Utilization of prilled fat on milk production and milk quality fed to lactating dairy cows

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Abstract. The objective was to determine the effects of supplemental prilled fat in lactating dairy cows’ diet on milk production and milk quality. There hasn't been any novel information about the effect of different content of palmitic acid in the prilled fat. The study conducted for 49 days, consisted of 42 days of adaptation and 7 days of data collection. Sixteen mid-lactation multiparous Friesian Holstein cows were assigned in a completely randomized block design experiment of four dietary treatments and four groups. The treatments were: basal diet (T1), basal diet + 2% of prilled fat with 75% of palmitic acid (T2), basal diet + 2% of prilled fat with 85% of palmitic acid (T3), and basal diet + 2% of prilled fat with 95% of palmitic acid (T4). The basal diet that used containing approximately 60% forages and 40% grains. The total dry matter intake resulted highest in T2 (P<0.05) with an average 17.42 kg/head/day, whereas, the milk production was not affected. The milk quality analysed were total solid (TS), %fat, %protein, %lactose and solid non-fat (SNF). The %fat resulted the best in T2 with average 4.22% (P<0.05), while there were not any significant differences in TS, %protein, %lactose and SNF.

1. Introduction
According to the survey, the population of dairy cows in Indonesia was 597.26 thousand heads [1] and the fresh milk production was 996.44 thousand tons [2]. This showed that the productivity of dairy cows in Indonesia was still very low to be able to meet the increasing demands of the milk consumers. The low productivity of dairy cows is due to the Indonesia is a tropical country that has an undesired climate compared to the comfort zone of the dairy cows. The species of dairy cows that mainly used in Indonesia is Friesian Holstein. Moreover, the main diet of dairy cows is roughage, especially grass in Indonesia has much lower quality than the grass in subtropical countries because the tropical climate will fasten the lignification process. Lactating dairy cows need energy not only for living, but also to produce milk. If the energy requirement exceeded the energy that available in the diet, it would cause a negative energy balance. An effort that could be done to overcome negative energy balance is fat supplementation in the diet.

Fat is one of the nutrients in the diet that needs to be considered beside protein to support the productivity of dairy cows and to produce fat in the milk. The compounds of nutrients contained in fat are fatty acids. The importance of supplementing fatty acids in diet is because their higher calorie content compared to other ingredients [3]. One of the sources of the fatty acids feed ingredients that
can be used is vegetable oil origin. Palmitic acid is a long-chain saturated fatty acid derived from vegetable oils and has little effect on rumen microbes or as an inert rumen (rumen bypass). The amount of palmitic acid that escapes from the rumen is almost the same as the amount consumed [4]. Besides giving positive effects resulting from the use of palmitic acid, negative effects may also arise. The addition of fat in the diet may disrupt the fermentation in the rumen, thereby the digestibility of energy from non-fat sources will be decreased. Fat can reduce the rate of dry matter digestion and increase propionate production and the growth of cellulolytic bacteria will be inhibited.

The method that can be done to reduce the negative effects of fat is to modify the fat to be bypass or to protect it from rumen degradation. Prilled fat will not melt due to low pH, escape from rumen degradation and will be digested in the small intestine by lipase enzyme [5]. Prilled fat will not react in the rumen and will survive from hydrolysis, so that the total energy supplemented in the diet will be available. The positive effect resulted from the utilization of palmitic acid supplementation in the form of prilled fat, makes it necessary to be utilized. However, there was no information available yet about the utilization of different content palmitic acid in the form of prilled fat on the dairy cows’ productivity. Therefore, this study aims to determine the effect of prilled fat supplementation to increase milk quality but will not interfere with milk production and feed intake.

2. Materials and methods

2.1. Animal and housing

The research was conducted at the Mandiri Sejahtera Farm in Tajur Halang Village, Cijeruk District, West Java, Indonesia. Sixteen multiparous Frisian Holstein crossbred cows in their mid-lactation phase were assigned for 7 weeks feeding trial. The 6 weeks was the adaptation period and the last 1 week was for the data collection. All cows had unrestricted access to the diets and to the drinking water. The housings that used were 2 colony houses and between the feed bunks was facilitated with partition. Each house was facilitated with a thermo-hygrometer.

2.2. Diet and experimental design

The basal diet used was the conventional diet that usually given from the farm, contained roughage, grains and the by-product of the tofu industry. The order of the feeding practice by farmer was the grains and the by-product of tofu industry were mixed as in concentrates then fed to the cows. After the grains were consumed, the roughage (napier grass) were fed. The prilled fats that used were obtained commercially with different palmitic acids content (75%; 85%; and 95%). Prilled fat are fat that originated from vegetable oil and will not be hydrogenated in the rumen and containing more than 85% palmitic acids with high melting point [5].

The experiment design that used was randomized completely block designs with four treatments and four replicates. The four treatments were: T1 = 100% basal diet; T2 = basal diet + 2% prilled fat (75% palmitic acid content); T3 = basal diet + 2% prilled fat (85% palmitic acid content); and T4 = basal diet + 2% prilled fat (95% palmitic acid content). Four assay diets were then developed by substituting prilled fat for 2% of the basal diet. The level of the prilled fat inclusion was in accordance to the previous study which reported that the addition of palmitic acid as much as 2% in the dry matter of the diet had the potential to increase milk production and milk fat yield [6].

The nutrient of the basal diet is shown in Table 1 and the specification of the prilled fats is shown in Table 2.
Table 1. Nutrient content of the basal diet.

| Feed Ingredients          | DM a | Ash  | CP b | EE c | CF d | Beta-N | Ca  | P  | TDN e |
|---------------------------|------|------|------|------|------|--------|-----|----|-------|
| Prilled Fat               | 98.78| 2.91 | 0.00 | 99.00| 0.00 | 0.00   | 0.00| 0.00| 0.00  |
| Napier Grass              | 24.67| 12.00| 8.69 | 2.71 | 32.3 | 43.7   | 0.47| 0.34| 52.40 |
| Grains                    | 81.77| 9.10 | 14.15| 8.05 | 15.15| 53.01  | 1.07| 0.72| 76.11 |
| By-product of Tofu Industry| 13.25| 12.19| 16.98| 2.75 | 25.51| 42.58  | 0.38| 0.45| 50.77 |

a DM = Dry Matter; b CP = Crude Protein; c EE = Ether Extract (Crude Fat); d CF = Crude Fiber; and e TDN = Total Digestible Nutrient; Calculated as in roughage = 1.6899 + 1.3844(CP) + 0.7526(Beta-N) – 0.8279(EE) + 0.3673(CF), protein source grains = 2.6467 + 0.6964(EE) + 0.9194(Beta-N) + 1.2159(EE) – 0.1043(CF), protein source = -37.3039 + 1.3048(CP) + 1.3630(Beta-N) + 2.1302(EE) + 0.3618(CF) [7].

Table 2. Specification of the prilled fats.

| Analysis                          | Palmitic Acids | Palmitic Acid | Palmitic Acid |
|-----------------------------------|----------------|---------------|---------------|
|                                   | 75%            | 85%           | 95%           |
| Iodine Value (g I2 100 g⁻¹)       | 14.39          | 9.81          | 3.41          |
| Free Fatty Acid (% as Palmitic)   | 0.06           | 37.88         | 77.70         |
| Melting Point (°C)                | 59.2           | 60.0          | 61.0          |
| Fatty Acid Profile (%)            |                |               |               |
| C12:0                             | 0.07           | 0.04          | 0.01          |
| C14:0                             | 0.20           | 0.74          | 0.20          |
| C16:0                             | 78.69          | 86.23         | 96.07         |
| C16:1                             | 0.04           | 0.08          | 0.13          |
| C18:0                             | 5.66           | 3.65          | 1.03          |
| C18:1 Cis                         | 11.73          | 7.55          | 2.09          |
| C18:2 Cis                         | 2.60           | 1.67          | 0.46          |
| C18:3 Cis                         | 0.05           | 0.03          | 0.01          |

2.3. Procedures

2.3.1. Feed intake. The schedule of feeding trial was adjusted to the farmer practice then prilled fats were added to the grains and by-product of the tofu industry at 6 AM. The feed residues were collected and the feed intake was calculated daily. Feed intake was calculated from the weight of the diet that fed subtracted by weight of feed residues for each experimental unit. Dry matter intake was obtained from the calculation of the amount of feed intake multiplied by the dry matter content. The roughage and grains that fed were weighed as the total basis weight using digital hanging scale with 50 kg capacity. Samples of 1 kg of grass and 200 g for grains were obtained for dry matter and nutrient content analysis.

2.3.2. Milk production. Milking was done twice a day in the morning at 6 – 7 AM and in the afternoon at 2 – 3 PM. Milk production was measured using a 1 000 mL volumetric flask. The amount of milk produced was recorded in litres for each experimental unit.

2.3.3. Statistical analysis. The data of feed intake were analysed with analysis of variants, while the data of milk production and milk quality were analysed by analysis of covariates. If significant differences were found, the test would be continued using Tukey test. All the data were analysed using the GLM procedure of statistical program SAS (SAS 9.2; SAS Institute Inc.).
3. Results and discussion

3.1. Feed intake
The result of the prilled fat supplementation on the feed intake and dry matter intake are shown in Table 3. The prilled fat treatments (T2, T3 and T4) increased the dry matter intake compared with the control (T1). These results agree with most studies feeding highly enriched (≥85%) sources of palmitic acid, in which dry matter intake (DMI) is typically not decreased when palmitic acid is fed up to 2% of diet DM [6-8].

Table 3. Average daily total basis feed intake and dry matter intake.

| Feed Ingredients | Intake T1       | Intake T2       | Intake T3       | Intake T4       |
|------------------|-----------------|-----------------|-----------------|-----------------|
| Total Basis (kg head⁻¹d⁻¹) |                 |                 |                 |                 |
| Roughage          | 38.94 ± 1.32    | 44.58 ± 4.96    | 41.77 ± 3.23    | 43.22 ± 2.84    |
| Grains            | 20.28 ± 5.55    | 23.29 ± 2.49    | 19.86 ± 5.08    | 19.91 ± 5.28    |
| DM Basis (kgDM head⁻¹d⁻¹) |                 |                 |                 |                 |
| Roughage          | 9.61 ± 0.33     | 11.00 ± 1.22    | 10.30 ± 0.80    | 10.66 ± 0.70    |
| Grains            | 5.51 ± 1.19     | 6.42 ± 0.21     | 5.63 ± 0.96     | 5.64 ± 0.97     |
| Total             | 15.21 ± 0.88    | 17.42 ± 1.09    | 15.94 ± 0.64    | 16.30 ± 1.49    |

a, ab, b Superscripts indicate significant difference (P<0.05).

The DMI of T3 and T4 were lower compared to the T2 because the different specification of the prilled fat that shown in Table 2. The prilled fat T2 was not in the form of free FA, but in the form of triglycerides. While prilled fat T3 and T4 had bigger content of palmitic acids in the form of free FA. Previous study reported that supplementing palmitic acid in the free FA form decreased the dry matter intake [9]. The study was done using abomasal-infused unsaturated free FA reported that esterification of fatty acid to glycerol might obstruct the sensing mechanism in the upper part of duodenum by which free FA inhibits the dry matter intake. Hydrolysis of triglycerides to be free FA and glycerol occurs mainly in the jejunum. If free FA sensors were mostly located in the upper duodenum, then triglycerides might not activate the sensing mechanism as the same extent as free FA [10], so the T3 and T4 might have started to reach the sensor that prohibit the dry matter intake. However, there has been no further information available yet regarding to the saturated free FA effect on the dry matter intake.

3.2. Milk production and milk quality
According to Table 4, the treatments did not affect the milk production. However, there was a trend that prilled fat supplemented cows (T2, T3, T4) showed better milk production than cows that were not supplemented (T1).

Table 4. Milk production and milk composition of cows fed treatment diets.

| Parameters | T1             | T2             | T3             | T4             |
|------------|----------------|----------------|----------------|----------------|
| Milk Production (l head⁻¹d⁻¹) | 9.72 ± 4.38 | 14.19 ± 2.66 | 13.73 ± 0.87 | 12.04 ± 4.67 |
| Milk Components (%) |                 |                 |                 |                 |
| - Fat      | 3.18 ± 0.33    | 4.22 ± 0.52    | 3.71 ± 0.22    | 3.81 ± 0.30    |
| - Lactose  | 4.19 ± 0.12    | 4.22 ± 0.19    | 4.13 ± 0.20    | 4.13 ± 0.10    |
| - Protein  | 2.78 ± 0.08    | 2.80 ± 0.13    | 2.75 ± 0.13    | 2.75 ± 0.07    |
| - Solid non-fat (SNF) | 7.32 ± 0.18 | 7.17 ± 0.46 | 7.19 ± 0.35 | 7.16 ± 0.27 |
| - Total Solid (TS) | 10.50 ± 0.29 | 11.39 ± 0.61 | 10.89 ± 0.49 | 10.97 ± 0.08 |

a,ab,b Superscripts indicate significant difference (P<0.05).
These findings were supported by some studies that there were no effect of supplemental C16:0-enriched on milk yield [9,11], although the trend also resembled some of the previous studies that C16:0-enriched supplementation could increase milk yield [6,12]. The data also showed that there was a respective decreasing milk production along with increasing free FA content (T2, T3, T4). It was likely due to the reduced in nutrient intake [13].

From the data of Table 4 also conveyed that all the supplementation of prilled fat treatments increased the milk fat content of the milk compared to the control (T1). The best result was shown in T2 and these findings agree with the previous study that feeding pure C16:0 would increase milk fat yield by 0.86% units and increase two folds amount of the C16:0 in milk fat but did not affect the milk production [14], but this study also contrasted to another study that feeding high palmitic acid supplemented diet gave no effect on the milk fat, but milk fat yield tended to decrease linearly with decreasing C16:0 in the lipid supplement [15]. If T2 (triglyceride form) compared to T3 an T4 (free FA form), the milk fat showed a respective decrease. According to the study of infusing unsaturated free FA compared to unsaturated triglyceride showed the similar responses to this study. Milk fat yield was decreased markedly by unsaturated free FA infusion, but was relatively unaffected by infusion of triglycerides [13].

The treatments did not affect the other milk components, including milk lactose and protein. Nonetheless, there was a similar trend with the other parameters. The lactose content tended to increase on the T2, yet decrease respectively with the presence of the free FA in T3 and T4. This result agrees with the previous study that milk lactose content were reduced linearly as amount of free FA increased [13]. Nevertheless, the high lactose content in T2 compared to the others might also indicate the divided energy portion that comes from supplemental fat, in some cases most of it appeared as milk fat and some are utilized as energy to synthesis milk or other purposes. It is possible that circulating C16:0 might have stored some glucose for milk lactose synthesis that showing positive milk yield responses. Increased glucose availability can be reflected in increased lactose synthesis and its secretion into milk [9].

Overall, the milk protein content and total solids content resulted in similar trend. However, the trend of milk protein content was slightly in line with a study that the milk protein concentration was slightly lower for C16:0-supplemented cows [9], unless for the T2 that had slightly higher milk protein content than the others. This result was in contrast to some other findings that milk protein concentration would be decreased when fats were supplemented to dairy cows [16,17], yet the number of milk protein content would remain in the similar range [18]. Total solids (TS) content was also not affected by the prilled fat supplementation, but the trend of the TS content was highest in T2 then decreased with the presence of free FA in T3 and T4. It was also reported that total solids yield decreased linearly, with the extent of greater decrease for unsaturated free FA [13]. The same result was shown in milk SNF content that it was not affected by the treatments. The trend showed that supplementation of prilled fat slightly decreased the SNF content. This agrees with another study that the different inclusion level of prilled fat to the dairy cows diet did not affect the SNF content but the trend was also showing a slight decrease in order to the increase supplementation of fatty acids from palm oil [12].

4. Conclusion

This study concluded that 2% of prilled fat supplementation could improve the dry matter intake and increase the percentage of milk fat and did not disrupt the other milk components. The best supplemental prilled fat was shown in T2 which contains 75% palmitic acid in the triglyceride form.

References

[1] Sudaryanto B and Hermawan A 2014 Reformasi Kebijakan Menuju Transformasi Pembangunan Pertanian, ed Haryono, et al. (Jakarta: IAARD Press)
[2] BPS 2019 Fresh Milk Production by Province. In: Directorate General of Livestock and Animal Health Services, Ministry of Agriculture, ed F M P b Province (Jakarta, Indonesia: BPS RI)

[3] Santos J E, Greco L, Garcia M, Thatcher W and Staples C 2013 The role of specific fatty acids on dairy cattle performance and fertility. In: Florida Ruminant Nutrition Symposium, (University of Florida. Gainesville, Florida

[4] Wu Z, Ohajuruka O and Palmquist D 1991 Ruminal synthesis, biohydrogenation, and digestibility of fatty acids by dairy cows Journal of Dairy Science 74 3025-34

[5] Kundu M, De A K, Jeyakumar S, Sunder J, Kundu A and Sujatha T 2014 Effect of prill fat supplementation on hormones, milk production and energy metabolites during mid lactation in crossbred cows Veterinary World 7 384-8

[6] Piantoni P, Lock A and Allen M 2013 Palmitic acid increased yields of milk and milk fat and nutrient digestibility across production level of lactating cows Journal of Dairy Science 96 7143-54

[7] Wardeh M F 1981 Models for estimating energy and protein utilization for feeds

[8] De Souza J, Preseault C and Lock A 2016 Lactational responses to palmitic acid supplementation when replacing soyhulls or dry ground corn Journal of dairy science 99 1945-50

[9] Lock A, Preseault C, Rico J, DeLand K and Allen M 2013 Feeding a C16: 0-enriched fat supplement increased the yield of milk fat and improved conversion of feed to milk Journal of Dairy Science 96 6650-9

[10] Bremmer D, Ruppert L, Clark J and Drackley J K 1998 Effects of chain length and unsaturation of fatty acid mixtures infused into the abomasum of lactating dairy cows Journal of Dairy Science 81 176-88

[11] Rico D, Ying Y and Harvatine K J 2014 Effect of a high-palmitic acid fat supplement on milk production and apparent total-tract digestibility in high-and low-milk yield dairy cows Journal of dairy science 97 3739-51

[12] Mosley S, Mosley E, Hatch B, Szasz J, Corato A, Zacharias N, Howes D and McGuire M 2007 Effect of varying levels of fatty acids from palm oil on feed intake and milk production in Holstein cows Journal of Dairy Science 90 987-93

[13] Litherland N, Thire S, Beaulieu A, Reynolds C, Benson J and Drackley J K 2005 Dry matter intake is decreased more by abomasal infusion of unsaturated free fatty acids than by unsaturated triglycerides Journal of dairy science 88 632-43

[14] Steele W and Moore J 1968 The digestibility coefficients of myristic, palmitic and stearic acids in the diet of sheep Journal of Dairy Research 35 371-6

[15] Chamberlain M and DePeters E 2017 Impacts of feeding lipid supplements high in palmitic acid or stearic acid on performance of lactating dairy cows Journal of Applied Animal Research 45 126-35

[16] Steele W 1969 The effects of dietary palmitic and stearic acids on milk yield and composition in the cow Journal of Dairy Research 36 369-73

[17] Wu Z and Huber J 1994 Relationship between dietary fat supplementation and milk protein concentration in lactating cows: a review Livestock Production Science 39 141-55

[18] Rabiee A, Breinhild K, Scott W, Golder H, Block E and Lean I 2012 Effect of fat additions to diets of dairy cattle on milk production and components: A meta-analysis and meta-regression Journal of dairy science 95 3225-47