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The main fatty acids of bulk milks can be predicted with rapid farm surveys

M. Coppa[1,2,3,*], A. Ferlay[1,2], C. Chassaing[1,2], C. Agabriel[1,2], F. Glasser[1,2], Y. Chilliard[1,2], G. Borreani[3], R. Barcarolo[4], T. Baars[5], D. Kusche[6], O.M. Harstad[7], J. Verbič[8], J. Golecký[9] and B. Martin[1,2]

[1]INRA, UMR 1213 Herbivores, F-63122 Saint-Genès-Champanelle (France)
[2]Clermont Université, VetAgro Sup, UMR Herbivores, BP 10448, F-63000 Clermont-Ferrand (France)
[3]University of Turin, Dept. Agricultural, Forest and Food Sci., Via da Vinci 44, 10095, Grugliasco (TO) (Italy)
[4]Veneto Agricoltura, Ist. Qualità e Tecnologie Agroalimentari, Via S. Germano 74, 36016, Thiene (VI) (Italy)
[5]Research Institute of Organic Agriculture (FiBL) Ackerstrasse, 5070 Frick (Switzerland)
[6]Kassel University, Faculty Organic Agricultural Sci., Nordbahnhofsstr. 1, 37213 Witzenhausen (Germany)
[7]Norwegian University of Life Sciences, Dept. Animal & Aquacultural Sci., Arboretveien 6, 1430 Ås (Norway)
[8]Agricultural Institute of Slovenia, Hacquetova 17, SI-1000 Ljubljana (Slovenia)
[9]Plant Production Research Center (PPRC) – Grassland and Mountain Agriculture Research Institute (GMARI), Mladeznicka 36, 974 21 Banska Bystrica (Slovakia)
*e-mail: mauro.coppa@unito.it

Abstract. This study aimed to predict the cow milk fatty acid (FA) composition using farming practices described through on-farm surveys. The FA composition of 1248 bulk milk samples and the related farming practices came from 20 experiments conducted in 10 different European countries. Samples derived from farms located between 44°N to 60°N altitude, and from sea level to 2000 m altitude. The prediction equations of milk FA composition were considered good ($R^2 > 0.50$) for C16:0, saturated FA (SFA), poly-unsaturated FA (PUFA), and odd-chain FA (OCFA), and very good ($R^2 \geq 0.60$) for C18:1t11, CLAc9t11, total trans-FA, C18:3n-3, n-6/n-3 ratio, and branched-chain FA (BCFA). The main predictors were variables describing diet composition and altitude, whereas animal-related factors (i.e. lactation stage, breed, milk yield, proportion of primiparous cows in the herd) were not significant in any of the models. The predictor having the highest effect in almost all FA models was the proportion of fresh herbage in cow diet. However, when models were calculated using only samples derived from conserved forage-based diets, good predictions were also obtained for OCFA, BCFA, C18:1t10 and C18:3n-3 ($R^2 \geq 0.46$, 0.54, 0.52, and 0.70, respectively). These prediction models could be a valuable tool to help farmers to improve the nutritional quality of the milk they produce.

Keywords. Bulk milk – Fatty acid – Farming practices – Prediction models.

Les acides gras du lait de tank peuvent être prédits par des enquêtes rapides en ferme

Résumé. *L'objectif de ce travail était de prédire la composition en acides gras (AG) du lait en utilisant des données de condition de production collectées par des enquêtes rapides en ferme. La composition en AG de 1248 laits de tank et leurs conditions de production associées provenaient de 20 expérimentations réalisées dans 10 pays européens. Les échantillons ont été collectés dans des fermes localisées entre 44°N et 60°N de latitude et entre zéro et 2000 m d'altitude. Les équations de prédiction des AG du lait ont été considérées comme bonnes ($R^2 > 0,50$) pour le C16:0, les AG saturés (AGS), les AG polyinsaturés (AGPI), et les AG à chaine impaire (OCFA), et comme très bonnes ($R^2 \geq 0,60$) pour le C18:1t11, CLAc9t11, les AGtrans totaux, le C18:3n-3, le ratio n-6/n-3, et les AG à chaine ramifiée (BCFA). Les principaux prédicteurs étaient des variables décrivant l'alimentation des troupeaux et l'altitude. En revanche, les facteurs liés à l'animal (tels que stade de lactation, race, production de lait, proportion de primipares dans le troupeau) n'étaient pas significatifs dans les modèles. Dans presque tous les modèles, c'est la proportion d'herbe fraîche dans la ration qui était le meilleur prédicteur des AG du lait. Dans une sous-population d'échantillons de lait issus de troupeaux alimentés seulement avec des fourrages conservés, de bonnes prédictions ont également été obtenues pour les OCFA, BCFA, C18:1t10 et pour le C18:3n-3 ($R^2 \geq 0,46$, 0,54, 0,52, et 0,70, respectivement). Ces modèles de prédiction obtenus à l'échelle de l'exploitation pourront être utilisés par les éleveurs pour améliorer la qualité nutritionnelle de leur lait.*

Mots-clés. *Lait de mélange – Acides gras – Conditions de production – Modèles de prédiction.*

I – Introduction

In agreement with the World Health Organisation recommendations on fatty acid (FA) consumption for human nutrition, several dairy companies in various EU countries (including France, Belgium, The Netherlands, etc.) apply a price premium for cow's milk rich in health-promoting FA (i.e. n-3 and PUFA; Borreani *et al.*, 2013). Thus, farmers need to obtain information on the expected FA profile of their milk. However, the majority of studies investigating the effect of diet and animal-related factors on milk FA profile were controlled trials (i.e. Couvreur *et al.*, 2006; Ferlay *et al.*, 2006), usually applying measurements of farming practices not suitable on farm. This is also the case for milk FA prediction models that are reported in literature (Glasser *et al.*, 2008; Moate *et al.*, 2008). To our knowledge, no model has yet attempted to predict FA composition of bulk milk from commercial farms, based on simple farm surveys. Farming practices vary widely according to country and agronomical context, but most of the literature tends to operate at tight territorial scale. Collecting data from a wide territory makes it possible to explore a broad range of farming practices and thus of FA profiles of commercial milk. This study aimed to predict the cow milk FA composition using farming practices collected via on-farm surveys in different European countries.

II – Materials and methods

The FA profiles of 1248 bulk milk or cheese samples and their related farming practices were compiled from a selection of 20 published or unpublished studies carried out from 2000 to 2010 in 10 different European countries: France, Germany, Italy, Norway, Slovakia, Slovenia, Czech Republic, Denmark, Sweden, and The Netherlands. The details of the experiments used are given by Coppa *et al.* (2013). The experiments were conducted on-farm and included bulk milk collected on commercial farms at between 44°N to 60°N latitude, from sea level up to 2000 m altitude, from 13 different cow breeds during different seasons. Data on farming practices were collected on-farm at each milk sampling by surveys (Coppa *et al.*, 2013), that included herd characteristics, diet composition of lactating cows, and altitude. The milk FA analyses were performed by 5 different laboratories using gas-chromatographic methods. To develop a prediction of FA composition based on farming practices data, a general linear model (GLM) was applied using experiment as fixed factor and farming practices as covariates. Root mean square error (RMSE) and R^2 were used to describe model fitting. The Fisher's F-distribution of each variable included in a model was used as an indicator of the relative weight of the variable in determining the model itself. As the proportion of fresh herbage in cow diet was expected to be the main covariate of most models, new models were developed on a subset of data where milk samples derived from cow fed diets based on conserved forages. Statistics were performed with Minitab 14.1 software (Minitab Inc., State College, PA).

III – Results and discussion

The predictive equations of milk FA composition are given in Table 1 and were considered as good ($R^2 > 0.50$) for C16:0, saturated FA (SFA), polyunsaturated FA (PUFA), and odd-chain FA (OCFA), and very good ($R^2 \geq 0.60$) for C18:1t11, CLAc9t11, total trans-FA, C18:3n-3, n-6/n-3 ratio, and branched-chain FA (BCFA). The C16:0 increased with concentrates and decreased with fresh herbage and grass silage proportions in herd diet. The increase in milk SFA was well predicted by increases in all the conserved forages and concentrates in herd diet, confirming the high proportion of SFA found in milk from conserved forages and concentrate-rich diets (Dewhurst *et al.*, 2006; Ferlay *et al.*, 2008). The OCFA increased with the increasing proportions of hay and grass silage in the diet and decreased with increasing proportions of maize silage and concentrates. The BCFA were well predicted by an increase in fresh herbage and hay and a decrease in maize silage and concentrates in diet. This is consistent with the hypothesis that high-NDF feeds (i.e. fresh herbage and hay) favour ruminal populations of cellulolytic bacteria (Vlaemink *et al.*, 2006).

Table 1. Prediction models of FA proportions (g/100g FA) in bulk milk based on farming practices†

Fatty acids	Global equations	n	RMSE	R^2
All milk samples				
C16:0	32.83(±0.28)-7.51(±0.28)×FH-2.42(±0.47)×GS+4.33(±0.71)×C	987	2.12	0.57
C18:1t11	1.39(±0.18)+1.9(±0.1)×FH+0.43(±0.13)×GS-0.61(±0.15)×MS-9.31(±2.16)×C	592	0.50	0.72
C18:1c9+t13	19.11(±0.34)+2.2(±0.29)×FH-1.95(±0.35)×H+2.76(±0.69)×C	993	1.90	0.41
C18:2n-6	0.97(±0.04)-0.14(±0.05)×GS-0.11(±0.04)×H+0.50(±0.06)×MS+0.66(±0.08)×C +0.217(±0.030)×A	902	0.25	0.36
C18:3n-3	0.65(±0.04)+0.26(±0.03)×FH+0.28(±0.03)×H-0.39(±0.05)×MS-0.37(±0.06)×C	990	0.15	0.66
CLAc9t11	0.9(±0.04)+0.77(±0.03)×FH-0.31(±0.06)×MS-0.61(±0.09)×C	996	0.27	0.70
SFA	58.69(±0.29)+6.31(±0.54)×GS+7.68(±0.40)×H+7.87(±0.58)×MS+6.21(±0.8)×C	930	2.58	0.55
MUFA	25.4(±0.39)+4.22(±0.31)×FH-1.58(±0.48)×H-0.050(±0.030)×A	666	2.09	0.41
PUFA	2.8(±0.08)+1.58(±0.09)×FH+0.28(±0.14)×H+0.547(±0.080)×A	684	0.62	0.54
OCFA	2.36(±0.03)+0.40(±0.03)×H-0.17(±0.05)×MS-0.97(±0.06)×C	739	0.20	0.50
BCFA	2.45(±0.06)+0.33(±0.05)×FH+0.43(±0.06)×H-0.41(±0.08)×MS-0.93(±0.11)×C 737 0.24 0.61			
Σ trans-FA	2.56(±0.11)+3.21(±0.14)×FH	540	0.96	0.66
Σ n-6/Σ n-3	4.49(±0.15)-3.56(±0.16)×FH-3.24(±0.24)×H-3.77(±0.21)×GS	435	0.59	0.67
Only conserved forages-derived milk samples				
C18:1t10	0.06(±0.19)+0.23(±0.02)×MS+0.42(±0.04)×C	226	0.06	0.56
C18:3n-3	0.45(±0.02)+0.43(±0.03)×H-0.33(±0.04)×MS	442	0.12	0.75
OCFA	2.24(±0.06)+0.51(±0.06)×H-0.78(±0.13)×C	298	0.19	0.61
BCFA	1.45(±0.09)+0.83(±0.13)×GS+1.19(±0.11)×H+0.52(±0.13)×C +0.213(±0.046)×A	330	0.19	0.65

† FH, GS, H, MS, and C indicate fresh herbage, grass silage, hay, maize silage and concentrate in the cow diet, respectively, expressed as percentage divided by 100; A: altitude, expressed as km a.s.l.; Coefficients are reported as means (± SE); RMSE: root mean square error.

Increasing fresh herbage and hay and decreasing maize silage and concentrates in the diet increased milk C18:3n-3 proportion, in agreement with literature data (Chilliard *et al.*, 2007). Milk C18:2n-6 proportion increased with increasing maize silage and concentrate proportions in the diet. The C18:2n-6 is already an indicator of maize silage-based diets as maize is rich in this FA (Dewhurst *et al.*, 2006). Even so, the prediction was relatively poor ($R^2 = 0.36$), possibly due to the multiple dietary sources of C18:2n-6 in cow diet (Chilliard *et al.*, 2007). The decrease in milk PUFA and n-6/n-3 with decreasing fresh herbage or hay proportions in the diet is in agreement with the higher n-3 PUFA and relatively lower n-6 intake with these diets (Chilliard *et al.*, 2007). The increases in CLAc9t11, C18:1t11 and total trans FA proportion with increasing proportion of fresh herbage and grass silage and decreasing proportion of maize silage and concentrates are in agreement with literature (Dewhurst *et al.*, 2006). The low fits of C18:1c9+t13 can be related to the multiple sources of this FA in milk, being mainly derived from mammary ∆9-desaturation of C18:0, from diet and from mobilization of body fat reserves, (Chilliard *et al.*, 2007), but also depending on pasture type and phenology (Coppa *et al.*, 2011).

The quality of the models was maintained for BCFA and n-6/n-3 ratio and improved for OCFA, C18:1t10, C18:2n-6 and C18:3n-3 when calibration was made only on milk samples derived from conserved forages diets. The C18:1t10 increased with increasing starch and C18:2n-6 sources in the diet, in agreement with Griinari *et al.* (1998). Milk C18:3n-3 proportion increased with increasing proportion of hay in the diet but decreased with increasing proportion of maize silage, confirming that hay-derived milk fat is rich in C18:3n-3 (Chilliard *et al.*, 2007).

IV – Conclusions

This work provided original models to predict the FA profile of bulk milk based on farming practices collected via rapid on-farm surveys. An European scale dataset was used. Good prediction models were found for several FA. The large range of our dataset and the quality of the predictions highlighted the robustness of the cow feed effect on milk FA profile found in controlled conditions compared to animal-related factors, that seem to be negligible at farm scale. These prediction models could offer a valuable tool to help farmers to increase the proportions of health-promoting FA in milk fat.

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References

Borreani G., Coppa M., Revello-Chion A., Comino L., Giaccone D., Ferlay A. and Tabacco E., 2013. Effect of different feeding strategies in intensive dairy farming systems on milk fatty acid profiles, and implications on feeding costs in Italy. In: *Journal of Dairy Science,* 96, p. 6840-6855.

Chilliard Y., Glasser F., Ferlay A., Bernard L., Rouel J. and Doreau M., 2007. Diet, rumen biohydrogenation and nutritional quality of cow and goat milk fat. In: *European Journal of Lipid Science and Technology*, 109, p. 828-855.

Coppa M., Ferlay A., Chassaing C., Agabriel C., Glasser F., Chilliard Y., Borreani G., Barcarolo R., Baars T., Kusche D., Harstad O.M, Verbič J., Golecký J. and Martin B., 2013. Prediction of bulk milk fatty acid composition based on farming practices collected through on-farm surveys. In: *Journal of Dairy Science*, 96, p. 4197-4211.

Coppa, M., Ferlay A., Monsallier F., Verdier-Metz I., Pradel P., Didienne R., Farruggia A., Montel M.C. and Martin B., 2011. Milk fatty acid composition and cheese texture and appearance from cows fed hay or different grazing systems on upland pastures. In: *Journal of Dairy Science*, 94, p. 1132-1145.

Couvreur S., Hurtaud C., Lopez C., Delaby L. and Peyraud J.L., 2006. The linear relationship between the proportion of fresh grass in the cow diet, milk fatty acid composition, and butter properties. In: *Journal of Dairy Scienc*e, 89, p. 1956-1969.

Dewhurst R.J., Shingfield K.J., Lee M.R.F. and Scollan N.D., 2006. Increasing the concentrations of beneficial polyunsaturated fatty acids in milk produced by dairy cows in high-forage systems. In: *Animal Feed Science & Technology*, 131, p. 168-206.

Ferlay A., Agabriel C., Sibra C., Journal C., Martin B. and Chilliard Y., 2008. Tanker milk variability of fatty acids according to farm feeding and husbandry practices in a French semi-mountain area. In: *Dairy Science and Technology*, 88, p. 193-215.

Ferlay A., Martin B., Pradel P., Coulon J.B. and Chilliard Y., 2006. Influence of grass-based diets on milk fatty acid composition and milk lipolytic system in Tarentaise and Montbéliarde cow breeds. In: *Journal of Dairy Science*, 89, p. 4026-4041.

Glasser F., Ferlay A. and Chilliard Y., 2008. Oilseed lipid supplement and fatty acid composition of cow milk: a meta-analysis. In: *Journal of Dairy Science*, 91, p. 4687-4703.

Griinari J.M., Dwyer D.A., Mcguyre M.A., Bauman D.E., Palmquist D.L. and Nurmenla K.V.V., 1998. Trans-octadecenoic acids and milk fat depression in lactating dairy cows. In: *Journal of Dairy Science*, 81, p. 1251-1261.

Moate P.J., Chalupa W., Boston R.C. and Lean I.J., 2008. Milk fatty acids II: prediction of the production of individual fatty acids in bovine milk. In: *Journal of Dairy Science*, 91, p. 1175-1188.

Vlaeminck B., Fievez V., Cabrita A.R.J., Fonseca A.J.M. and Dewhurst R.J., 2006. Factors affecting odd- and branched-chain fatty acids in milk: a review. In: *Animal Feed Science & Technology*, 131, p. 389-417.