Genetic parameters of feed efficiency in dairy goats under commercial conditions

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Abstract

The economic importance of genetically improving feed efficiency has been recognized in dairy production. Feed efficiency is a genetically complex trait that can be described as units of product output (e.g. milk yield) per unit of feed input. Previous work showed that feed efficiency is heritable in many species. This study aimed to investigate the heritability for Residual Energy Intake in two breeds of dairy goats (Alpine and Saanen) under commercial conditions. Heritabilities were moderate for both breeds (0.18±0.08 in Alpine and 0.20±0.07 in Saanen).

Introduction

Feeding costs are one of the largest expenditures in dairy production. For reducing their production costs and having a positive impact on environmental sustainability of dairy industry, breeders have increased interest in improving the balance between output (milk production) and input (feed intake). Feed efficiency has been introduced into pig and poultry breeding programmes and begins to be introduced in dairy cattle (Brito *et al*., 2021). In small ruminants (sheep and goat), feed efficiency is poorly documented and need to be evaluated. The European SMARTER (SMAll RuminanTs breeding for Efficiency and Resilience) project aims to develop innovative strategies to improve feed efficiency and farm resilience in small ruminants. This study has been conducted as part of this project and aims to estimate genetic parameters of feed efficiency under commercial conditions, for a large diversity of breeding systems in two breeds of dairy goats (Alpine and Saanen).

Materials & methods

Animals and housing. The experiment was performed in 14 commercial farms and at the Experimental Farm of La Sapinière (INRAE, Bourges), between 2019 and 2021. To date, 1,636 (663 Alpine and 973 Saanen) primiparous dairy goats were phenotyped for feed efficiency. Feed intake was recorded 4 times during the lactation: 2 times at the beginning of the lactation (between 0 and 60 DIM and between 60 and 90 DIM), around the reproduction (between 210 and 260 DIM) and at the end of the lactation (between 240 and 280 DIM). A total of 4,827 records (1,879 and 2,948 for Alpine and Saanen, respectively) were included in the dataset.

Animals were fed with different forages and concentrates, depending on the breeder. At each test day, feed intake was determined by weighing the total ration distributed and that wasted, by trained staff from the milk recording organisms. The forage quantity was measured by weighing all the offered forage, with a scale, at the batch or farm level (not individually). For concentrates, the quantity was measured either individually with automatic feeders or manually in milking parlour, or at the batch level by weighing all the offered concentrates, depending on the farm. Thus, for farms without individual distribution of concentrates, the individual feed intake was the average feed intake of the batch to which the animal belongs (83% of the dataset). For farms with individual distribution of concentrates, the individual feed intake was the average feed intake of the batch to witch the animal belongs for forage plus the individual intake of concentrates

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(17%). Dry matter intake (DMI) was thus estimated from the information indicated on the concentrate labels and from forage analysis, for each animal and each test day. Energy Intake (EI) was estimated by multiplying DMI and energy concentration. Nutritional feed quality was recorded for each forage and each concentrate and energy content was given by INRAE (Agabriel, 2010). Test day milk recording data (milk yield, fat and protein contents) were also measured, at the same time than the feed intake control.

The chest width (CW) was used as a proxy of the body weight and was measured one time during the lactation (about 150 DIM). No body condition scores were performed.

REI estimation. To estimate feed efficiency, Residual Energy Intake (REI), was estimated as the residual of a linear regression model (1):

$$EI= \beta_0 + \beta_1 \times MY + \beta_2 \times FC + \beta_3 \times PC + \beta_4 \times CW + REI \quad (1)$$

Where, EI is the energy intake (expressed in Unité Fourragère Lait unit (UFL), 1 UFL=1.7 Mcal), β_0 is the intercept, β_1 is the regression coefficient for milk yield (MY), β_2 and β_3 are the regression coefficients of fat and protein contents (FC and PC) and β_4 is the regression coefficient for chest width (CW).

We classified the animals in 3 groups of REI, using standard deviation (sd_REI): inefficient (REI>0.5 × sd_REI), intermediate (-05 × sd_REI≤REI≤0.5 X sd_REI), efficient (REI<-0.5 × sd_REI).

Estimation of genetic parameters. The traits analysed were REI and MY. The genetic parameters were estimated, for each breed separately, using WOMBAT software (Mayer, 2007), with the following animal linear models:

$$Y=Flock + Camp + Htd + PhSt + a_n + perm_p + e \quad (2)$$

$$Y=Age + Camp + Htd + PhSt + a_n + perm_p + e \quad (3)$$

Where, Y is the observation vector for REI (2) or MY (3), Flock is the fixed effect of the flock, Age is the effect of the age at kidding, Camp is the fixed effect of the lactation campaign, Htd is the fixed effect of the herd test day, PhSt is the fixed effect of the physiological stage. The random effects included in the model were the additive genetic effect of the animal (a_n), the permanent environmental effect ($perm_p$) and the residual (e).

Only animals with two or more test day records are kept. The final data set comprised 1,331 and 2,414 test day records of 455 and 785 Alpine and Saanen goats, respectively. Animals were the progeny of 74 and 94 sires and 355 and 576 dams and the pedigree contained 7,484 and 8,652 animals for Alpine and Saanen breeds, respectively.

Results

A general description of the data is presented in Table 1. DMI was on average 2.7 kg with a standard deviation of 310 and 280 g in Alpine and Saanen breed, respectively. EI was on average 2.5 UFL for both breeds, with a moderate variability (CV of 13 and 11%). The residual energy intake (REI) was zero on average by definition. The milk yield was on average 3.40 l in Alpine breed and 3.04 l in Saanen breed with a standard deviation of 940 ml and 770 ml respectively. The mean chest width was 88 cm in the two breeds, with a low variability (CV of 5% for both breeds).

Table 1. Descriptive statistics of REI (residual energy intake), DMI (dry matter intake), energy intake (EI), milk yield (MY) and chest width (CW) per goat breed.

Breed	Trait	n	Min	Mean	Max	Sd[1]	CV[2]
Alpine	REI	1,879	-1.02	0.00	0.71	0.27	11%
	DMI (kg)	1,879	2.01	2.68	3.63	0.31	12%
	EI (UFL)	1,879	1.66	2.48	3.41	0.31	13%
	MY (L)	1,879	0.90	3.40	6.50	0.94	28%
	CW (cm)	1,879	76.00	88.24	103.00	4.29	5%
Saanen	REI	2,948	-0.87	0.00	1.01	0.28	11%
	DMI (kg)	2,948	2.02	2.82	3.78	0.28	10%
	EI (UFL)	2,948	1.78	2.62	3.85	0.29	11%
	MY (L)	2,948	0.30	3.04	6.60	0.77	25%
	CW (cm)	2,948	76.00	88.51	103.00	4.64	5%

[1] Standard deviation.
[2] Coefficients of variation.

Dry matter intake was higher in the inefficient group, and lower in the efficient group, with a difference of 0.49 kg of DMI per day in Alpine breed and 0.57 kg in Saanen breed between both groups (Table 2). This difference was explained both by a lower CDMI (concentrates DMI) and a lower FDMI (forage DMI) for the inefficient group. The ratio of milk output to DMI (DMI/MY) is lower for the efficient group. MY (results not shown) is the same in the three groups

Variance components, heritabilities and repeatability of the traits analysed are shown in Table 3. The heritability of test day milk yield was 0.19 and 0.20 in Alpine and Saanen breeds, respectively. Estimated heritabilities for REI, in both breeds, were moderate (0.18 and 0.20), with higher repeatability for Alpine breed (0.31) than Saanen breed (0.12).

Discussion

Feed efficiency is a difficult trait to measure under commercial conditions due to the diversity of feeding systems and the lack of individual feed intake data, due to the expensive cost of automatic feeders for breeders. Our results show that feed efficiency can be estimated, and that a ranking on the REI could be set up to classify goats: efficient *vs* inefficient. The heritability of test day milk yield were around 0.20 in

Table 2. Descriptive statistics of DMI (dry matter intake), energy intake (EI), ratio of milk output to DMI (DMI/MY), concentrates DMI (CDMI) and forage DMI (FDMI) per group of REI and per goat breed.

Trait	Mean (sd)					
	Inefficient		Intermediate		Efficient	
	Alpine (n=526)	Saanen (n=724)	Alpine (n=879)	Saanen (n=1,317)	Alpine (n=474)	Saanen (n=907)
DMI (kg)	2.86 (0.26)	3.11 (0.15)	2.73 (0.26)	2.86 (0.16)	2.37 (0.20)	2.54 (0.21)
EI (UFL)	2.71 (0.15)	2.98 (0.16)	2.55 (0.15)	2.64 (0.11)	2.08 (0.26)	2.32 (0.21)
DMI/MY	0.95 (0.25)	1.13 (0.44)	0.79 (0.23)	0.99 (0.25)	0.83 (0.30)	0.89 (0.37)
CDMI (kg)	1.29 (0.17)	1.02 (0.22)	1.24 (0.17)	0.95 (0.09)	1.03 (0.17)	0.79 (0.19)
FDMI (kg)	1.57 (0.38)	2.08 (0.19)	1.47 (0.36)	1.89 (0.14)	1.33 (0.20)	1.74 (0.21)

Table 3. Variance components: additive genetic variance (V_A), permanent environmental variance (V_E) and residual variance (V_R), heritabilities (h^2) and repeatability (R) for residual energy intake (REI) and milk yield (MY), with SEs in brackets.

Breed	Trait	V_A	V_E	V_R	H^2	R
Alpine	REI	0.004 (0.001)	0.006 (0.002)	0.009 (0.001)	0.18 (0.08)	0.31 (0.08)
	MY	0.096 (0.049)	0.186 (0.044)	0.227 (0.011)	0.19 (0.09)	0.37 (0.09)
Saanen	REI	0.003 (0.001)	0.002 (0.001)	0.011 (0.0001)	0.20 (0.07)	0.13 (0.06)
	MY	0.097 (0.036)	0.185 (0.031)	0.202 (0.007)	0.20 (0.07)	0.38 (0.07)

both Alpine and Saanen breeds. Arnal *et al.* (2019) found higher heritabilities of 0.27 and 0.28 on test day milk yield for the same breeds. The estimated heritability of REI were slightly lower than the feed efficiency heritability reported by Desire *et al.* (2017) in mixed-breed (Saanen, Alpine and Toggenburg) population (around 0.25). In Smarter project, feed efficiency was also investigated in dairy ewes, under commercial farms. Machefert *et al.* (2022) found a lower heritability (0.12) for a feed efficiency conversion ratio, in Lacaune ewes. According to Berry and Crowley (2013), heritability varies between studies depending on the type of model used to estimate feed efficiency (ratio traits or regression/residual traits) and on the type of animal involved (growing and adult animals). Further analysis needs to be conducting before considering a selection on REI in dairy goats.

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