SMAll RuminanTs breeding for Efficiency and Resilience

SMARTER – Which novel traits to improve feed efficiency?

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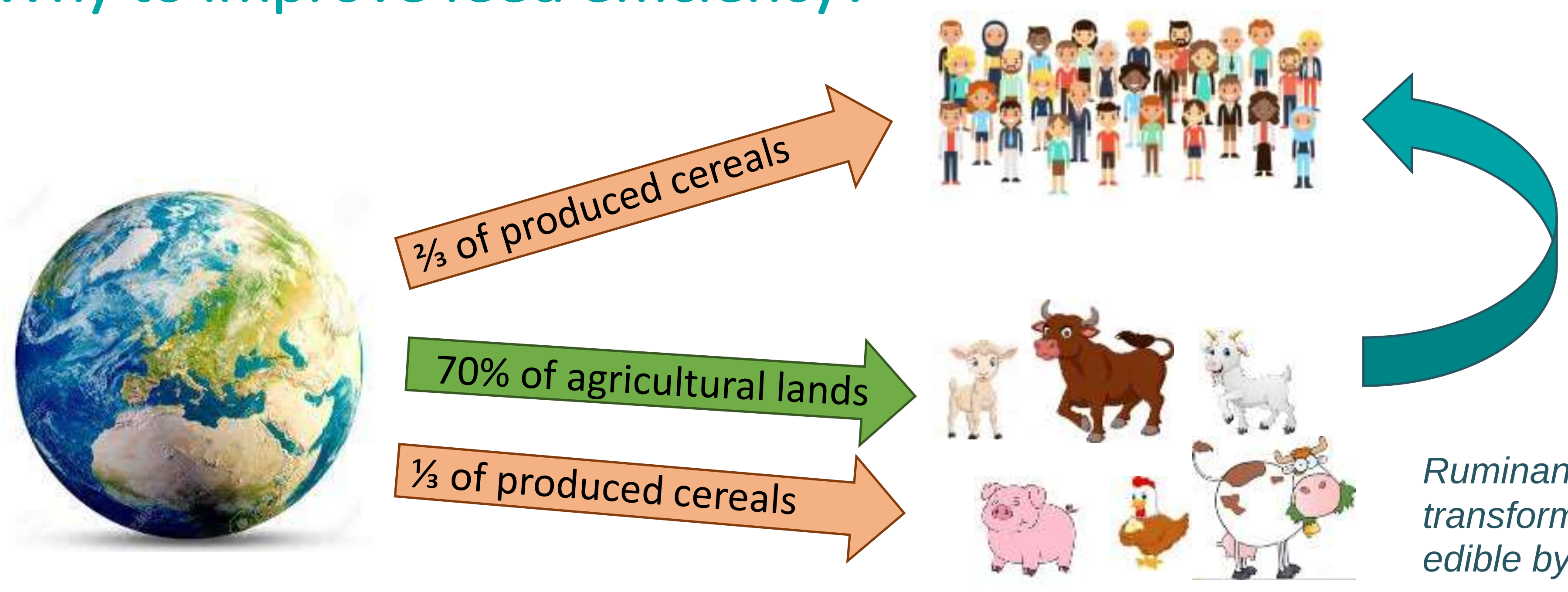
Why to improve feed efficiency?



1/3 of proteins ingested by human comes from livestock

Livestock production

Ruminants are the only ones able to transform the ingested fibres into food edible by humans.

Human population is increasing → higher demand in animal proteins

Livestock production has to increase BUT some limits have to be set on
- the proportion of crop dedicated to livestock (feed-food competition)
- environmental impacts of livestock production (GHG emissions, soil pollution,...)

→ Improvement of resource use efficiency

How to estimate feed efficiency?

Feed intake

- Individual trough
- Automatic feeders
- Metabolic crates

Maintenance

- Body weight

Production

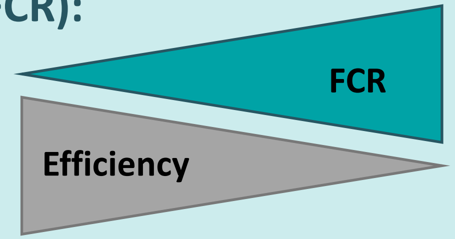
- Milk, fat and protein yields
- Average daily gain
- Body composition (ultrasound, CT scan,…)

Loss estimates

- Metabolic crates (urine and faeces)
- GHG emissions
- Activity

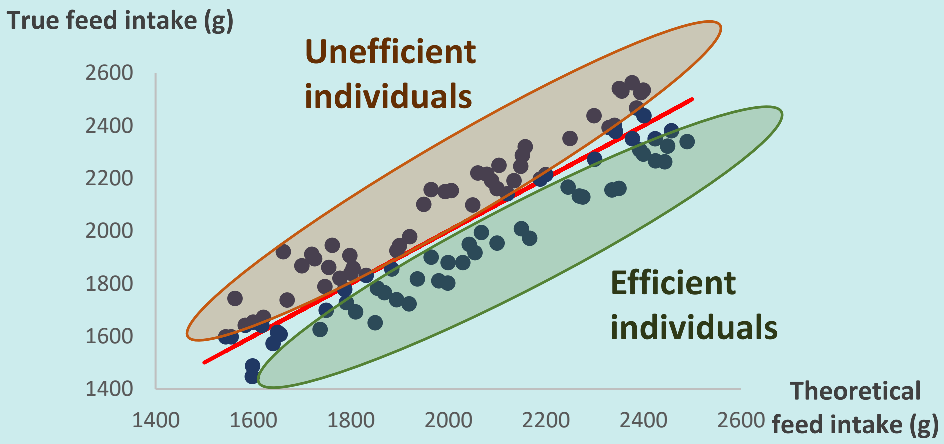
Feed Conversion Ratio (FCR):

$$\frac{Feed\ intake}{Production}$$

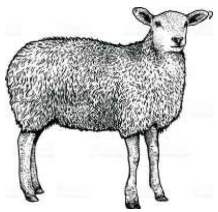


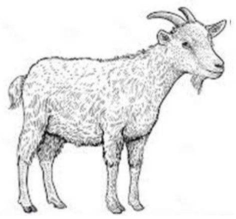
Residual Feed Intake (RFI):

$$True\ feed\ intake - theoretical\ feed\ intake$$



How to improve feed efficiency ?



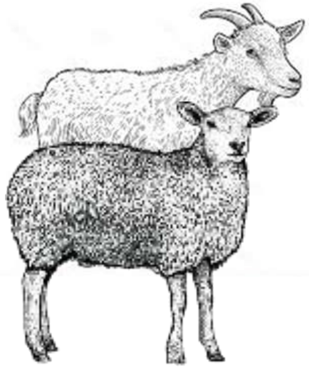


Feeding strategies

Selection : FCR and RFI are heritable traits.

Species	Breeds	h^2 RFI	h^2 FCR	references	protocols
Meat sheep	Targhee	0.26 ± 0.07		Snowder and Van Velck, 2003	Post-weaning period
	Composite population (Columbia, Hampshire, Suffolk)	0.11 ± 0.05		Cammack et al., 2005	Post-weaning period
	Merino (from post-weaning to adult)	From 0.07 to 0.29 (± 0.08)		Paganoni et al., 2017	Post-weaning, hoggets and adults
	New Zealand maternal breed	0.46 ± 0.13		Johnson et al., 2018	Post-weaning period under a concentrate diet
	Romane	0.45 ± 0.08	0.30 ± 0.08	Tortereau et al., 2020	Post-weaning period
Dairy sheep					
Dairy goats	mixed-breed (Saanen, Alpine, and Toggenburg)			Desire et al., 2017 (feed intake : h^2~0.25)	

How to improve feed efficiency?



Feeding strategies

Selection : FCR and RFI are heritable traits. → It requires feed intake to be recorded.

Individual troughs

Forage and concentrate automatic feeders

with forage

with forage or concentrate

INRAE

INRAE

SRUC

INIA-Uruguay

These devices are too expensive to be widely spread in breeding companies

→ Proxies for feed intake (and/or feed efficiency) have to be identified

Which novel traits for feed efficiency improvement?

These new traits must be relevant, easy to measure and cheap enough to be used in a large number of animals.

Total or partial feed intake

Non-invasive traits

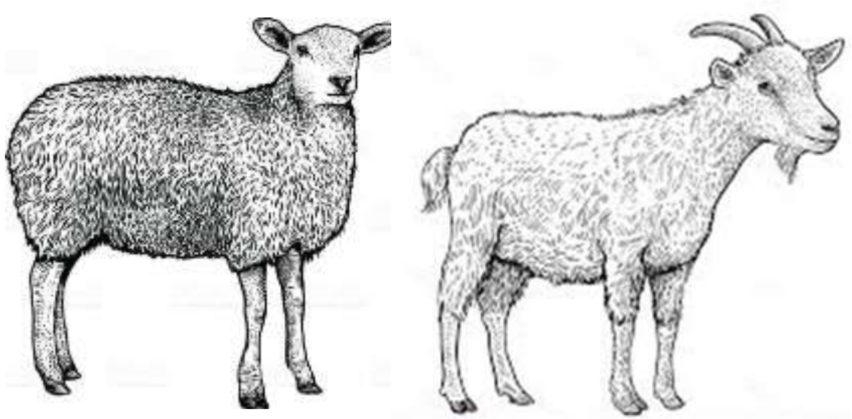
- body weights
- body composition (ultrasound)
- body condition score
- body measurements (chest width, depth)
- milk yield and composition
- gas emissions (CH_4, CO_2)

From milk samples:

- MIR spectra

From faecal samples:

- NIR spectra



- body composition (CT-scan)

Invasive traits

From blood samples:

- genotypes
- metabolites (targeted or *untargeted*)

From rumen samples:

- *microbiota*
- *metabolites*
- *fatty acids*

In italics are traits that can be considered for research purposes only

Breeding and feeding practices
Health status
Climatic data indoor /outdoor (T°C, humidity,...)

First results – dairy sheep

In Greece **(AUTH)** – 1st records of targeted metabolites
N=30 dairy ewes from 4 breeds
Lacaune, Assaf, Chios and Frizarta

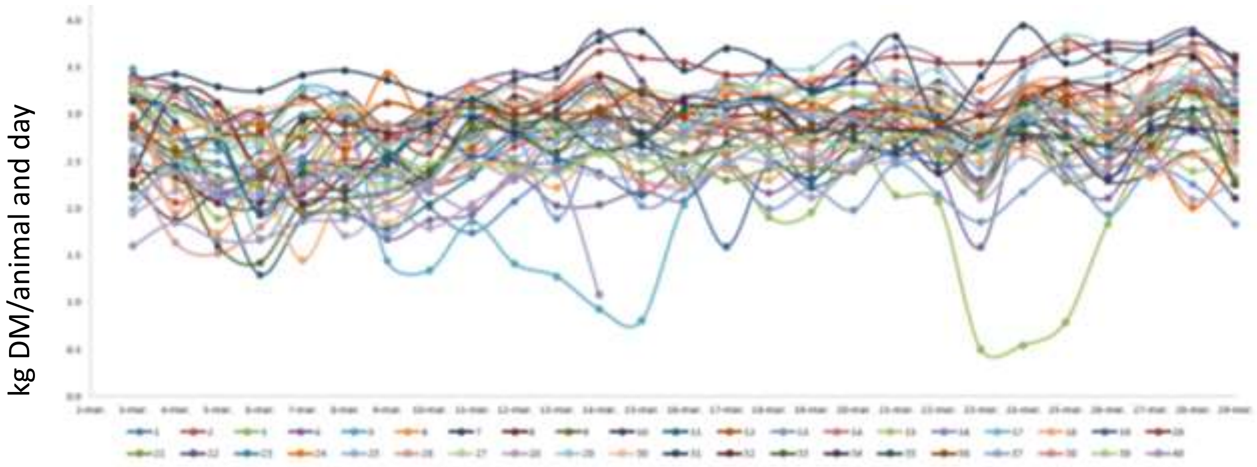
Objective = identification of body composition traits (US) as potential predictors of energy balance.

Negative energy balance status
→β-HB ≥0.8 mmol/L, NEFA ≥0.3 or 0.7 mmol/L

Blood biochemical analysis *(= targeted analyses)*
- Beta-hydroxy-butyrate
- Non-esterified fatty acids
- TP
- Albumin
- BUN

In Spain **(UniLéon)** – 1st records of feed intake, ~1 year after nutritional challenge
N=40 dairy ewes (breed = Assaf)

Objective = determine the effects of a severe protein restriction of ewe replacement lambs during their pre-puberal stage on their feed efficiency in their adult life (as dairy ewes).



High variability in voluntary feed intake among ewes

First results – dairy goats

In France **(INRAE)** : 1st records of feed intake (concentrate) on goats divergently selected on longevity
→ additional information on feeding behaviour

Trait	N	Mean		SE	
	LGV- / LGV+	LGV-	LGV+	LGV-	LGV+
Nb visits / day	18 / 29	15.8	17.4	4.1	7.3
Intake per visit (kg)	18 / 29	0.05	0.05	0.01	0.01
Intake per day (kg)	18 / 29	0.64	0.63	0.12	0.14
Intake duration per day (s)	18 / 29	551	678	170	508
Intake speed per day (kg/hrs)	18 / 29	4.72	4.40	0.75	1.24

Photos: C HUAU

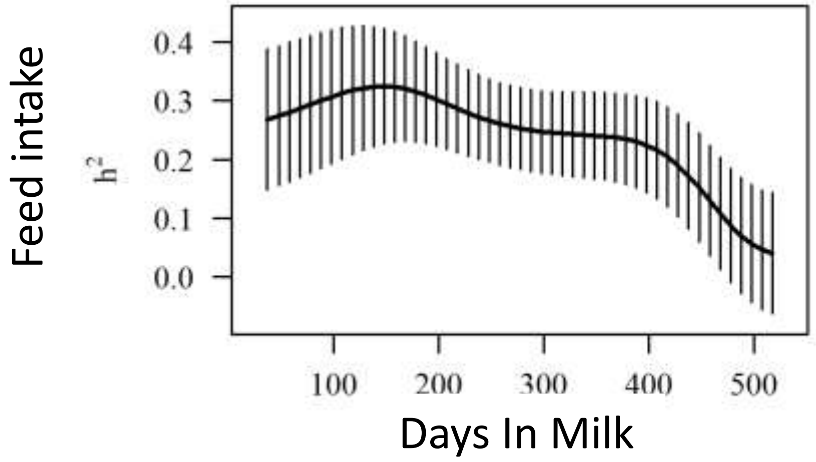
Automatic feeders developped at INRAE

In Scotland **(SRUC)**

YORKSHIRE DAIRY GOATS

42,434 feed intake records
3,421 animals

Model:-Yield-adjusted feed intake (+ year-season, age at kidding, herd test day, and fixed lactation curves using third order polynomials nested within lactation number)



First results – meat sheep

INRAE

In France **(INRAE)** : divergent selection on residual feed intake

Phenotypic results for lambs fed *ad libitum* with concentrate, in the 3rd generation of selection (2019 and 2020):

	RFI+ (n=79)	RFI- (n=90)	P-value
Average daily feed intake (g/d)	2111 ± 240	1916 ± 195	<0.0001
RFI (g/d)	75 ± 130	-66 ± 117	<0.0001
End-test Backfat thickness (mm)	5.76 ± 0.97	5.76 ± 0.91	0.73
End-test Muscle depth (cm)	2.81 ± 0.24	2.76 ± 0.20	0.34
End-test Body weight (kg)	55.16 ± 6.23	53.41 ± 5.43	0.0003
ADG (g/d)	334 ± 64	327 ± 60	0.03

Δ ADFI= 195 g/d
Δ RFI= 1.9 σ_g

Due to the 2020 serie mainly

Differences observed on :
- plasmatic amino acids
- microbiota composition

NSG

In Norway **(NSG)** : first records of GHG emissions , and estimations of genetic parameters

Single trait animal model
1,624 phenotyped animals ; 16,092 animals in pedigree

Fixed class effect : flock*group, age
Fixed regressions : Live weight [1], minutes since off feed

1) Regression on weight included for traits 1, 2, 4 and 5.

Trait	Heritability
1) gram CH_4 per hour	0.181
2) gram CO_2 per hour	0.455
3) gram CH_4 per hour / kg live weight	0.141
4) gram CH_4 per hour / gram CO_2 per hour	0.263
5) gram CH_4 per hour / (gram CH_4 per hour + gram CO_2 per hour)	0.262
6) Live weight	0.317

Conclusions

Many fine phenotypes collected in experimental farms to :

- dissect the biology underlying feed efficiency
- identify **proxies** of feed intake/feed efficiency

Use these proxies in larger populations (commercial populations) to

- Estimate genetic parameters
- Estimate the feasability of a routine collection of these new traits
- Include feed efficiency in selection programs

SMARTER PARTNERS

Thank you for your attention

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