Development of a new equation based on MIR spectra to predict lipolysis in dairy goats

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Abstract

France, Europe's leading producer, uses most of its goat's milk for cheese processing. The French goat industry therefore has a strong interest in producing high quality milk. The rate of lipolysis of milk is a quality criterion which must be controlled to maintain the quality of milk and dairy products. In France, a prediction equation has been calibrated using bovine mid-infrared spectra (MIR) to quantify the free fatty acids indicative of lipolysis, but to date there is no instrumental method to evaluate lipolysis in goat milk.

The present study aims to develop a prediction equation for milk lipolysis in goat milk. For this purpose, 518 milk samples were collected from 4 experimental farms. A joint analysis of lipolysis according to ISO/TS 22113 (BDI method) and MIR spectrometry was performed on each sample.

The equation, developed by partial least squares regression after square root transformation, achieved a coefficient of determination R^2=0.91, with a residual standard deviation (Sy,x) of 0.20 meq/100 g fat. The relatively high accuracy of this equation should allow to use it to explore the genetic determinism of milk lipolysis in goats. This work offers new perspectives to deepen our knowledge of the mechanisms of lipolysis in goat milk and to improve its control on the farm.

Keywords: lipolysis, goat, mid infrared spectroscopy.

Introduction

France is Europe's leading producer of goat's milk, with 709,510 tonnes of raw milk produced per year. A large proportion of this milk is used for cheese processing, with 97,960 tonnes of cheese produced (FAO, 2020). In France, one-sixth of goat's cheese is produced on the farm, and the country has 15 goat's cheeses with protected designations of origin (PDO). It is therefore in the interest of the French goat industry to produce high quality milk. While milk quality has traditionally focused on fat and protein contents, or bacterial and somatic cell counts, the rate of lipolysis in milk is a quality criterion that must be monitored to maintain the quality of milk and dairy products.

Lipolysis is the breakdown of milk fat by the hydrolysis of triglycerides, the main component of milk fat. This hydrolysis leads to the release of free fatty acids that may affect the flavour as well as their possible oxidation products in the milk. As a result, a high rate of lipolysis leads to a deterioration in the organoleptic (rancid taste) and technological (inability to be processed) properties of the milk.

In France, a prediction equation has been calibrated using bovine mid-infrared spectra (MIR) to quantify the free fatty acids indicative of lipolysis (Gelé *et al.*, 2022). Although the use of MIR spectra has been developed strongly in dairy cattle since the end of the 2000s to phenotype new traits on a large scale, to date, there is no instrumental method to evaluate lipolysis in goat milk.

The present study aims to develop a prediction equation for milk lipolysis for goat milk.

Material and methods

Five hundred and eighteen goat milk samples were taken to meet the objectives. A joint analysis of lipolysis according to ISO/TS 22113|IDF/RM 204 (BDI method) and MIR spectrometry was carried out on each sample.

Data collection

Milk samples collected on farms.

Five hundred and eighteen goat milk samples were collected from four experimental farms located in several regions in France, between March and October 2021. Around 40 goats were sampled on each farm three times at different periods to maximise the diversity of diets and to represent the two main dairy goat breeds found in France, Alpine and Saanen (Table 1).

During sampling, vials containing 0.02% bronopol preservative (wt/vol) were fully filled (100 mL) to avoid "churning" of the milk that could damage fat globules and thus favour lipolysis during transport.

After collection, milk samples were stored at 4°C to limit bacterial proliferation and lipase-associated activities. Milk samples were sent at 4°C to ACTALIA CECALAIT (39800 Poligny, France) for subsequent analyses.

Table 1. Distribution of samples collected between farms and sampling periods.

Experimental farm	Number of milk samples			
	March/April	May-June	September-October	Total
P3R	40	40	47	127
MoSAR	40	40	40	120
FERLUS	45	45	45	135
IE PL	48	48	40	136
Total	173	173	172	518

Recording of MIR spectra and measurement of lipolysis in milk

MIR spectra were recorded at ACTALIA CECALAIT using MilkoScan™ FT+ spectrometer (Foss, Hillerød, Denmark).

Reference values for lipolysis in milk were determined using the ISO/TS 22113|IDF/RM 204 BDI (Bureau of Dairy Industry) method which determines the titratable acidity of milk fat. This analysis was carried out by ACTALIA CECALAIT within 36 hours of sampling. Lipolysis measured by BDI method averaged 0.85 meq/100 g fat (sd=1.00 meq/100 g fat), with a median value of 0.51 meq/100g fat.

Development of the equation for predicting lipolysis of goat's milk

Five hundred and nine individuals were selected after removing nine outliers for the development of the goat milk lipolysis prediction equation. The lipolysis reference values obtained by the BDI method were square-root transformed. The equation was developed by partial least squares (PLS) regression using R software on a calibration set made up of 2/3 of the data. The predictions were then squared and bounded at 5 meq/100g fat. The remaining third of the data was used as a validation set.

Results and discussion

The lipolysis prediction equation developed for goat's milk has a coefficient of determination $R^2 = 0.91$ and a residual standard deviation $Sy,x = 0.20$ meq/100 g fat. Figure 1 shows the predicted results using this equation, compared with the reference values from the BDI method. The accuracy of this equation is much higher than the one developed for cow's milk under the same conditions: $R^2 = 0.72$ and $Sy,x = 0.19$ meq/100 g fat (Gelé *et al.*, 2022).

In 2011, Soyeurt *et al.* indicated that equations with an R^2 greater than 0.95 could be used in milk payment systems, and that their use for genetic improvement is possible

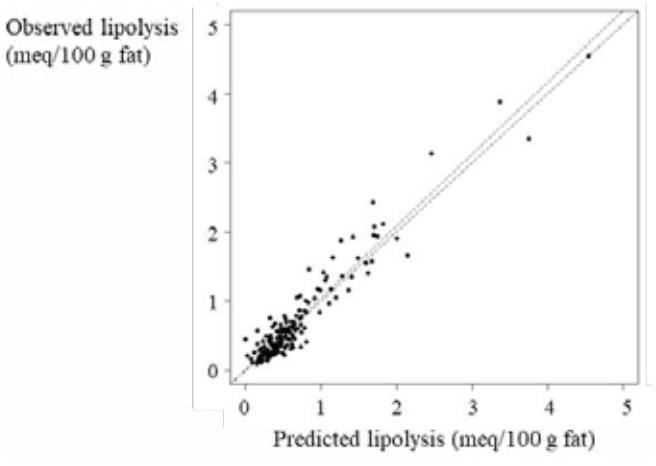

Figure 1. Goat's milk predicted lipolysis compared with the values observed by BDI method.

from 0.75. Our equation has an R^2 of 0.91, which makes it possible to envisage not only genetic exploration of the lipolysis trait, but also routine use in the field to discriminate milks according to their level of lipolysis with a satisfactory level of confidence. This equation represents a first step towards better characterising goat's milk and improving its quality on a routine basis.

Conclusion

This work has led to the development of a new equation for predicting milk lipolysis specific to goat's milk. The high accuracy of this equation opens new prospects for increasing our knowledge of the mechanisms of lipolysis in goat milk and for improving its control on farms through finer herd management and even selection.

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