feed offered and refused were weighed and recorded daily throughout the trial. All heifers were weighed twice (day 1 and day 20) of each period. During the last 3-days of the data collection period, feed samples were collected, dried at 60°C for 72 h; ground, and composited to analyze for dry matter (DM), crude protein (CP), ether extract (EE), and ash (AOAC, 1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were measured by the method of Van Soest et al. (1991). Organic matter (OM) was calculated as follows: OM = 100 – Ash %. Condensed tannin was examined by the method of Broadhurst and Jones (1978). On the last day of each period at 4 h post-feeding, rumen fluid was sampling using an esophageal tube, filtered through four layers of sheet cloth, and measured pH with a portable pH meter (pHtestr 30®, EUTECH Instruments, Singapore). The population of rumen microorganisms; including bacteria, protozoa, and fungi, was measured by total direct count, followed the method described by Galyean (1989). Blood samples were taken from a coccygeal vein at 4 h after feeding and subsequent analysis for biochemical profiles using Auto Biochemistry Analyzer (Model TC 220, Tecom Science Corporation, China); for electrolytes using Electrolyte Analyzer (Model URIT-910C Plus, URIT Medical Electronic Co, Ltd., China); for complete blood using Automated Hematology Analyzer (Model URIT-3000 Plus, URIT Medical Electronic Co, Ltd., China).

STATISTICAL ANALYSIS

Data were analyzed using the general linear procedure for Analysis of Variance (ANOVA), and significance was set at P-value less than 0.05. Treatment means were compared by the least significant difference (LSD) (SPSS 2006).

RESULTS

CHARACTERISTICS OF EXPERIMENTAL DIETS

Nutrient composition and physical characteristics of experimental diets are present in Table 2. The mean concentration of CP was relatively low in the 0 g/kg TMLM but high in the 300 g/kg TMLM while the amount of EE was in contrast due to the high-fat content of the RB ingredient. All dietary treatments were low in fiber contents, as indicated in terms of NDF, and ADF. In contrast, ash contents were high in all treatments in response to some feed ingredients that high in inorganic contents, such as dicalcium phosphate, sulfur, premix, and lime.

FEED INTAKE AND NUTRIENT INTAKE

Feed intake, nutrient intake, and average body weight of heifers are present in Table 3. Increasing TMLM in MBB had no significant effects on daily MBB intake (P>0.05). However, daily grass intake and total DM intake were significantly influenced by increasing of TMLM as well as intake of neutral detergent fiber (NDF), and acid detergent fiber (ADF) (P<0.05). Heifers fed grass with a higher proportion of TMLM tended to consume more metabolizable energy (ME) than those other groups. The condensed tannin intake was numerically greater for heifers fed the higher inclusions of TMLM compared with those fed the lower levels of TMLM (P<0.05).
Table 1: Ingredients of experimental diets, %DM

| Items                  | TMLM, g/kg DM |
|------------------------|---------------|
|                        | 0  | 75  | 150 | 300 |
| TMLM                   |    | 7.5 | 15  | 30  |
| Urea                   | 10 | 10  | 10  | 10  |
| Molasses               | 30 | 30  | 30  | 30  |
| RB                     | 30 | 22.5| 15  | 0   |
| Ground corn            | 5  | 5   | 5   | 5   |
| Salt                   | 5  | 5   | 5   | 5   |
| Dicalcium phosphate    | 4  | 4   | 4   | 4   |
| Sulfur                 | 0.5| 0.5 | 0.5 | 0.5 |
| Premixed               | 0.5| 0.5 | 0.5 | 0.5 |
| Lime                   | 15 | 15  | 15  | 15  |
| Total                  | 100| 100 | 100 | 100 |

TMLM: tannin-rich *Mimosa pigra* leaf meal; RB: rice bran

Table 2: Nutrient contents and physical characteristics of diets, %DM

| Nutrient contents   | TMLM, g/kg DM | TMLM | RB  | Grass |
|---------------------|---------------|------|-----|-------|
| DM                  | 88.03         | 84.85| 86.20| 88.24 | 78.12 | 91.74 | 44.37 |
| OM                  | 71.55         | 72.44| 72.53| 71.27 | 92.97 | 92.12 | 81.85 |
| CP                  | 37.44         | 46.17| 45.96| 48.56 | 21.88 | 13.15 | 7.86  |
| EE                  | 2.87          | 1.19 | 1.22 | 0.92  | 4.66  | 14.50 | 1.56  |
| NDF                 | 8.39          | 5.10 | 6.13 | 11.75 | 56.25 | 19.58 | 62.31 |
| ADF                 | 4.17          | 4.61 | 8.37 | 12.51 | 43.82 | 8.24  | 47.72 |
| Ash                 | 28.44         | 27.55| 27.46| 28.72 | 7.03  | 7.88  | 19.47 |
| ME, Mcal/kgDM       | 2.69          | 2.68 | 2.62 | 2.55  | 2.03  | 2.62  | 1.97  |
| Condensed tannin     | 5.55          | 10.94| 21.37| 6.60  |

Physical characteristics

| Weight, kg           | 2.70          | 2.90 | 2.57 | 2.61  |
| Density, g/cm³       | 2.95          | 3.17 | 2.91 | 2.86  |

TMLM: tannin-rich *Mimosa pigra* leaf meal; RB: rice bran; DM: dry matter; OM: organic matter; CP: crude protein; EE: ether extract; NDF: neutral detergent fiber; ADF: acid detergent fiber; GE: gross energy; ME: metabolizable energy by calculation according to the equation of Donker (1989) as ME (Mcal/kgDM) = 2.76 – 0.00165 (gADF/kgDM)

Table 3: Feed intake and nutrient intake of heifers offered tannin-rich *Mimosa pigra* leaf meal (TMLM).

| Items                  | TMLM, g/kg DM | SEM | P-value |
|------------------------|---------------|-----|---------|
| Dry matter intake      |               |     |         |
| - Molasses-based blocks|               |     |         |
| kg/h/d                 | 0.29          | 0.33| 0.570   |
| % BW                   | 0.08          | 0.10| 0.498   |
| g/kgBW\(^{0.73}\)     | 3.79          | 4.32| 0.517   |
| - Grass                |               |     |         |
| kgDM/h/d               | 7.59\(^{a}\)  | 7.17\(^{a}\)| 8.11\(^{ab}\) | 8.59\(^{ab}\) | 0.55 | 0.045 |
| % BW                   | 2.32\(^{ab}\) | 2.23\(^{a}\)| 2.52\(^{bc}\) | 2.66\(^{c}\) | 0.15 | 0.031 |
| g/kgBW\(^{0.73}\)     | 98.30\(^{ab}\) | 94.61\(^{a}\)| 106.56\(^{bc}\) | 112.65\(^{c}\) | 6.55 | 0.029 |
| - Total intake         |               |     |         |
| Nutrient intake, kg/h/d | kgDM/h/d | 7.88 | 7.51 | 8.36 | 8.85 | 0.54 | 0.054 |
|------------------------|----------|------|------|------|------|------|-------|
| % BW                   | 2.41a    | 2.34a| 2.60b| 2.74b| 0.16 | 0.045|
| g/kgBW^{-0.75}         | 102.09a  | 98.94a| 109.82ab| 115.85b| 6.70 | 0.042|

Table 4: Rumen parameters of heifers offered tannin-rich *Mimosa pigra* leaf meal (TMLM).

| Items                           | TMLM, g/kg DM | SEM   | P-value |
|---------------------------------|---------------|-------|---------|
| Rumen pH                        | 7.42          | 7.50  | 7.80    | 7.79  | 0.27 | 0.220|
| Rumen microbial population count, cell/ml | 3.93          | 4.97  | 6.64    | 3.65  | 1.64 | 0.138|
| Bacteria, x 10^{11}             | 3.13          | 2.40  | 2.49    | 2.42  | 0.44 | 0.163|
| Protozoa, x 10^{6}              | 1.67          | 1.45  | 1.17    | 1.15  | 0.24 | 0.119|

Table 5: Blood biochemical profiles of heifers offered tannin-rich *Mimosa pigra* leaf meal (TMLM).

| Items                           | TMLM, g/kg DM | SEM   | P-value |
|---------------------------------|---------------|-------|---------|
| Glucose, mmol/L                 | 4.06          | 4.37  | 4.28    | 4.06  | 0.15 | 0.136|
| Urea, mmol/L                    | 3.93          | 4.26  | 4.13    | 4.26  | 0.53 | 0.786|
| Total Protein, g/L              | 77.00         | 75.75 | 74.00   | 75.50 | 3.25 | 0.653|
| Triglyceride, mmol/L            | 0.72          | 0.75  | 0.75    | 0.76  | 0.05 | 0.791|
| Cholesterol, mmol/L             | 3.32          | 3.37  | 3.47    | 3.19  | 0.10 | 0.054|
| Creatinine, μmol/L              | 86.19         | 86.85 | 93.26   | 81.54 | 19.57 | 0.864|
| SGOT, μkat/L                    | 1.42          | 1.46  | 1.21    | 2.64  | 1.14 | 0.361|
| SGPT, μkat/L                    | 0.29          | 0.36  | 0.36    | 0.35  | 0.05 | 0.330|
| Calcium, mmol/L                 | 2.15          | 1.93  | 2.13    | 2.04  | 0.17 | 0.362|
| Potassium, mmol/L               | 4.50          | 4.57  | 4.72    | 4.77  | 0.43 | 0.798|
| Sodium, mmol/L                  | 139.50        | 140.00 | 139.25  | 140.00 | 0.85 | 0.551|
| Chloride, mmol/L                | 101.25        | 103.50 | 101.75  | 104.00 | 2.04 | 0.265|

TMLM: tannin-rich *Mimosa pigra* leaf meal; BW: body weight; OM: organic matter; CP: crude protein; EE: ether extract; NDF: neutral detergent fiber; ADF: acid detergent fiber, ME: metabolizable energy by calculation according to the equation of Donker (1989) as ME (Mcal/kgDM) = 2.76 – 0.00165 (gADF/kgDM)

superscripted means within a row that are not same differ at (P<0.05)
Table 6: Complete blood counts of heifers offered tannin-rich *Mimosa pigra* leaf meal (TMLM).

| Items                  | TMLM, g/kg DM | SEM  | P-value |
|------------------------|--------------|------|---------|
|                        | 0            | 75   | 150     | 300 |
| Hb, g/L                | 79.25        | 80.25| 78.66   | 78.75| 8.65 | 0.938 |
| Hct, %                 | 23.20        | 23.12| 23.46   | 22.45| 2.55 | 0.924 |
| RBC, 10^12/L           | 4.31         | 4.64 | 4.41    | 4.35 | 0.53 | 0.820 |
| MCV, fL                | 50.52        | 50.17| 52.60   | 51.12| 1.14 | 0.273 |
| MCH, fmol/L            | 1.12         | 1.09 | 1.10    | 1.17 | 0.07 | 0.503 |
| MCHC, mmol/L           | 22.54        | 21.92| 21.03   | 23.00| 1.10 | 0.614 |
| RDW, %                 | 19.05        | 19.45| 18.46   | 18.30| 1.26 | 0.555 |
| WBC, 10^9/L            | 12.85        | 14.40| 11.26   | 12.00| 2.73 | 0.495 |
| PMN, %                 | 44.25        | 33.25| 33.00   | 33.25| 9.17 | 0.427 |
| Lymphocyte, %          | 44.25        | 57.25| 49.66   | 56.50| 8.25 | 0.200 |
| Monocyte, %            | 2.00         | 1.50 | 1.66    | 1.50 | 0.75 | 0.744 |
| Eosinophil, %          | 9.50a        | 8.00a| 5.33b   | 2.00a| 2.54 | 0.031 |

TMLM: tannin-rich *Mimosa pigra* leaf meal; Hb = hemoglobin; Hct = hematocrit; RBC = red blood cell count; MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration; RDW = red blood cell distribution; WBC = white blood cell; PMN = polymorphonuclear neutrophil

a Superscripted means within a row that are not same differ at (P<0.05).
decreased feed, and nutrient intake. Besides, the lack of effects of condensed tannin on dry matter intake has been reported (Pathak et al., 2013; Piñeiro-Vázquez et al., 2018). The inclusion of TMLM did not increase crude protein intake as expected and slightly below those recommended by NRC (2001) because of low MBB consumptions in all groups. These imply low palatability of MBB due to the astringent taste of TMLM and high inorganic ingredients such as lime. The increasing consumption of NDF and ADF of the green chopped guinea grass was consistent with many previous works (Mirza et al., 2004; Golombeski et al., 2006; Taylor-Edwards et al., 2009; Giallongo et al., 2015).

Rumen pH can be used as an indicator for monitoring the healthy rumen function of ruminants. In the present study, rumen pH reflected adequate dietary fiber consumption for chewing and salivation mechanisms of heifers. Besides, some heavy alkali ingredients such as lime may cause rumen pH of all treatments above seven. The inclusion of TMLM in MBB did not influence rumen microbial populations. However, the bacterial population tended to increase continuously when the inclusion rate of TMLM was added and up to 150 g/kg DM, but tended to decline sharply after the inclusion rate of TMLM was more than 150 g/kg DM. This could be the sign of optimal synchrony of nitrogen utilization by rumen cellulolytic bacteria due to its slow release (Russell et al., 2009). The lack of significant difference for the protozoa population may indicate the low availability of dietary starch (Santra and Pathak, 2001). This result agrees with Piñeiro-Vázquez et al. (2018), who observed no change in the population of rumen protozoa in heifers fed condensed tannin from Leucaena leucocephala. Normally, the protozoa population changes dramatically with high starch or fat diets (Zhang et al., 2015; Panyakaw et al., 2020). The lack of difference in the population of fungal zoospores despite higher consumption of grass may have been due to condensed tannin in diets. Saminathan et al. (2019) reported that population, community structure, and diversity of fungi were decreased by the addition of condensed tannins.

Blood biochemical profiles can be used to monitor the metabolism and health status of ruminant animals. Plasma glucose is synthesized mainly in the liver using propionic acid as a precursor by the gluconeogenesis pathway, especially in response to high grain feeding. Because of low MBB consumption in all groups, no difference in blood glucose was detected in this trial. Besides, variation in glucose levels may be an indicator to detect animal stress (Wheelock et al., 2010). The inclusion of TMLM in this study resulted in no changes in blood urea nitrogen; this may be contributed to lower consumption of MBB than expected due to palatability interference of some feed ingredient. Therefore, ammonia nitrogen to be absorbed across the rumen wall into the portal vein to process the urea cycle is the limit. Feeding with tanniniferous supplements is generally a decrease in blood urea nitrogen (Mkhize et al., 2018; Zhang et al., 2019) in response to the formation of nitrogen complexes condensed tannin in the rumen and enhancing protected protein supply into the small intestine (Min and Hart 2003). Although high in inorganic contents of MBB, no sign of impaired kidney function was detected in response to total protein and creatinine levels. Inclusions of TMLM in MBB did not affect liver function due to SGOT and SGPT levels and blood electrolytes, including calcium, potassium, sodium, and chloride. A complete blood count (CBC) is an optional tool to evaluate overall animal health status and detect a wide range of disorders in response to TMLM feeding. According to the results, high levels of TMLM inclusion caused a lower number of eosinophils in CBC. This finding contradicts Pathak et al. (2013), who reported higher mean eosinophil counts with condensed tannin of leaf meal mixture in sheep. Reduction in eosinophils may impair the efficiency of body immune systems and associate the risk of infections.

CONCLUSION

The TMLM inclusion in MBB in dairy heifers significantly increased grass intake, total feed intake, NDF, and ADF intake without any adverse effects on rumen parameters, blood biochemical profiles, and complete blood counts (except eosinophils). The results of the current study suggest that TMLM inclusion in MBB should limit not more than 150g/kg dry matter for feeding dairy heifers as a condensed tannin source with green chopped guinea grass as the basal diet.

CONFLICT OF INTEREST

The authors wish to declare that they had no conflict of interest.

AUTHORS CONTRIBUTION

All authors contributed equally.

REFERENCES

• AOAC (1990). Official methods of analysis. 15th ed. Association of Official Analytical Chemists. Arlington, Virginia., USA.
• Broadhurst RB, Jones WT (1978). Analysis of condensed tannins using acidified vanillin. J. Sci. Food Agric. 29 (9): 788-794. https://doi.org/10.1002/jsfa.2740290908
• Cherdthong A, Wanapat M, Rakwongrit D, Khota W, Khantharin S, Tangmuthapattharakun G, Kang S, Foiklang S, Phesatcha K (2014a). Supplementation effect with slow-release urea in feed blocks for Thai beef cattle-nitrogen utilization, blood biochemistry, and hematology. Trop Anim
Cherdthong A, Wanapat M, Wongwungchun W, Yeekeng Cidrini IA, Prados L, Foresto W, Mariano E, Souza W, Dey A, Dutta N, Sharma K, Pattanaik AK (2006). Evaluation of condensed tannins from Ficus bengalensis leaves on feed utilization, milk production and antioxidant status of crossbred cows. Asian–Australas J. Anim. Sci. 27:342-348. https://doi.org/10.5713/ajas.2013.13229

Dey A, Dutta N, Sharma K, Pattanaik AK (2006). Evaluation of condensed tannins from tropical tree leaves and its impact on in vitro nitrogen degradability of groundnut cake. Anim. Nutr. Feed Techn. 6:215–222.

Donker JD (1989). Improved energy prediction equations for dairy cattle rations. J. Dairy Sci. 72:2942–2948. https://doi.org/10.3168/jds.S0022-0302(89)79446-7

Dschaaak CM, Williams CM, Holt MS, Eun JS, Young AJ, Min BR (2003). Tannins for Suppression of Internal Parasites. J. Anim. Sci. 91 (Suppl. 3): 331–332. https://doi.org/10.1093/jas/ske258.638

Galyean M (1989). Laboratory procedure in animal nutrition research. New Mexico state University. New Mexico, USA.

Golombeski GL, Kalscheur KF, Hippen AR, Schingoethe DI (2001). Evaluation of cotton seed meal and sunflower seed meal in urea molasses blocks versus commercial concentrate as supplement to basal ration of wheat straw with stall-fed buffalo calves. Asian–Australas J. Anim. Sci. 17:193–198. https://doi.org/10.5713/ajas.2004.193

Horton LM, Ellerman TJ, Muller HC, Drouillard JS (2017). Effects of slow-release urea on rumen fermentation, methane production and population of rumen protozoa in heifers fed low-quality forage. Asian–Australas J. Anim. Sci. 31:1738-1746. https://doi.org/10.5713/ajas.17.0192

In vitro basal ration of wheat straw with stall-fed buffalo calves. Asian–Australas J. Anim. Sci. 17:193-198. https://doi.org/10.5713/ajas.1999.735

Kratuks S I, Van Bibber-Krueger CA, Cravens CL, Herlinger AR, Hertel JD, Schoeneman SM (2014). Tannins for Suppression of Internal Parasites. J. Anim. Sci. 91 (Suppl. 3): 331–332. https://doi.org/10.1093/jas/ske258.638

Min BR, Hart SP (2003). Tannins for Suppression of Internal Parasites. J. Anim. Sci. 81 (Suppl.2): E102-E109. https://doi.org/10.2527/2003.8114_suppl_2E102x

Mira H, Khan AG, Azim A, Mirza MA (2002). Effect of supplementing grazing cattle calves with urea-molasses blocks, with and without Yucca schidigera extract, on performance and carcass traits. Asian–Australas J. Anim. Sci. 15(9): 1300–1306. https://doi.org/10.5713/ajas.2002.1300

Mirza IH, Anjum MJ, Khan AG, Azim A (2004). Comparative evaluation of cotton seed meal and sunflower seed meal in urea molasses blocks versus commercial concentrate as supplement to basal ration of wheat straw with stall-fed buffalo calves. Asian–Australas J. Anim. Sci. 17:193–198. https://doi.org/10.5713/ajas.2004.193

Mkhiize NR, Heitik MA, Scoings PF, Hattas D, Dziba LE, Prins HHT, de Boer WF (2018). Seasonal regulation of condensed tannin consumption by free-ranging goats in a semiarid savanna. PloS ONE. 13(1): e0189626. https://doi.org/10.1371/journal.pone.0189626

Mueller-Harvey J (2006). Unravelling the conundrum of tannins in animal nutrition and health. J. Sci. Food Agric. 86:2010–2037. https://doi.org/10.1002/jsfa.2577

NRC (2001). Nutrient requirements of dairy cattle. 7th revised ed. National Academies Press. Washington DC, USA. https://doi.org/10.17226/9825

Panyakaew P, Schonewille JT, Fievez V, Goel G, Boon N, Huangklang C, Hendrikz W (2020). Coconut and to a lesser extent krabok oil, depress rumen protozoa in beef cows. J. Sci. Agri. Technol. 1:26-32. https://doi.org/10.14456/jsat.2020.4

Pathak AK, Dutta N, Banerjee PS, Pattanaik AK, Sharma K (2013). Influence of dietary supplementation of condensed tannins through leaf meal mixture on intake, nutrient utilization and performance of Haemonchus contortus Infected Sheep. Asian–Australas J. Anim. Sci. 26:1446-1458. https://doi.org/10.5713/ajas.2013.13066

Piñeiro-Vázquez AT, Molina-Solis JR, Jiménez-Ferrer GO, Alayón-Gamboa JA, Choy-Canul AJ, Ayala-Burgos AJ, Aguilar-Pérez CF, Ku-Yera JC (2018). Effect of condensed tannins from Leucaena leucocephala on rumen fermentation, methane production and population of rumen protozoa in heifers fed low-quality forage. Asian–Australas J. Anim. Sci. 31:1738-1746. https://doi.org/10.5713/ajas.17.0192

Plaizier JCB, Nkya R, Shem MN, Urio NA, McBride BW (1999). Supplementation of dairy cows with nitrogen molasses mineral blocks and molasses urea mix during the dry season. Asian–Australas J. Anim. Sci. 12:735–741. https://doi.org/10.5713/ajas.1999.735

Russell JB, Muck RE, Weimer PJ (2009). Quantitative analysis of cellulose degradation and growth of cellulolytic bacteria in the rumen. FEMS Microbiol. Ecol. 67: 183–197. https://doi.org/10.1111/j.1574-6941.2008.00633.x.

Saminathan M, Ramiah SK, Gan HM, Abdullah N (2019). In vitro study on the effects of condensed tannins of different molecular weights on bovine rumen fungal population and diversity. Ital. J. Anim. Sci. 18:1451-1462. https://doi.org/10.1080/1229051X.2019.1681304

Santra A, Patankh PN (2001). The effect of dietary concentrate level on rumen enzyme profile and ciliate protozoa population in cattle fed wheat straw diet. J. Anim. Feed Sci.10:589–604.

SPSS (2006). SPSS 15.0 brief guide. SPSS Inc. Chicago, Illinois, USA.

Taylor-Edwards CC, Hibbard G, Kitts SE, McLeod KR, Axe DE, Vanzant ES, Kristensen NB, Harmon DL (2009). Effects of slow-release urea on ruminal digesta characteristics and growth performance in beef steers. J. Anim. Sci. 87:200-208. https://doi.org/10.2527/jas.2008-0912

TGG (2015). Animals for Scientific Purposes Act, B.E. 2558. The Thai Government Gazette, Vol. 132, Part 18a, dated 13th

December 2021 | Volume 9 | Issue 4 | Page 469
• Van Soest PJ, Robertson JB, Lewis BA (1991). Methods for dietary fiber neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583–3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

• Wheelock JB, Rhoads RP, Vanbaale MJ, Sanders SR, Baumgard LH (2010). Effects of heat stress on energetic metabolism in lactating Holstein cows. J. Dairy Sci. 93:644-655. https://doi.org/10.3168/jds.2009-2295

• Wittayakun S, Innaree W, Pranamornkith P (2017). Yield, nutrient content and rumen in vitro digestibility of giant sensitive tree (Mimosa pigra) as dairy feed. Asian J. Agric. Biol. 5:355-360.

• Zhang J, Xu X, Cao Z, Wang Y, Yang H, Azarfar A, Li S (2019). Effect of different tannin sources on nutrient intake, digestibility, performance, nitrogen utilization, and blood parameters in dairy cows. Animals. 9:507. https://doi.org/10.3390/ani9080507

• Zhang X, Zhang H, Wang Z, Zhang X, Zou H, Tan C, Peng Q (2015). Effects of dietary carbohydrate composition on rumen fermentation characteristics and microbial population. Ital. J. Anim. Sci. 14 (3): 524-531. https://doi.org/10.4081/ijas.2015.3366.