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Nutritional management in goat production systems

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Ruminants in Sardinia

Species	*Heads*	*% of Italy*
Sheep	3,250,000	41.2
Goats	253,000	22.7
Cattle	249,000	4.0

Sardinia

330.000 tons of sheep milk (65% of Italy) = 1.1-1.4 €/kg

28.000 tons of goat milk (25% of Italy) = 0.70-0.85 €/kg

200.000 tons of cattle milk (2% of Italy) = 0.35-0.38 €/kg

Sheep cheese production in Sardinia

- 55000 tons/y
- mostly exported (50% to USA)
- 95% processed by cheese making industry (private + coop), 5% on farms
- 27000 tons of Pecorino romano, all exported (9 €/kg, 240 million €/y)

Goat production

Italy : 798,000 dairy goats; 105.000 tons of milk

Sardinia : 243,000 dairy goats; 28.000 tons of milk (25% of Italy)

Breeds in Sardinia:
Sarda
Maltese
Crosses

Saanen
Alpine
Murciano Granadina

Cheese-making ⇓⇓

Yoghurt and soft cheese ⇑

UHT milk ⇑

Pasteurized ⇑⇑

Cattle production

Sardinia : 250,000 heads

Most cattle kept in extensive cow-calf systems for meat production

- **Based on grazing; veals sold to mainland Italy feedlots**

Small but very competitive dairy cattle industry

- 200.000 t/y of cow milk
- about 300 farms with 23000 cows (Holstein, Brown)
- 9600 kg/y of milk per cow (the highest in Italy)
- 1 cooperative collects and processes 90% of the milk
- based onTMR, corn silage main forage

Outline

- **Ration formulation**
- **Energy requirements**
  - **Monitoring the energy balance**
- **Protein requirements**
  - **Monitoring the protein status: milk urea**

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Balancing diets for goats

Ration formulation

Production and nutritional indicators

Goals:

- highly productive and healthy animals
- high quality of the products
- minimization of costs, feed wastage, environmental impact

Nutritional unbalances

Nutritional unbalances can have broad effects on production, welfare, health status, and environmental impact

- **Macro-nutrient unbalances**
  - ✓ Energy and body reserves
  - ✓ Energy/Protein ratio
  - ✓ Dietary protein
  - ✓ Fiber content and structure
- **Specific micro-nutrient deficits**
  - ✓ Mineral (Se, Zn, Mn, Fe)
  - ✓ Vitamin (vit. E, vit. A, beta-carotene, vit. C)

The Small Ruminant Nutrition System

Cannas A., Tedeschi L., Fox D.G., Van Soest P.J., Pell A.N. 2004. *JAS*, 82:149-169

Tedeschi L.O., Cannas A., Fox D.G. 2010. Small Ruminant Research, 89, 174–184.

Cattle CNCS → Sheep CNCPS → SRNS (sheep and goats)

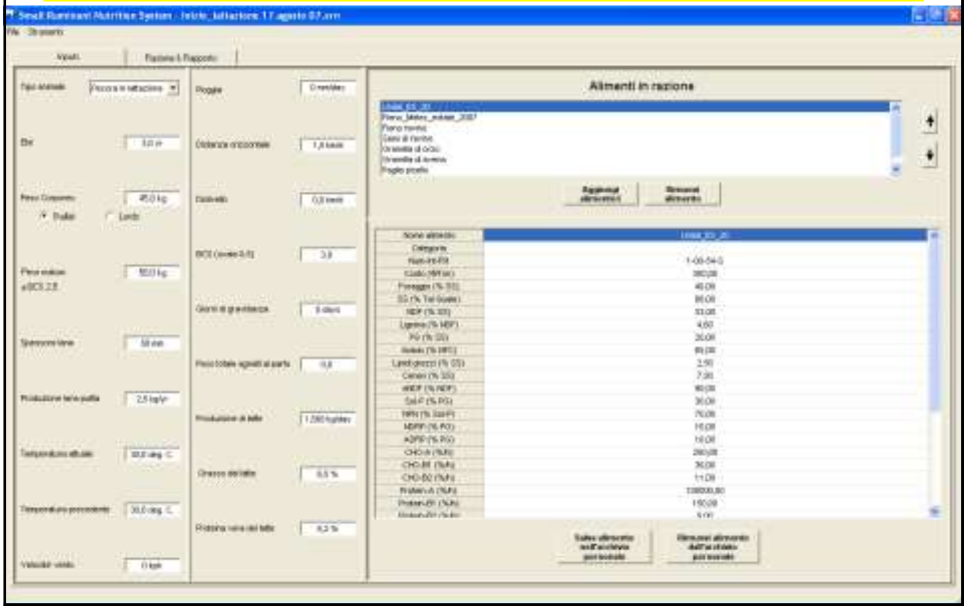
- **DMI prediction:** equations of Pulina et al. (1998) and AFRC
- **Requirements:** integration and modification of existing feeding systems and new equations
- **Nutrient supply:** based on the nutrient supply submodel of the CNCPS for cattle (new equations for Kp)
- **Extensive evaluations carried out**

- **NRC (2007) based its requirements for sheep on the CNCPS for Sheep**

- **SRNS sofware web site:** **http://nutritionmodels.tamu.edu**
- **free use for university students**
- **Multilingual: English, Portoguese, Italian, Spanish, Turkish, Korean**

Small Ruminant Nutrition System

Nutritional model and software, multilingual, free for research and academic use



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Energy requirements

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ME for maintenance and milk production in goats

- Cost of milk production similar among systems: 770 kcal NE and 1180 kcal of ME per kg of milk

4% fat corr. milk yield kg/d	50 kg of BW				70 kg of BW			
	AFRC	IGR	INRA	SRNS	AFRC	IGR	INRA	SRNS
0	1.99	2.25	2.00	2.01	2.56	2.90	2.58	2.59
1	3.17	3.42	3.17	3.15	3.74	4.07	3.75	3.73
3	5.55	5.76	5.51	5.43	6.12	6.40	6.08	6.01
5	7.93	8.09	7.84	7.72	8.50	8.74	8.42	8.29
7	10.31	10.43	10.18	10.00	10.88	11.08	10.75	10.58

Values fairly similar among feeding systems, so are they all the same?

Energy requirements of a flock of 100 does + 18 replacements + 2 billies

Milk per goat, kg/y	**Total milk,** kg/y	**Total NEL required** Mcal/y	**NEL per kg of milk** Mcal/kg	**NEL for mil** % of total	**NEL for other requirements** % of total
200	**18 080**	**75143**	**4.16**	**17**	**83**
400	**36 160**	**89531**	**2.48**	**29**	**71**
600	**54 240**	**103919**	**1.92**	**38**	**62**
800	**72 320**	**118199**	**1.63**	**46**	**54**
1000	**90 400**	**132694**	**1.47**	**52**	**48**

Sources of variations of ME_m in lactating cattle

Variable	% increase ME_m	Source
Breed	0 → 30	CNCPS
Age	0 → -16	CSIRO
Sex	0 → 15	AFRC, CSIRO
Diet quality	0 → 10	AFRC, CSIRO, INRA
Urea cost	0 → 14	CNCPS
Feeding level	0 → 40	CSIRO
Previous nutrition (BCS)	-20 → 20	CNCPS - NRC
Cold stress	0 → 75	CSIRO – CNCPS
Heat stress	0 → 35	CNCPS
Activity confined	0 → 12	CNCPS
Grazing activity	8 → 55	CNCPS

CHO during the lactation of sheep and goats

- Well defined refernce values fro NDF, starch, sugars, fiber particle size in dairy cattle
- No feeding systems suggest optimal, max and min NDF and NSC (or NFC) values during the lactation of ewes and goats

Serious limitation when balancing the diets of small ruminants

Optimal concentrations of NDF, CP and NFC depending on the productive levels of the sheep (Avondo & Cannas, 2001, Cannas, 2004)

The estimates refer to sheep with BW of 50 kg and assume a total dietary concentration of ash + fat around 12 % of DM

	Production of 6.5% fat corrected milk yield (g/d)					
	< 500	500–799	800-1099	1100–1399	1400–1699	1700–2100
NDF (% DM)	45.0	45.0	44.5	41.2	38.9	33.2
CP (% DM)	14.5	15.0	15.5	16.3	16.7	17.3
NFC (% DM)	28.0	28.0	28.0	31.0	33.0	38.0

Dietary concentrations of free-choice diets selected by goats (Fedele et al., 2002)

	NEL/kg Mcal	Starch %	CP %	Starch/ CP	NDF %
Maintenance	1.20-1.32	30.3-23.9	12.6-13.0	0.37-0.40	38.2-39.5
Pregnancy 5th month	1.36 –1.51	27.7-32.7	15.9-17.0	0.51-0.55	40.2-41.0
Lactation					38.9-41.8
Beginning	1.46-1.58	34.2-36.3	14.0-14.9	0.37-0.41	
Intermed.	1.48-1.60	35.9-39.4	12.7-13.4	0.34-0.36	
Final	1.46-1.56	33.1-35.7	11.7-12.9	0.33-0.36	

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Monitoring energy balance & body reserves

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Why to monitor the energy balance?

- **Highly productive animals** are often in negative energy balance
- The **increasing size of farms** makes more difficult the appropriate management of the diet, since animal with very diverse requirements are fed the same diet
- Energy balance affects production and reproduction performances and animal's health

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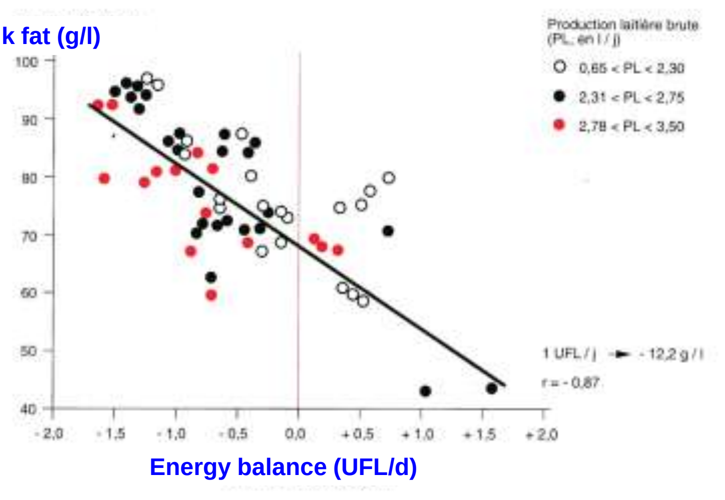
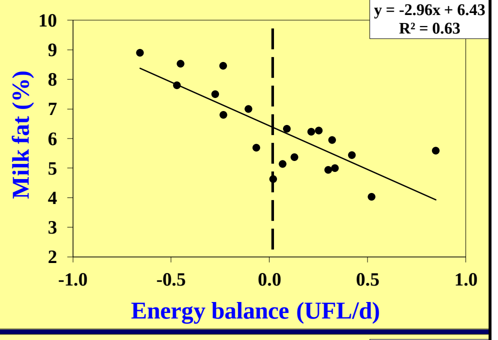
Monitoring ENERGY BALANCE by using MILK FAT CONTENT in dairy sheep



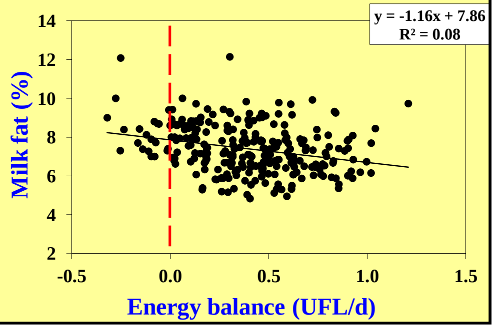
Bocquier & Caja (2001)

Energy balance vs. milk fat in Comisana dairy ewes (Avondo and Cannas, 2002)

Milk yield 1.2 - 1.6 kg/d



Milk yield 0.4 - 0.8 kg/d



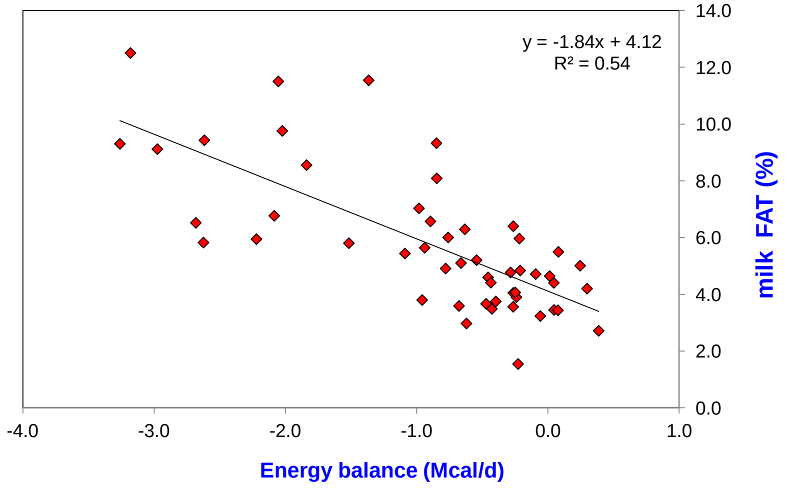
Effect of the energy balance (LW variations) in the fatty acid profile of the milk of Sarda ewes

(Rossi & Pulina, 1991)

Fatty acids (%)	Live weight variations (kg per week)		
	+1,5	-1,1	-3,8
C4:0	3.31	2.49	2.21
C6:0	2,81 a	1,29 b	0,84 b
C8:0	2,87 a	1,09 b	0,65 b
C10:0	5,62 a	2,70 b	1,52 b
C12:0	4,07 a	1,88 b	1,10 b
C14:0	9,84 a	6,96 a	3,43 b
C16:0	22,86	24,67	24,15
C16:1	1,50	1,56	1,57
C18:0	7,14 a	10,93 a	13,58 b
C18:1	16,91 a	21,52 a	28,47 b
C18: 2	5,42	5,86	6,47
C18:3	0,31 a	0,27 a	0,65 b

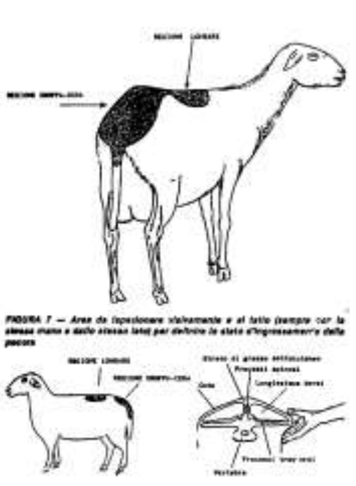
Monitoring ENERGY BALANCE by using MILK FAT content in Saanen goats

(51 goats from 0 to 8 wks lactation)



Silva de Oliveira (2015)

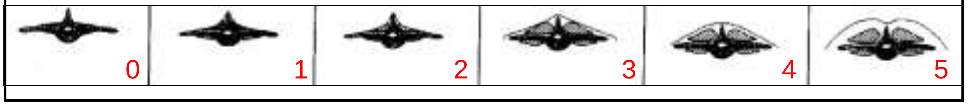
Energy balance, body reserves and BCS



Body condition score (BCS)

Used to:

- **persue optimal body reserve status in the various physiological stages**
- **estimate the energetic cost of body reserve variations**
- **indicator of welfare?**



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BCS and health status of dairy ewes in the transition period (-15 d to +30 d from lambing)

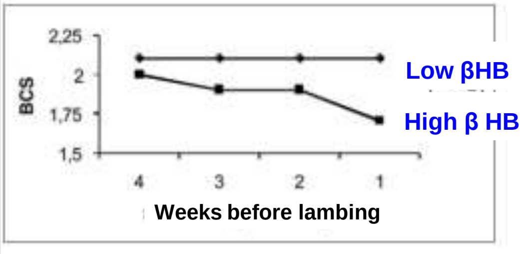
(Karagiannis et al., 2014)

	BCS	Health problems	
		NO	YES
Thin	BCS <2.75	69%	31%
Normal	BCS 2-5-3.5	88%	12%
Fat	BCS >3.5	67%	33%
βHB (mmol/l)*		0.849	1.118
NEFA (mmol/l)*		0.345	0.494

* at -30 d

Health problems (% of 241 ewes controlled): pregnancy toxiemia (2.6%), placental retention (1.4%), metritis (8.6%), clinical mastitis (4.8%), culling (8.2%, for diseases or low milk yield)

Subclinic ketosis in sheep: effects on immune defenses (Lacetera et al., 2001, 2002)



Subclinic ketosis =
β HB >0.86 mmol/L

	Low βHB (<0.86 mmol/L)	High βHB (>0.86 mmol/L)
Blood IgG (g/L)	14.5 ± 2.9 *	7.1 ± 2.7
Total IgG in the first colostrum (g/L)	8.1 ± 1.6 **	1.6 ± 0.8

* P<0.05: ** P<0.01

Sublcinical ketosis → Immunesuppression → increases susceptibility to infectious diseases (e.g. metritis and mastitis)

J. Dairy Sci. 95:3419–3427
http://dx.doi.org/10.3168/jds.2011-4732

A single nucleotide polymorphism in the acetyl-coenzyme A acyltransferase 2 (*ACAA2*) gene is associated with milk yield in Chios sheep

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- **11% more milk in the Chios heterozygous of dominant fro the ACAAA2 gene**
- **This enzyme catalyzes the last step in fatty acid β-oxydation, leading to incease in acetyl-CoA**
- **Less susceptible to sub-ketosis?**

Definition of prepartum hyperketonemia in dairy goats **(JDS, 2015)**

V. Doré, J. Dubuc, A. M. Bélanger, and S. Buczinski[1]
Département de Sciences Cliniques, Faculté de Médecine Vétérinaire, C.P. 5000, Université de Montréal, Saint-Hyacinthe, Québec, J2S 7C6, Canada

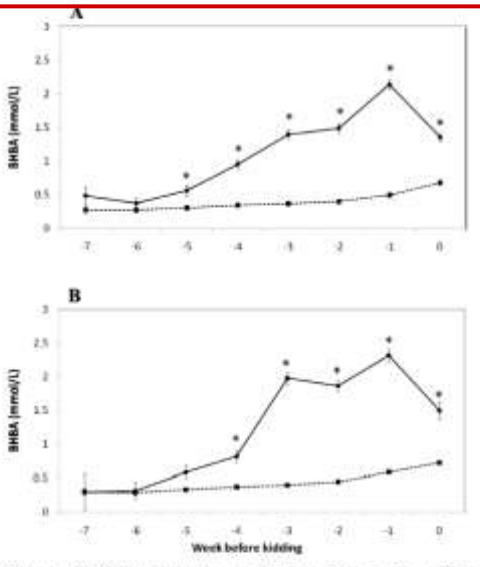

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Table 1. Optimal BHBA thresholds for each week prepartum based on the maximal sum of sensitivity and specificity to predicting goats at a high risk of subsequent pregnancy toxemia

Week prepartum	BHBA threshold[1] (mmol/L)	Goats at or above threshold[2] (%)	Sensitivity (%)	Specificity (%)	*P*-value
5	≥0.4	33.0	61.8	69.8	<0.01
4	≥0.4	44.4	70.4	58.4	<0.01
3	≥0.5	25.6	63.3	78.5	<0.01
2	≥0.6	25.9	73.7	79.0	<0.01
1	≥0.9	14.6	60.5	89.7	<0.01

[1]Blood BHBA value having the greatest sum of sensitivity and specificity for predicting subsequent risk of pregnancy toxemia.
[2]Proportion of goats with a blood BHBA value equal or greater to the threshold value.

High correlation between βHB at week – 4 and pregnancy toxiemia

What about subclinical ketosis ?

βHB easily measured in the field with portable equipments

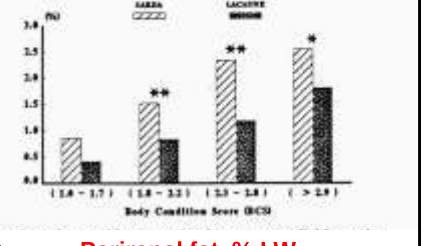
Can we monitor energy balance with BCS?

BCS variations:

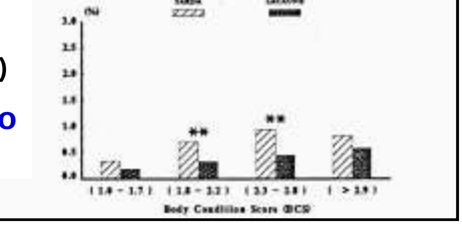
- **Difficult to assess short term variations**
- **Small range of variation of BCS in some dairy breeds, due to their high visceral fat accumulation**
  e.g. in Sarda ewes 75% of 2240 records of 9 farms had BCS between 2.50 and 2.75 (Gaias, 2013)
- **Little data to associate BCS to body fat in dairy sheep**

BCS vs. visceral fat in Sarda and Lacaune ewes (Ronchi et al., 1993)

Pelvic fat, % LW



Perirenal fat, % LW



Body fat content vs. BCS in sheep

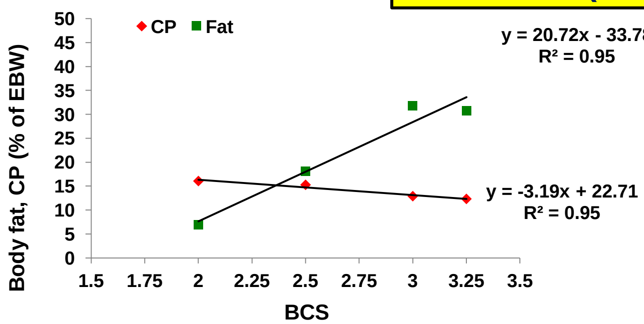
Body fat, as % of empty body weight (Cannas et al., 2007)

BCS 0-5	SRNS *	Aragonesa	Churra	Lacaune	Merino	Sarda	Wester-range
1	11.4	7.2	9.6		22.4		10.3
2	20.1	13.9	20.2		28.8	6.9	16.2
2.5	24.4	17.6	24.6		32.0	18.1	19.1
3	28.8	21.5	28.5	25.6	35.2	31.8	22.0
3.3	31.4	23.9	30.6	32.7	37.1		23.8
4	37.5	29.9	34.7		41.6		27.9

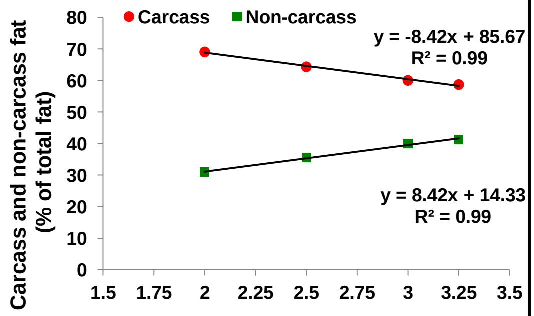
* Small Ruminant Nutrition System

- **Very little data available**
- **High variability among the few breeds studied**

Sarda ewes (Gaias et al., 2012)



As BCS increased, body fat increased more quickly in the non carcass than in the carcass



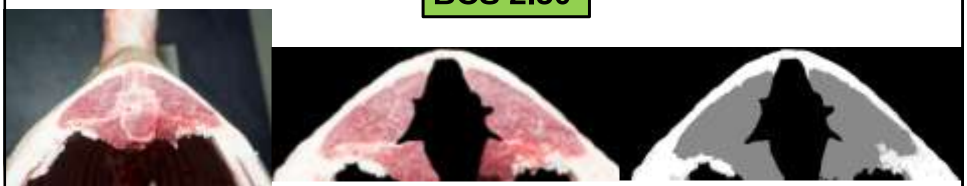
Results

BCS 2.0

Loin cut | Loin cut without bone | Loin cut gray image

BCS 2.0 triangular while for other classes it was convex.
This contrasts with the criteria used to classify BCS (Russel et al., 1969)

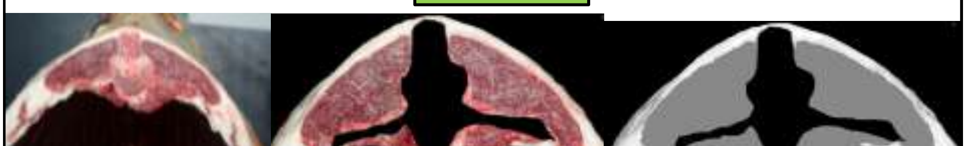
BCS 2.50



Loin cut | Loin cut without bone | Loin cut gray image

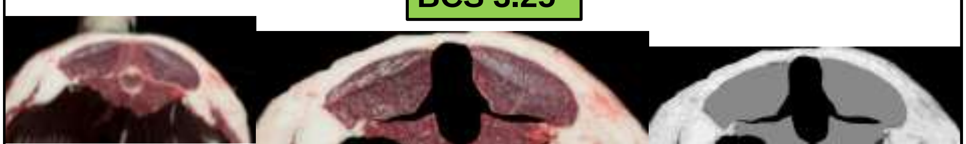
Results

BCS 3.00

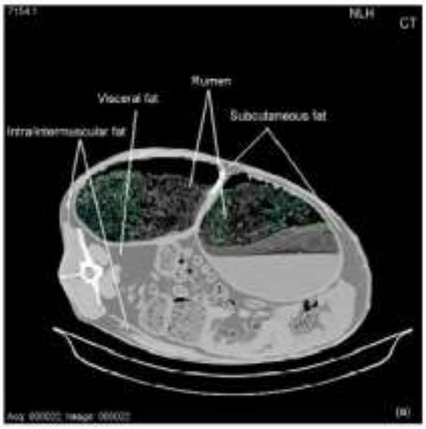


Loin cut | Loin cut without bone | Loin cut gray image

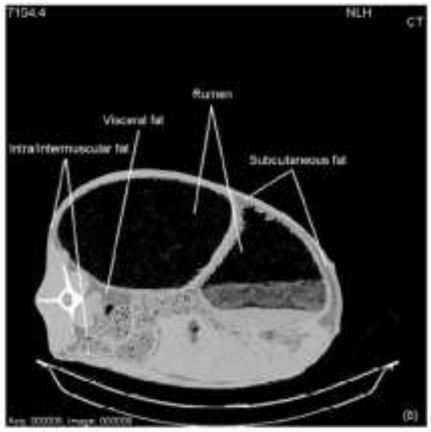
BCS 3.25



Loin cut | Loin cut without bone | Loin cut gray image



Fat goat

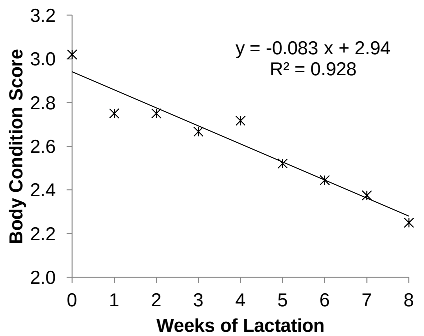


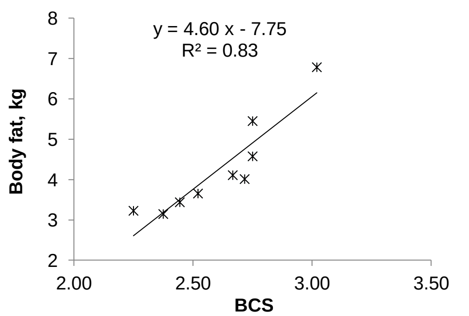
Lean goat

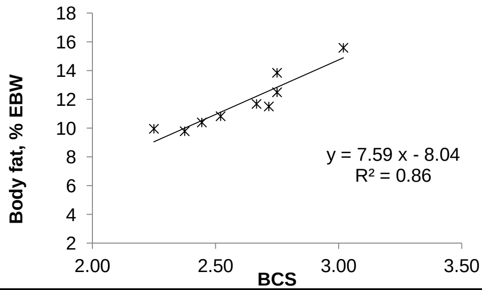
Fig. 1. Fat depots in CT images of the same goat on (a) day 11 of lactation and (b) day 125 of lactation (adipose tissue = dark grey, proteinous tissue and non-fat visceral components = light grey, bone = white, air = black).

Eknaes et al., SRR 2006, 63:1-11

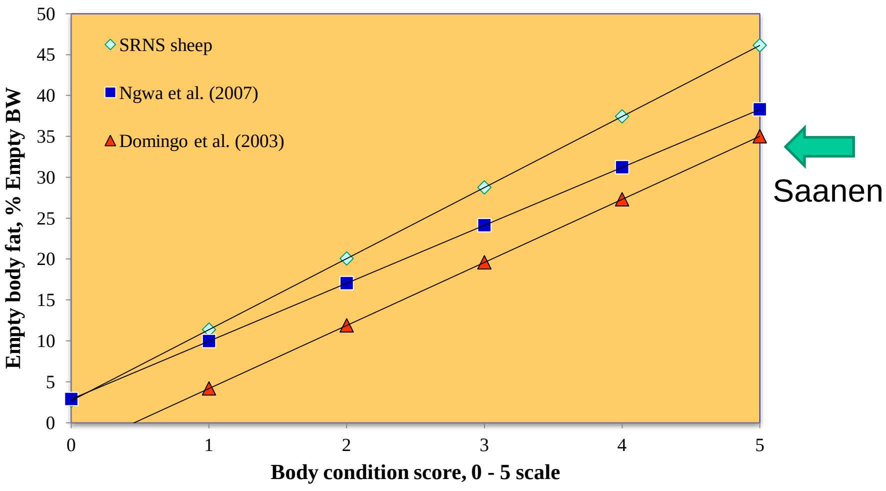
Saanen goats (51 goats from 0 to 8 wks lactation; Silva de Oliveira, 2015)







Relationship BCS and EB Fat for goats



Can we monitor energy balance?

- **BCS = not always appropriate, especially in short term assessments. High need to produce breed specific data**
- **Milk fat content or its variations over time**
  - **Affected by level of production**
- **Milk fatty acids? They can be analyzed with MIR (e.g. Milkoscan) techniques on a routine basis, as for example done by the Regional milk lab of Sardinia**

Misurando	Descrizione Risultato	Espressione Risultato	Tecnica di Prova
Grasso	Gr.	g/100 ml	FT Infrarosso
Proteina	Prot.	g/100 ml	FT Infrarosso
Lattosio	Latt.	g/100 ml	FT Infrarosso
Cellule somatiche	Cell.	cell/µl	Citometria di flusso
Punto crioscopico	Cr.FT	°C	FT Infrarosso
Carica batterica totale	C.Bat.	UFC/µl	Citometria di flusso
pH	pH FT	pH	FT Infrarosso
Urea	Ur.FT	mg/dl	FT Infrarosso
Acidi grassi saturi	A.G.S.	g/100 g	FT Infrarosso
Acidi grassi insaturi	A.G.I.	g/100 g	FT Infrarosso
Acidi grassi monoinsaturi	A.G.M.	g/100 g	FT Infrarosso
Acidi grassi polinsaturi	A.G.P.	g/100 g	FT Infrarosso
Cloruro di sodio	NaCl	mg/100ml	FT Infrarosso

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Protein requirements and utilization

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MP requirements for maintenance

Variable		AFRC	IGR	INRA	SRNS
UEN	g/d	$0.12 \times BW^{0.75}$	$0.165 \times BW^{0.75}$	$0.10\text{-}0.13 \times BW^{0.75}$	$0.147 \times BW + 3.375$
FEN	g/d	$0.15\text{-}0.20 \times BW^{0.75}$	**4.27 × DMI**	$0.10\text{-}0.19 \times BW^{0.75}$	**2.43 × DMI**
Hair+derm. N	g/d	$0.018 \times BW^{0.75}$	$0.032 \times BW^{0.60}$	$0.02 \times BW^{0.75}$	$0.0754 * BW^{0.75}$
Total NP	g/d	**$2.19 \times BW^{0.75}$**	**UEN+FEN+hair**	**$2.1\text{-}2.3 \times BW^{0.75}$**	**UEN+FEN+hair**
NP/MP		1	1	0.83	0.67

FEN = fecal endogenous N; **UEN** = urinary endogenous N; **hair** = hair & dermal N

IGR & SRNS = MP_m increases as DMI increseas to account for higher visceral costs

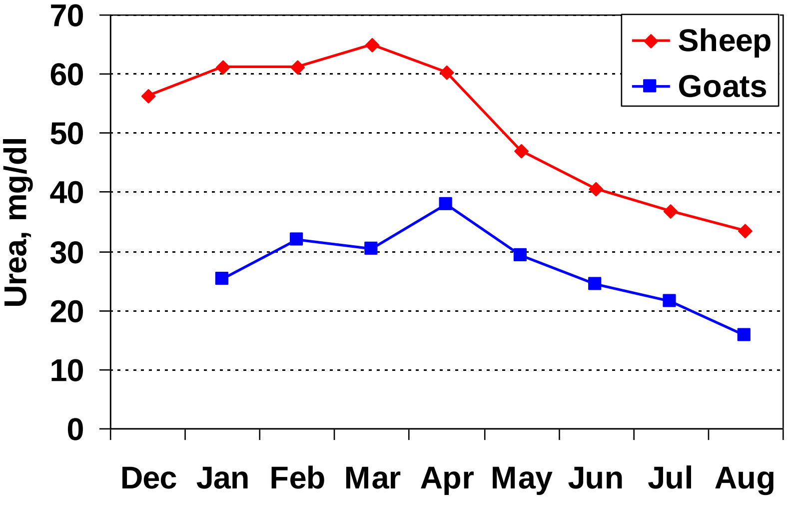
MP requirements at different feeding levels, g/d

Level of intake	50 kg of BW				70 kg of BW			
	AFRC	IGR	INRA	SRNS	AFRC	IGR	INRA	SRNS
1% of BW	41	35	44	29	53	46	56	39
3% of BW	41	62	44	52	53	84	56	71
5% of BW	41	88	44	75	53	121	56	103

Monitoring dietary PROTEIN with Milk Urea

- **Dietary protein excess**
  - alteration of ruminal environment
  - malsabsorption, increased incidence of mastitis and feet problems, energy waste, reproductive disorders
  - high energetic cost
  - decreased intake
  - protein wastage → pollution
- **Dietary protein shortage**
  - reduced intake, digestion and production
  - poor milk coagulation
  - immunosuppresion

Milk urea in Sardinia (ARA, 2000)



Milk urea and dietary CP in dairy sheep (Cannas et al., 1998)

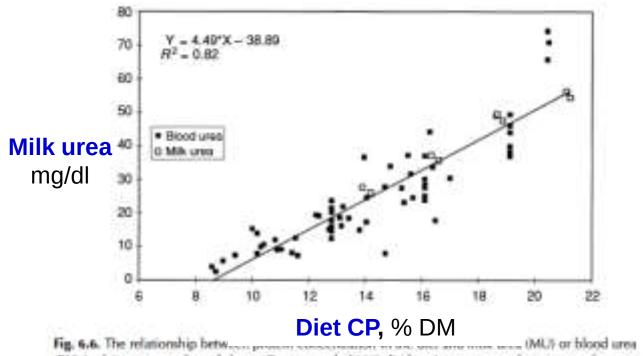


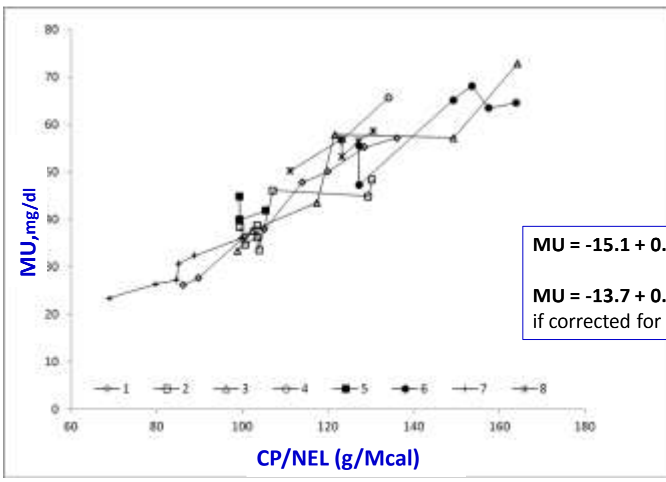
Fig. 6.6. The relationship betw… (MU) or blood urea (BU) in dairy, meat and wool sheep (Cannas et al., 1998). Each point represents the average of an experimental treatment.

Table 6.12. Relationship between MU and dietary CP concentrations in sheep (predicted by using the regression equation reported in Fig. 6.6). When dietary CP concentration is unknown, MU may be used for its estimation.

CP (% DM)	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0
Urea (mg/dl)	15.4	17.6	19.8	22.0	24.2	26.4	28.6	30.8	33.0
CP (% DM)	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5
Urea (mg/dl)	35.2	37.4	39.6	41.8	44.0	46.2	48.4	50.6	52.8

Milk urea vs. dietary CP and NEL of the diet in Sarda (Giovannetti et al., 2015; submitted)

Metanalysis based on this experiment and literature data



MU = -15.1 + 0.5 CP/NEL RMSE 4.6, R^2 =0.88

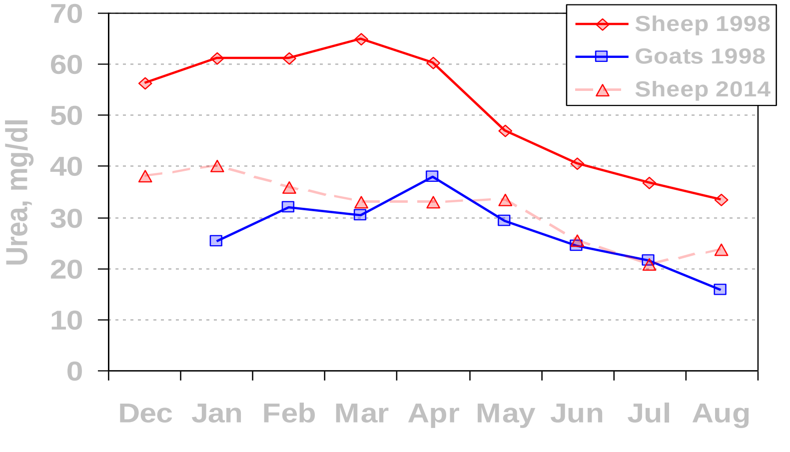
MU = -13.7 + 0.5 CP/NEL RMSE 3.3, R^2 =0.93
if corrected for study effect

Milk urea vs. dietary CP and NEL of the diet in Sarda ewes (Giovannetti et al., 2015, submitted)

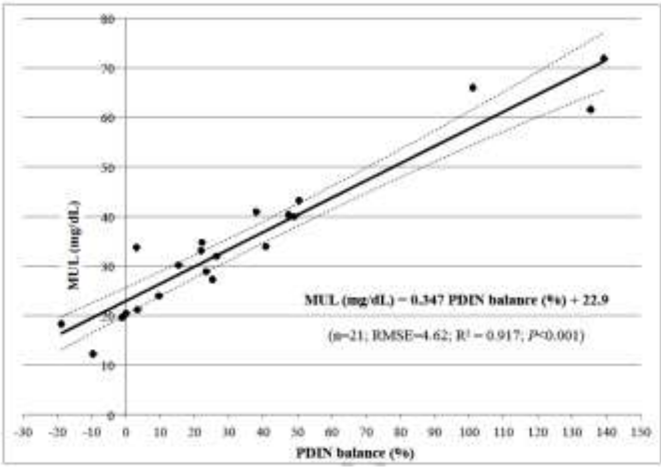
NEL diet Mcal/kg of DM	CP diet (g/kg DM) 120	130	140	150	160	170	180	190	200
1.2	38	42	47	52	56	61	65	70	74
1.3	**34**	38	42	46	50	55	59	63	67
1.4	30	**34**	38	42	46	50	54	57	61
1.5	27	30	**34**	38	41	45	49	52	56
1.6	24	27	31	**34**	38	41	45	48	52
1.7	22	25	28	31	**35**	38	41	44	47
1.8	19	23	26	29	32	**35**	38	41	44

In blue : more frequent values during lactation;
In red : risky for health and reproduction
In green : no excess or shortage of PDI (PDIN-PDI =0)

Milk urea in Sardinia (ARA, 2000)



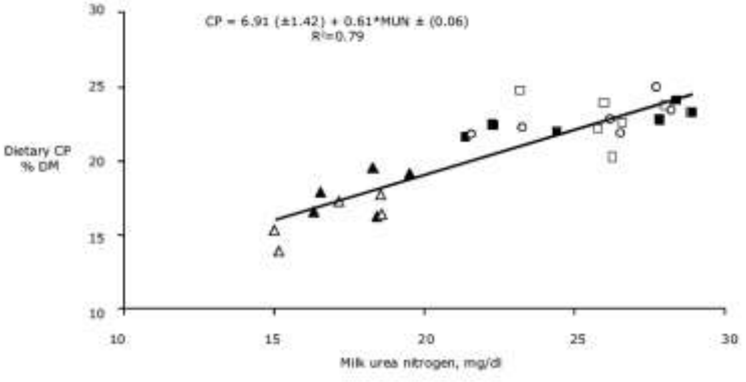
PDIN balance and milk urea in Saanen gaots (Rapetti et al., 2015)



Nitrogen excess above **23 mg/dl,**
Brun-Bellut (1994) suggested optimal value at **28-30 mg/dl**

Milk urea N and dietary CP in goats fed on pasture + barley grains at milking (Bonnano et al., 1998)

Figure 1. Relationship between mean data of milk urea nitrogen (MUN) and dietary crude protein (CP) content obtained from goats receiving the same feeding treatment at the same time (n=28).



Numbers in parentheses are standard error of the coefficients. ▲ ryegrass grazed in the morning by 64 goats/ha (n=5); △ ryegrass grazed in the afternoon by 64 goats/ha (n=5); ■ ryegrass and berseem clover grazed by 72 goats/ha (n=6); □ ryegrass and berseem clover grazed by 48 goats/ha (n=6); ○ ryegrass and berseem clover grazed by 36 goats/ha (n=6).

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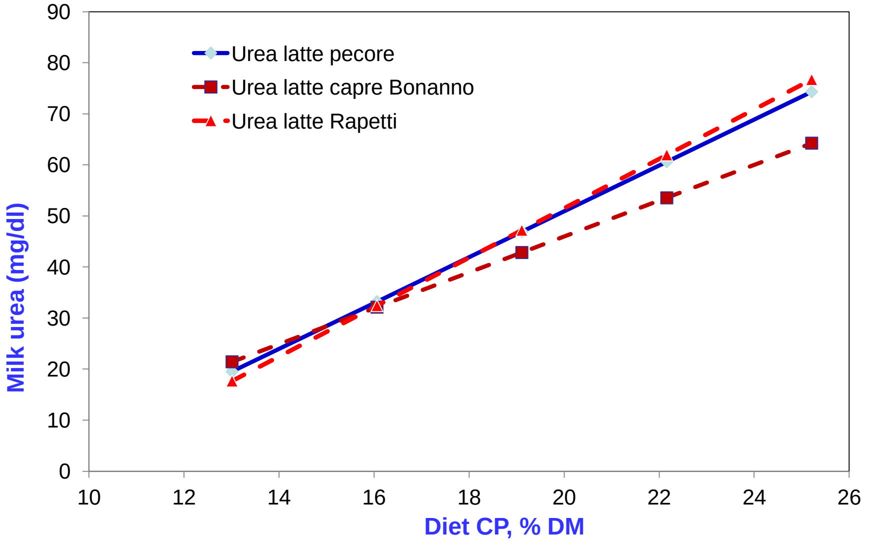
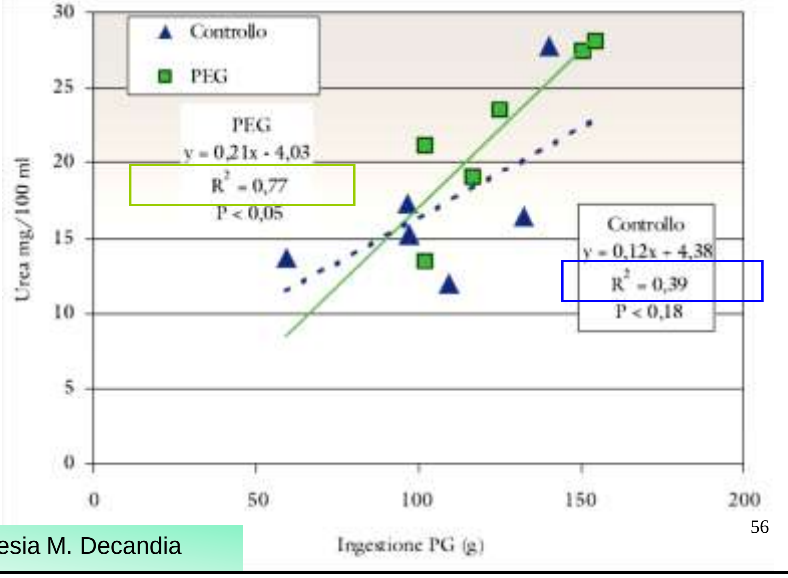
Milk urea: sheep (Cannas et al., 1998) vs. goats (Bonanno et al., 2008; Rapetti et al., 2014)

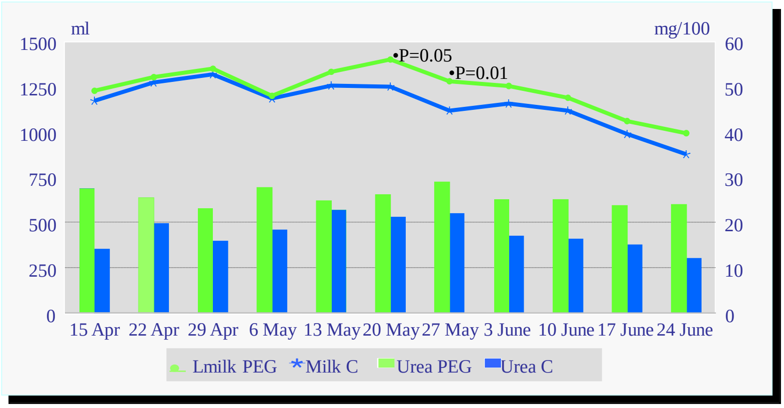


Relationship between intake of CP and milk urea in Sarda goats browsing Mediterranean maquis supplemented with polyethylene-glycol (PEG) or without it (Control) (Decandia et al., 2000a)



Cortesia M. Decandia

Milk production of Sarda goats browsing Mediterranean bushes supplemented with polyethylene-glycol (PEG, 50 g/d) or without it (Control) (Decandia et al., 2000a) – Mid lactation



Courtesy M. Decandia

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Monitoring dietary PROTEIN with Milk Urea

- **Milk urea is an excellent and cheap nutritional indicator of the dietary protein in sheep and goats**
  - Milk urea is particularly valuable on grazing animals, for which it would be difficult to asses protein intake with other methods
- In Sardinia since the routing measurement was introduced, **milk urea went down from mean values above 60 mg/dl from Jan to April, to values below 40 mg/dl**
  - This means that the average diet CP concentration went from 24% to 18%, i.e. current diets use 130 g/d per ewe less CP than before
  - this corresponds to a saving of 364 tons/d of CP

Conclusions

- Profitability and sustainability of dairy sheep and goats is dependent on the appropriate utilization of available resources
- The development and application of nutritional indicators can help to maximize milk production and composition, reduce wastage of resources and prevent nutritional disorders
- This is particularly true in the current conditions:
  - current high milk yield of dairy goats and sheep
  - utilization of rich diets and cultivated pastures
  - increased number of large dairy goat and sheep farms, in which individual monitoring of the animals is not feasible

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