Effect of inclusion of bakery by-products in the dairy cow’s diet on milk fatty acid composition

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Abstract

Bakery by-products (BP), rich in fats and sugars, are unconventional feed sources for cows whose effects on milk fat composition have not yet been evaluated. This research paper aimed to assess the effects of dietary BP inclusion rate and feeding period on the milk fatty acid composition. Twenty-four Simmental cows were fed a diet without BP (CON) for 1 week. Then they either continued with the CON diet or switched to one of the BP diets (with 15% or 30% BP in diet dry matter) for 3 weeks. Milk samples were taken before diet change and three times during BP feeding and analysed for fatty acid composition. Data showed that increasing BP content in the diet increased total fatty acid intake, especially of 18 : 1 n9. In the milk fat, the percentages of total monounsaturated fatty acids especially of the 18:1 origin linearly increased with increasing dietary BP level. The percentage of fatty acids de novo synthesized in the mammary gland (the sum of 4 : 0–14 : 0) remained similar among diets (32-34% of total fatty acids). The 16:0 percentage dropped from 32.5 to 29.6% and from 33.6 to 28.3% for 15% and 30% BP, respectively. Only 30% BP elevated the percentage of conjugated linoleic acids (CLA: by 59%) compared with CON throughout the 3 weeks. Proportions of 18:2 n6 and 18:3 n3 and the n6:n3 ratio were unaffected by BP and feeding time. BP feeding improved all those estimated health indices of the milk fat that are suggested to be related to coronary health. In summary, the inclusion of BP in dairy rations beneficially shifted the milk fatty acid profile to more 18:1 fatty acids at the expense of 16:0. At a 30% inclusion rate, BP feeding showed an additional benefit of increased CLA content in milk fat.

Keywords:
Bakery by-product; conjugated linoleic acid; dairy cow; milk fatty acid profile; oleic acid
fatty acid especially of MUFA and mammary de novo fatty acid fractions in the milk fat of cows fed BP.

**Materials and methods**

**Animals, diets and experimental design**

The experimental design and feeding are reported in more detail in our companion studies (Kaltenegger *et al.*, 2020, 2021). The experimental procedures involving animal handling and treatment were approved by the institutional ethics committee of the University of Veterinary Medicine (Vetmeduni) Vienna and the national authority according to §26 of the Law for Animal Experiments, Tierversuchsgesetz 2012- TVG (GZ: 68.205/80-V/3b/2018).

Twenty-four Simmental cows in mid-lactation were used (mean ± SD: days in milk of 149 ± 22.3 d, parity of 2.63 ± 1.38, initial BW of 756 ± 89.6 kg and mean energy corrected milk yield of 30 ± 0.3 kg at the start of the experiment). All cows started with a baseline diet containing 50% forage and 50% concentrate (wheat and triticale as the main cereal grains) on a dry matter (DM) basis for 7 d. Then they were blocked by days in milk, parity, feed intake and milk yield and randomly assigned to one of the three test diets (n = 8 per diet) including CON (same as the baseline diet), 15% BP (a diet containing 15% BP in replacement of wheat and triticale) and 30%BP (30% BP and no cereal grains) and tested for 4 weeks. All test diets contained the same forage sources (grass silage and corn silage, 1 : 1 on DM basis) and forage to concentrate ratio of 50 : 50 (DM basis). The dried BP was milled, mixed, and pelleted together with the other ingredients of the concentrate. The diet was then prepared as a total mixed ration and fed to animals twice a day (07.30 and 15.00). Feed refusal was removed daily before filling in freshly mixed feed. Cows were fed individually ad libitum and the daily intake was recorded. Cows always had access to fresh clean water and salt blocks throughout the trial. Cows were milked twice a day at 07.00 and 17.30. For fatty acid analysis, the pooled morning and afternoon milk samples were taken from each cow at the end of baseline, day14, day21, and day28 during the test period. The milk samples were stored at −20°C until analysis. Details on diet ingredients, chemical composition, feeding management, and housing are presented in Kaltenegger *et al.* (2020).

**Fatty acid analysis of diets and milk**

The fatty acid content and composition of diets were analysed using a one-step extraction and methylation using 10% methanoic HCl under heat (90°C) according to Palmquist and Jenkins (2003). Heptadecanoic acid (17:0, H3500, Sigma-Aldrich, Saint Louis, MO) was used as an internal standard. For milk samples, frozen samples were thawed at room temperature shortly before analysis. The extraction and transesterification of fatty acids in the milk were done using a sodium methylate solution (5% w/v) (Suter *et al.*, 1997). Prior to reaction, a mixture of internal standards including glycerol trivlarerate (93498, Sigma-Aldrich, Saint Louis, MO), tridecanoic acid, (T3882, Sigma-Aldrich, Saint Louis, MO), methyl undecanoate (94118, Sigma-Aldrich, Saint Louis, MO), and methyl nonadecanoate (74208, Sigma-Aldrich, Saint Louis, MO) was added. Fatty acid methyl esters (FAME) present in diets or milk samples were taken and analysed using a gas chromatograph (GC-2010 Plus, Shimadzu, Japan) equipped with a FID detector and a 100 m × 0.25 mm × 0.2 μm CP Sil-88 for FAME (CP7489, Agilent Technologies, Santa Clara, CA). Peak identification of FAME was achieved by comparison with external standards including FAME mixture (Supelco 37 Component FAME Mix, Supelco, Bellefonte, PA), linoleic acid, conjugated methyl ester (O5632, Sigma-Aldrich, Saint Louis, MO), and cis/Trans FAME Mix (35079, Restek, Bellefonte, PA). Fatty acids were quantified using the internal and external standards following the AOAC official method (AOAC, 2012).

**Calculations and statistical analysis**

Fatty acid intake was calculated from the analysed fatty acid composition and measured weekly average feed intake of individual cows. The compositions of fatty acids of milk samples are reported as relative concentrations (% of total fatty acids). Δ9-Desaturase activity index, atherogenicity index (AI), thrombogenicity index (TI), and hypercholesterolaemic and hypocholesterolaemic ratio (Hh) were calculated following previous publications (Vessby *et al.*, 2013; Giuffrida-Mendoza *et al.*, 2015).

Data of fatty acid intake, milk fatty acid composition, and fatty acid indices (thrombogenicity index (TI), atherogenicity index (AI) and hypercholesterolaemic to hypocholesterolaemic ratio (Hh ratio) were analysed using the MIXED procedure of SAS (version 9.4, SAS Institute Inc., Cary, NC, USA). The statistical model included fixed effects of diet, feeding time and their interaction and random effects of cow and block. We focused on the transitional change from baseline to test diets; baseline values were evaluated as an independent time point. Repeated measures within the cow were considered in the model and a spatial power covariance structure was used because the time points were unequally spaced. Data are reported as least-squares means and comparisons among diets or time of feeding were done following the Tukey’s method when the corresponding fixed effect was found significant (P ≤ 0.05).

**Results and discussion**

The fatty acid composition of the BP and complete diets is shown in Table 1. The dietary fatty acid composition of CON was dominated by 18 : 2 n-6 > 18 : 1 n9 > 16 : 0 > 18 : 3 n3, accounting for 80% of total fatty acids. The increasing level of BP in replacement of cereal grains increased the proportion of 18 : 1 n9 at the expense of 18 : 2 n6 and 18 : 3 n3. With 30% BP, 18 : 1 n9 became the most abundant fatty acid accounting for almost one-third of fatty acids in the profile. Due to the high lipid content of BP, the absolute intake (g/d) of dietary fatty acids increased with increasing BP level in the diet (Table 1). Notably, the change was more evident for SFA and MUFA intake than for PUFA intake in which both BP groups resulted in similar PUFA intake. Cows in this study were in a positive energy balance (Kaltenegger *et al.*, 2020), thus diets were the major contributors to milk fat synthesis.

Diet affected the milk fatty acid composition and an interaction between diet and time was found on several fatty acids (Table 2) generally because of the swift changes from baseline to BP diets (online Supplementary Table S1). Following the shift of fatty acid intake with BP diets, the proportion of total 18 : 1 fatty acids in milk fat increased (Table 2), which was maintained throughout the feeding period in 30% BP (Fig. 1a). The major milk fatty acid (18 : 1) was 18 : 1 n9, which linearly increased with increasing BP level in the diet (P < 0.001, Table 2). With minimal body fat mobilization, as in the present
study, this milk fatty acid originates mainly from diet and mammary desaturation of 18:0 (Chilliard et al., 2000). Since the dietary supply of 18:1 n9 was plentiful and milk 18:0 was similar between both BP diets, it seems plausible that the diet was the predominant source driving the differences in the milk among treatments. Similar 18:1 n9-promoting effects have been reported with other 18:1 n9 rich feedstuffs such as olive by-products (Abbeddou et al., 2011; Castellani et al., 2017).

C18 PUFA 18:2 n6 and 18:3 n3 are essential fatty acids and the daily requirements can be met only by dietary sources. However, in contrast to the effect found with 18:1 n9, the increased intake of 18:2 n6 and 18:3 n3 via BP inclusion did not lead to their enrichment in the milk fat (Table 2), even when the daily supply amount of 18:2 n6 was as high as that of 18:1 n9 (Table 1). In ruminants, C18 unsaturated fatty acids are modified by ruminal microbes in the process called biohydrogenation. Their presence in ruminant lipids thus depends on their escape from ruminal biohydrogenation. Therefore, our data suggest substantial lipolysis of BP lipids and subsequent biohydrogenation of fatty acids in the rumen. The higher transfer of 18:1 n9 into milk fat could be explained by its generally lower biohydrogenation rate in the rumen compared to C18 PUFA (Khiaosa-ard et al., 2009).

Conjugated linoleic acids (CLA) along with numerous 18:1 isomers are intermediates of biohydrogenation of C18 unsaturated fatty acids in the rumen. In the mammary gland, CLA is largely synthesized endogenously from trans11 18:1 (Chilliard et al., 2000). The naturally occurring CLA are considered to be potential health-beneficial fatty acids due to their multiple effects including anticarcinogenic, antiatherogenic, antidiabetogenic and immune-modulating properties (Rainer and Heiss, 2004).

Interestingly, 30% BP favoured an enrichment of trans18:1 (1.65 times the CON, \( P < 0.05 \)) and CLA (1.59 times the CON, \( P < 0.05 \)) in milk fat (Table 2). The positive effect on milk CLA was seen instantly when switching from baseline to 30% BP diet and was maintained throughout the trial (Fig. 1b). On the other hand, 15% BP did not improve over CON in this regard. It might be that the high BP diet led to surplus production of biohydrogenation intermediates, especially trans11 18:1, that could

### Table 1. Composition of major fatty acids in the diets (% of total fatty acids), dietary fatty acid content and the effect of dietary treatment on daily fatty acid intake

| Item                        | BP      | CON  | 15%BP | 30%BP | SEM   | P valueb | Linearc |
|-----------------------------|---------|------|-------|-------|-------|----------|----------|
| Fatty acid composition (% of total fatty acid) |         |      |       |       |       |          |          |
| 12 : 0                      | 3.18    | 0.24 | 1.14  | 1.75  | -     | -        | -        |
| 14 : 0                      | 3.12    | 0.48 | 1.11  | 1.64  | -     | -        | -        |
| 16 : 0                      | 18.08   | 16.34| 15.87 | 16.84 | -     | -        | -        |
| 18 : 0                      | 4.11    | 2.02 | 2.85  | 3.47  | -     | -        | -        |
| 18 : 1 n9                   | 40.33   | 20.48| 27.08 | 31.20 | -     | -        | -        |
| 18 : 2 n6                   | 21.22   | 33.01| 28.78 | 25.40 | -     | -        | -        |
| 18 : 3 n3                   | 2.15    | 10.05| 8.07  | 6.46  | -     | -        | -        |
| n6 : n3 ratio               | 9.88    | 3.30 | 3.57  | 3.94  | -     | -        | -        |
| SFA                         | 32.68   | 28.73| 29.78 | 31.05 | -     | -        | -        |
| MUFA                        | 42.41   | 23.55| 29.97 | 34.02 | -     | -        | -        |
| PUFA                        | 23.41   | 43.53| 37.11 | 32.01 | -     | -        | -        |
| Total fatty acids (% of DM) | 8.78    | 2.10 | 2.78  | 3.59  | -     | -        | -        |
| Intake (g/d)                |         |      |       |       |       |          |          |
| 16 : 0                      | -       | 77a  | 98b   | 129c  | 5     | <0.001   | *        |
| 18 : 0                      | -       | 9.3a | 16.6b | 24.9c | 0.6   | <0.001   | *        |
| 18 : 1 n9                   | -       | 96a  | 169b  | 227c  | 8     | <0.001   | *        |
| 18 : 2 n6                   | -       | 156a | 185b  | 206c  | 11    | <0.001   | *        |
| 18 : 3 n3                   | -       | 46a  | 52b   | 53b   | 4     | 0.111    | *        |
| SFA                         | -       | 135a | 183b  | 236c  | 7     | <0.001   | *        |
| MUFA                        | -       | 110a | 179b  | 249c  | 9     | <0.001   | *        |
| PUFA                        | -       | 204a | 239b  | 261b  | 15    | <0.001   | *        |
| Total fatty acids           | -       | 451a | 600b  | 747c  | 29    | <0.001   | *        |

SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids. Values sharing no common superscripts differ significantly (\( P < 0.05 \)) according to Tukey’s method.

aCON diet contained, on DM basis, 30% grain (wheat and triticale) and 0% bakery by-products (BP) in the total diet, 15%BP diet contained 15% grains and 15% BP, and 30%BP diet contained 0% grains and 30% BP. All diets had, on DM basis, identical proportions of other main ingredients (25% grass silage, 25% corn silage, and 17% rapeseed meal) in the total diet.

bThere were effects of week of sampling (\( P < 0.001 \)) and its interaction with dietary treatment (\( P < 0.001 \), except for 18 : 3 n3 \( P = 0.045 \)). For all fatty acids, the effect of dietary treatment on intake was detected after baseline and maintained through the trial.

cContrast analysis: variables with a significant linear effect (\( P < 0.01 \)) are marked with asterisk. No quadratic effect was detected.
| Item         | Diet               | SEM | P value       | Diet | Time<sup>b</sup> | Interaction | Linear<sup>a</sup> |
|--------------|--------------------|-----|---------------|------|-----------------|-------------|-------------------|
|              | CON | 15%BP | 30%BP |      |                 |             |                   |
| 4 : 0        | 2.53 | 2.46 | 2.72 | 0.25 | 0.509 | 0.715 | 0.314 | NS |
| 6 : 0        | 3.52 | 3.49 | 3.50 | 0.19 | 0.993 | 0.006 | 0.554 | NS |
| 8 : 0        | 1.97 | 2.04 | 1.96 | 0.11 | 0.797 | 0.501 | 0.117 | NS |
| 10 : 0       | 4.84 | 4.72 | 4.39 | 0.21 | 0.306 | 0.536 | 0.560 | NS |
| 12 : 0       | 5.90<sup>a</sup> | 5.57<sup>a,b</sup> | 5.10<sup>b</sup> | 0.21 | 0.030 | 0.099 | 0.760 | * |
| iso 13 : 0   | 0.03 | 0.02 | 0.02 | 0.01 | 0.941 | 0.669 | 0.723 | NS |
| anteiso 13 : 0 | 0.16<sup>a</sup> | 0.15<sup>a</sup> | 0.12<sup>b</sup> | 0.01 | <0.001 | 0.831 | 0.596 | NS |
| 14 : 0       | 15.39<sup>a</sup> | 15.12<sup>a,b</sup> | 14.37<sup>b</sup> | 0.29 | 0.041 | 0.279 | 0.249 | * |
| 14 : 1       | 1.32 | 1.33 | 1.04 | 0.10 | 0.036 | 0.511 | 0.208 | * |
| 15 : 0       | 2.31<sup>a</sup> | 1.88<sup>a,b</sup> | 1.66<sup>b</sup> | 0.17 | 0.021 | <0.001 | <0.001 | * |
| iso 15 : 0   | 0.27 | 0.25 | 0.22 | 0.02 | 0.078 | 0.170 | 0.180 | * |
| anteiso 15 : 0 | 0.59 | 0.54 | 0.52 | 0.03 | 0.213 | 0.414 | 0.328 | NS |
| iso 16 : 0   | 0.28 | 0.24 | 0.23 | 0.05 | 0.427 | 0.170 | 0.107 | NS |
| 16 : 0       | 31.66 | 30.38 | 29.41 | 0.76 | 0.066 | <0.001 | <0.001 | * |
| 16 : 1 n7    | 1.90 | 1.57 | 1.65 | 0.13 | 0.091 | 0.002 | 0.004 | * |
| 17 : 0       | 0.63<sup>a</sup> | 0.55<sup>a,b</sup> | 0.50<sup>b</sup> | 0.03 | 0.005 | <0.001 | <0.001 | * |
| iso 17 : 0   | 0.43 | 0.46 | 0.43 | 0.03 | 0.604 | 0.169 | 0.063 | NS |
| anteiso 17 : 0 | 0.69 | 0.69 | 0.67 | 0.03 | 0.835 | 0.092 | 0.775 | NS |
| 18 : 0       | 5.09<sup>a</sup> | 6.18<sup>a</sup> | 6.75<sup>a</sup> | 0.30 | 0.001 | <0.001 | 0.010 | * |
| 18 : 1 n9 (cis 9)<sup>c</sup> | 14.24<sup>b</sup> | 15.93<sup>a,b</sup> | 17.43<sup>a</sup> | 0.51 | <0.001 | <0.001 | <0.001 | * |
| 18 : 1 other cis | 1.30 | 1.25 | 1.19 | 0.08 | 0.200 | 0.001 | 0.199 | NS |
| 18 : 1 trans 10 + 11 | 0.83 | 0.93 | 1.17 | 0.12 | 0.117 | 0.018 | 0.351 | * |
| 18 : 1 other trans | 0.46<sup>b</sup> | 0.68<sup>a</sup> | 0.97<sup>c</sup> | 0.05 | <0.001 | <0.001 | <0.001 | * |
| Sum 18 : 1 trans | 1.30<sup>b</sup> | 1.62<sup>b</sup> | 2.15<sup>a</sup> | 0.16 | <0.001 | <0.001 | 0.111 | * |
| Σ18 : 1     | 16.82<sup>b</sup> | 18.78<sup>a</sup> | 20.74<sup>c</sup> | 0.57 | <0.001 | <0.001 | <0.001 | * |
| CLA<sup>d</sup> | 0.34<sup>b</sup> | 0.40<sup>b</sup> | 0.54<sup>a</sup> | 0.02 | <0.001 | <0.001 | 0.021 | * |
| 18 : 2 n6   | 1.52 | 1.42 | 1.54 | 0.11 | 0.491 | 0.624 | 0.004 | NS |
| 18 : 3 n3   | 0.33 | 0.30 | 0.32 | 0.03 | 0.562 | 0.194 | 0.436 | NS |
| Other long-chain fatty acids | 1.35 | 1.33 | 1.44 | 0.05 | 0.087 | 0.081 | 0.004 | NS |
| De novo origin<sup>e</sup> | 34.22 | 33.47 | 32.12 | 0.91 | 0.263 | 0.696 | 0.445 | NS |
| OBCFA<sup>f</sup> | 5.49<sup>b</sup> | 4.86<sup>a</sup> | 4.47<sup>a</sup> | 0.17 | <0.001 | <0.001 | <0.001 | * |
| SFA         | 74.05<sup>c</sup> | 72.59<sup>a,b</sup> | 70.59<sup>b</sup> | 0.72 | 0.005 | <0.001 | <0.001 | * |
| MUFA        | 20.32<sup>b</sup> | 21.91<sup>a,b</sup> | 23.65<sup>a</sup> | 0.62 | 0.001 | <0.001 | <0.001 | * |
| PUFA        | 2.90 | 2.89 | 3.24 | 0.18 | 0.111 | <0.001 | <0.001 | NS |
| Fatty acid secretion | 1.02<sup>b</sup> | 1.11<sup>a,b</sup> | 1.22<sup>a</sup> | 0.65 | 0.020 | 0.119 | 0.297 | * |
| Indices<sup>g</sup> |               |     |               |     |                 |             |                   |
| n6n3        | 4.73 | 4.80 | 4.97 | 0.18 | 0.288 | 0.113 | 0.630 | NS |
| Desaturase   | 2.81 | 2.59 | 2.60 | 0.11 | 0.307 | 0.001 | 0.132 | NS |
| TI          | 4.31<sup>a</sup> | 4.04<sup>a,b</sup> | 3.71<sup>b</sup> | 0.12 | 0.004 | <0.001 | <0.001 | * |
| AI          | 4.49<sup>a</sup> | 4.10<sup>a,b</sup> | 3.66<sup>b</sup> | 0.14 | 0.001 | <0.001 | <0.001 | * |

(Continued)
Odd- and branched-chain fatty acids in milk fat are largely derived from ruminal microbes (Vlaeminck et al., 2006). The lower proportions of these fatty acids in the milk fat despite more fatty acids secreted in the milk with BP diets may indicate that the presence of BP affected the rumen microbial population. This assumption is challenged by the fact that ruminal pH was not negatively affected by BP inclusion (Kaltenegger et al., 2020). Direct proof of the BP effect on ruminal microbiota in cows is currently not available, but a diet with 45% BP can impair ruminal fermentation and decrease microbial diversity as shown in vitro (Humer et al., 2018). At the hindgut level, high BP inclusion could increase the odds for hindgut dysbiosis of animals (Kaltenegger et al., 2021). Although 30% BP proved to be the most effective diet to enrich milk CLA, this high BP level might not be optimal for energy metabolism in mid-lactation cows (Kaltenegger et al., 2020) and may negatively affect the microbiota. Additional research in biohydrogenation of BP lipids would be necessary to find ways to promote bypass of such beneficial fatty acids to human edible products without the need for high inclusion levels of BP.

We showed previously that BP diets increased energy corrected milk yield (29.4, 31.5 and 34.3 kg/d, respectively) and caused a numerical increase in milk fat content (3.59%, 3.75% and 3.90% for CON, 15% BP and 30% BP, respectively), although neither this nor total fat yield achieved significance (Kaltenegger et al., 2020). In the current analysis, we showed a linear increase in fatty acid secretion with increasing BP in the diet (Table 2). On the one hand, increased production of lipogenic precursors with dietary sugars (Oba et al., 2015) may suggest more fatty acids synthesized de novo (4:0–14:0) in the mammary gland with BP diets. On the other hand, the provision of dietary lipids of long-chain origins (C18) could decrease mammary de novo

### Table 2.

| Item          | CON  | 15%BP | 30%BP | SEM | P value | Linear* |
|---------------|------|-------|-------|-----|---------|---------|
| Hh            | 2.94a | 2.61a,b | 2.33b | 0.10 | <0.001  | <0.001  | <0.001  |

* Contrast analysis: variables with a significant linear effect (P < 0.05) are marked with an asterisk and NS for non-significance. No quadratic effect was detected.

Fig. 1. Changes in percentages of selected fatty acids and groups of fatty acids in response to time of feeding of diets without (CON) or with 15 or 30% bakery by-products (BP). All cows received the same diet as CON in the baseline period. Except for fatty acids synthesized de novo (De novo FA), there are effects of diet, time and their interaction (P ≤ 0.01). Within each diet, asterisks indicate significant changes compared to their baseline (P = 0.05) according to Tukey’s method.
fatty acid synthesis (Chilliard et al., 2000). However, we found that the total proportion of milk 4:0 to 14:0 was not disturbed by BP (Table 2, Fig. 1c). Thus, the increased milk energy production by BP diets reported earlier (Kaltenegger et al., 2020) and more fatty acid secretion reported here was probably explained by greater uptake of the preformed fatty acids. It seems that the effect of long-chain fatty acids on reducing mammary de novo fatty acid synthesis could be compensated by a provision of carbohydrate sources that stimulate the production of lipogenic precursors (acetate and butyrate). Furthermore, with high-fat diets, there would be an increase in acetate needed for cholesterol biosynthesis (Liepa et al., 1978) to accommodate the prioritized transportation of more lipid to the tissues and organs. With a low production of acetate, mammary de novo fatty acid synthesis might be substantially limited. In our study, a slight but significant decrease in 12:0 and 14:0 in milk fat with 30% BP compared to CON was already evident (Table 2). Therefore, a pairing of groups of energy nutrients is important for the production and secretion of milk fatty acids in dairy cows.

Among SFA, 16:0 was the most abundant and the most responsive SFA to dietary change (Table 2, Fig. 1d). As C18 MUFA and CLA proportions in milk fat increased, the 16:0 proportion dropped, which could be considered beneficial as it contributed to a decrease in the SFA proportions of milk fat. In agreement with our results, studies underlined that increasing responsive SFA to dietary change (Table 2, Fig. 1d). As C18 PUFA, especially the n3 series, which otherwise would have been even more favourable. Omega-3 fatty acids are known for their effects on reducing the risk of many chronic diseases (Simopoulos, 2002). The basal diet used in the current study was based on maize silage, an n-6 PUFA source. Associative effects between BP lipids and n-3 PUFA rich feeds like pasture, concentrates. A. Kaltenegger acknowledges H. Wilhelm Schaumann Stiftung (Hamburg, Germany) for the PhD scholarship.

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