# Balancing diets of highly productive sheep and goats: combining performances and health

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# My presentation

**Objectives:**

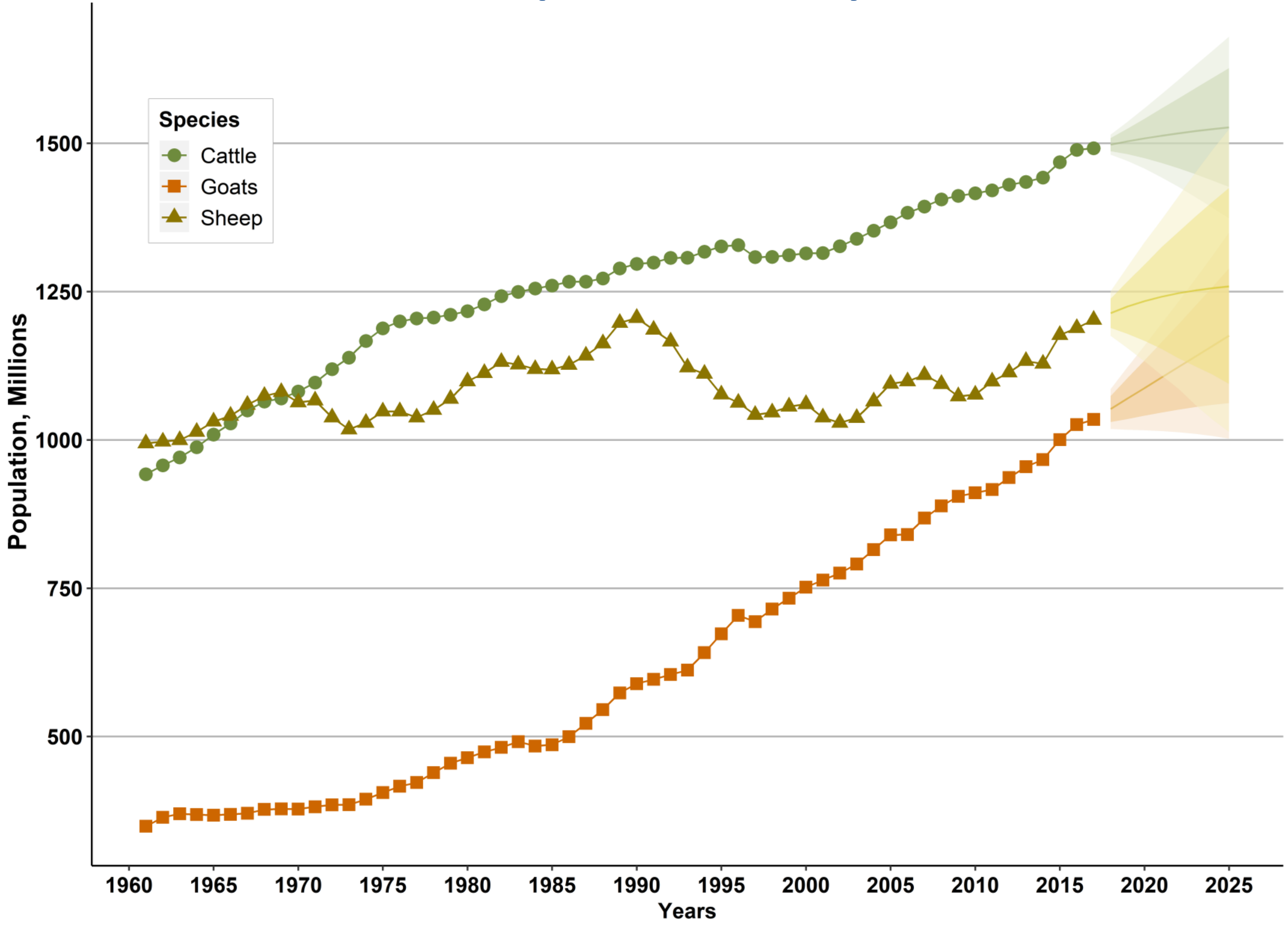
**-** convince you that **sheep and goats are quite different than cattle,** and often are even more challenging

- give some **nutritional scientific and technical information** for managing highly productive ewes and goats

**Outline**

- **Peculiar nutritional aspects of sheep and goats**
- **Nutrition during late pregnancy: challenges and techniques**
  - **CHO, protein, supplements**
- **Nutrition and feeding techniques during lactation**
  - **CHO, protein, nutritional indicators**

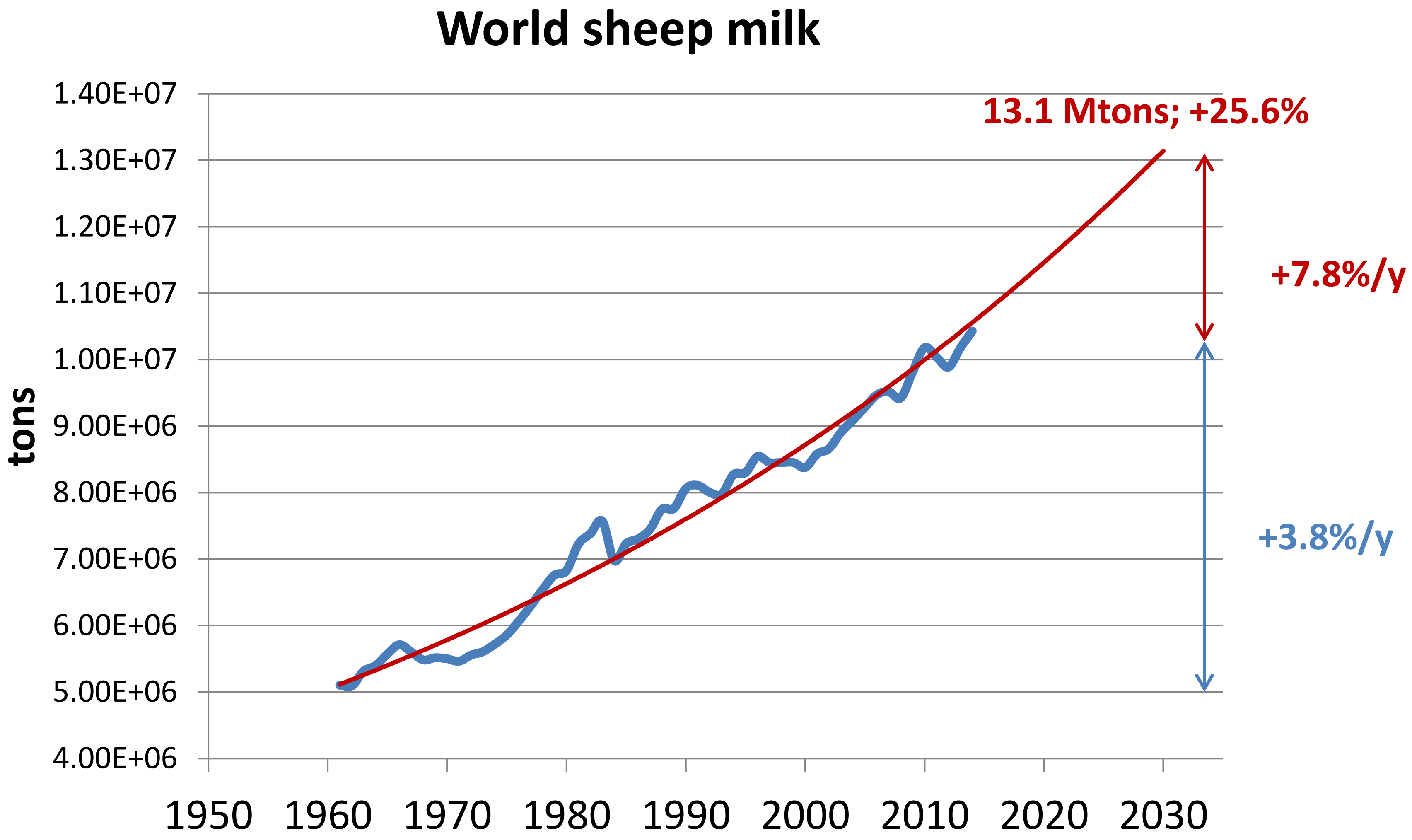
# World population of ruminants (number)



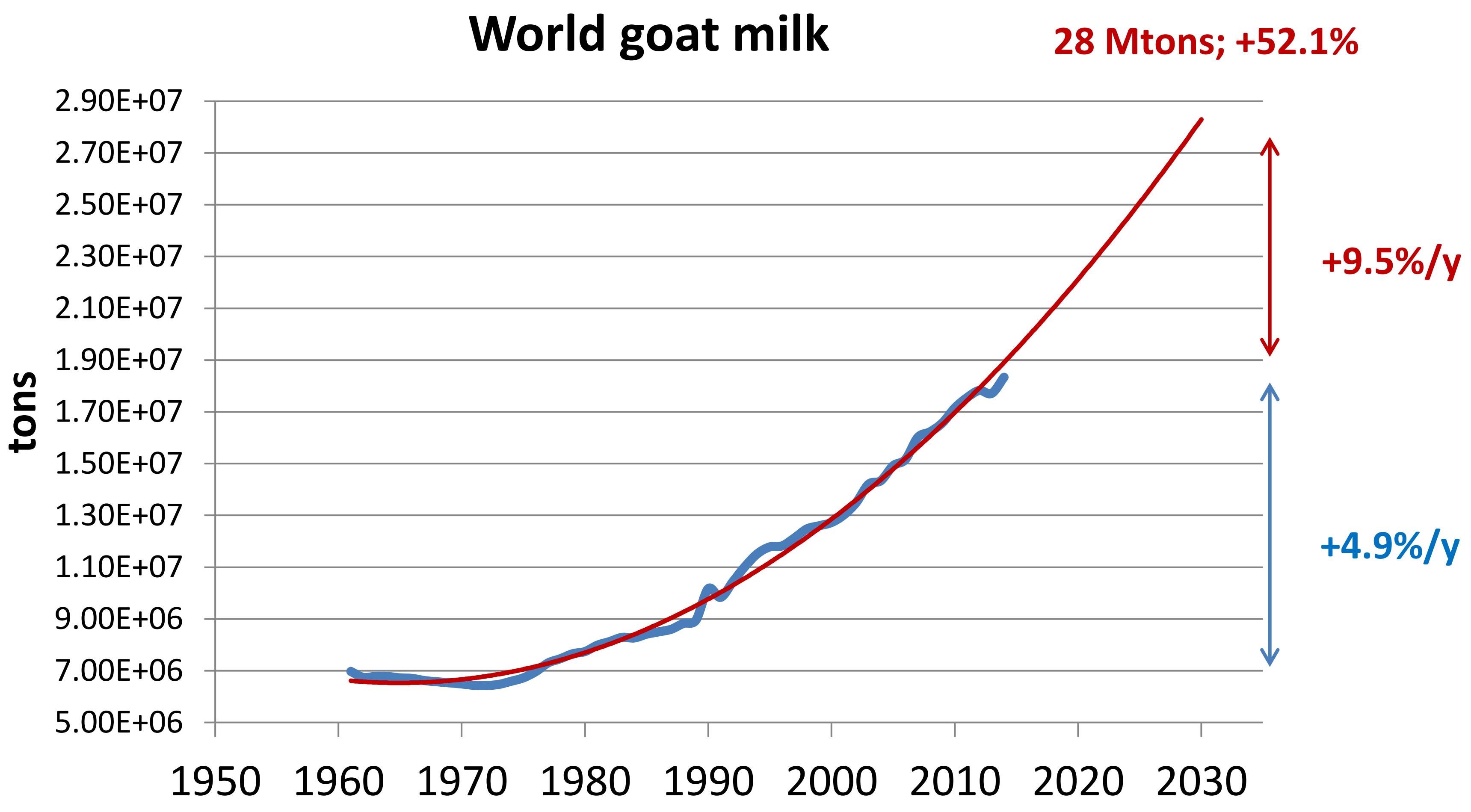

*FAO Data, 2019*

# The trend of sheep milk in 70 years

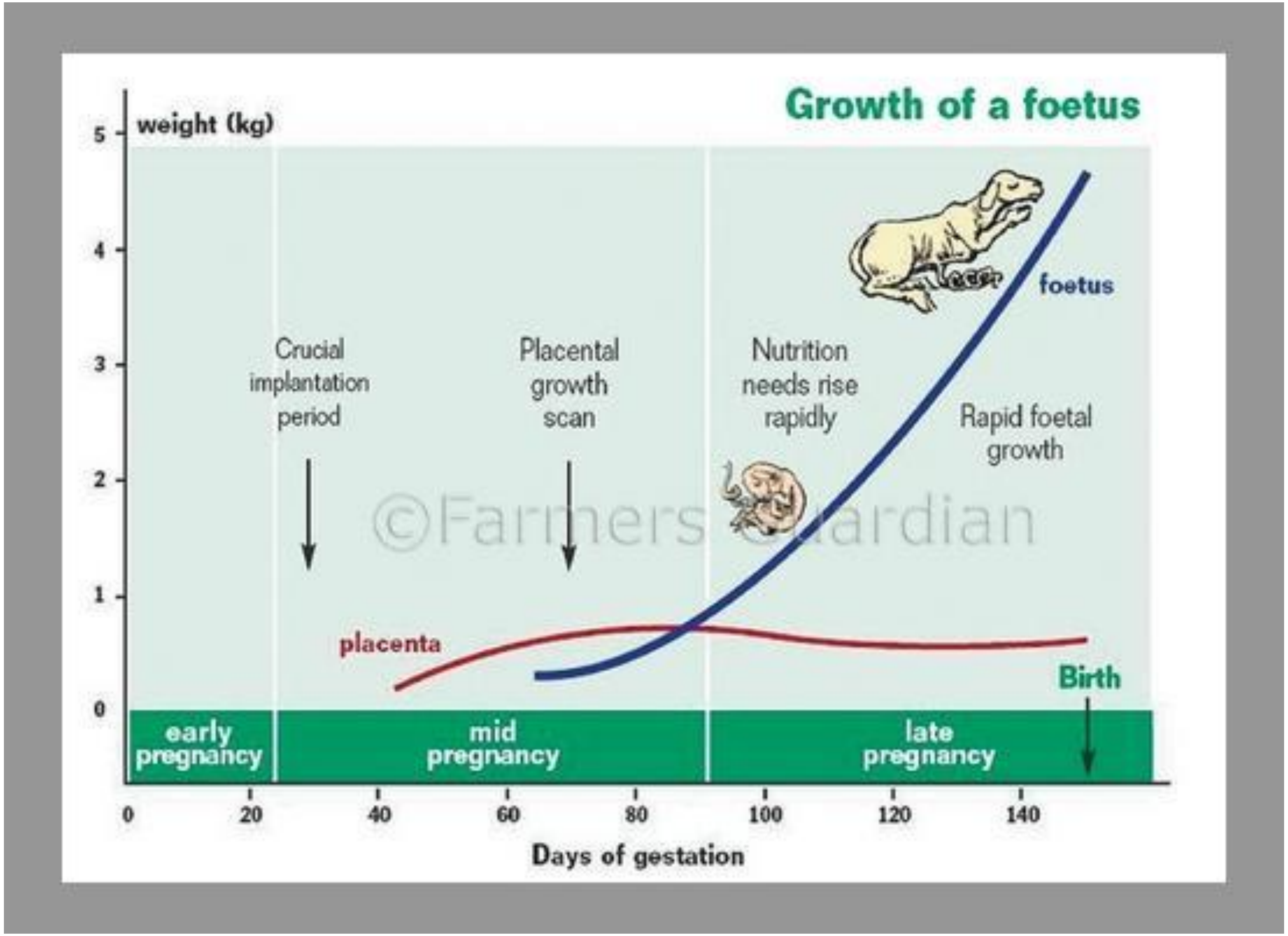
(our estimation on FAO data, 2017)



# The trend of goat milk in 70 year
## (our estimation on FAO data, 2017)



# Nutrition during pregnancy




*Source: Farmers Guardian*

**In sheep litter weight at birth** as a proportion of ewe weight at mating **declines from small to large breeds**

E.g.

50 kg BW mother: singles 7.8% , twins 12.8%

100 kg BW mother: singles 6.5%, twins 10.6%

*Expected birth weights of lambs for ewes of four body weight classes*

| Ewe weight at mating (kg) | Expected litter weight (kg) | | |
|---|---|---|---|
| | single | twins | triplets |
| 25 | 2·4 | 3·8 | 4·4 |
| 50 | 3·9 | 6·4 | 7·5 |
| 75 | 5·3 | 8·6 | 10·0 |
| 100 | 6·5 | 10·6 | 12·8 |

## Ratio of BW at birth

**Sheep**→ singles:twins:triplets = 100:160:185

**Goats***→ singles:double:triplets:quadruplets = 100:170:240:280

* Valid also for very prolific breeds, such as the Finnish Landrace

**Donald & Russel, Anim. Prod. 1970**

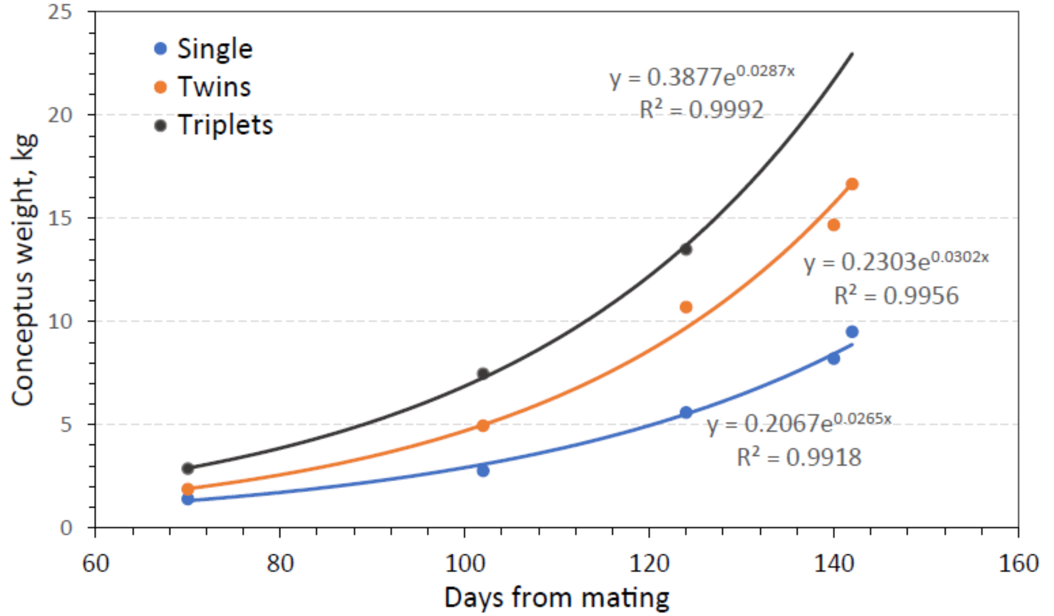



**Fig. 4.** Modeled growth of the ovine conceptus (ie, fetus, membranes, fluids) based on gestational age and number of fetuses. (Models based on data from Rattray and colleagues, 1974.[11])

Targhee ewes that had been mated to Suffolk

**Mongini & Van Saun, 2023**

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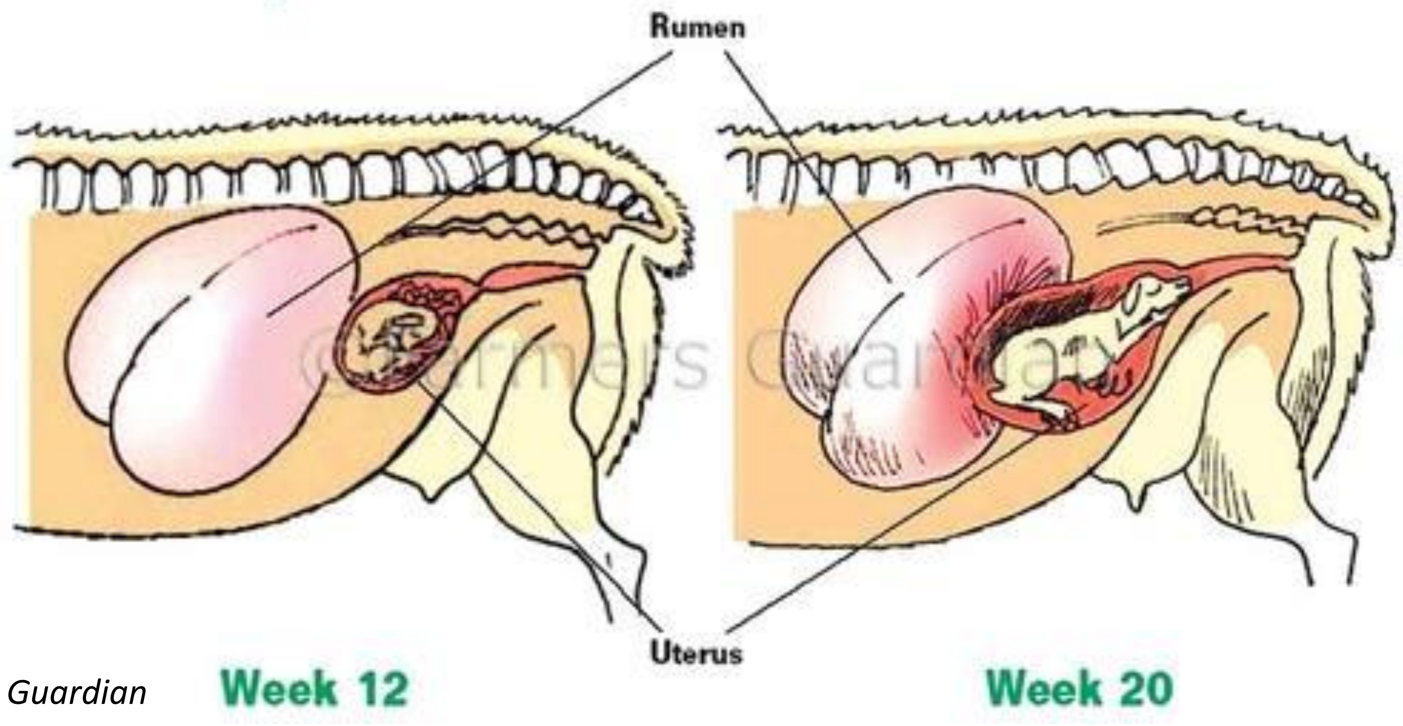
# Pregnancy

| Species | Mother weight kg | Duration gestation d | Birth weight kg | Birth weight/ Mother weight % | Fetus growth last 30 d pregnancy g/d x kg mother weight |
|---|---|---|---|---|---|
| Cow | 650 | 283 | 40 | 6.1 | 0.5 |
| Sheep/goat (single) | 65 | 147 | 4 | 6.1 | 1.1 |
| Sheep/goat (twins) | 65 | 147 | 7 | 10.8 | 2.0 |
| Sheep/goat (triplets) | 65 | 147 | 10 | 15.3 | 2.8 |

**Sheep and goats vs. cattle:**

- **More prolific**: greater nutritional effort
- **Shorter pregnancies**: more “concentrated” nutritional challenge
- **small breeds**: even higher challenge

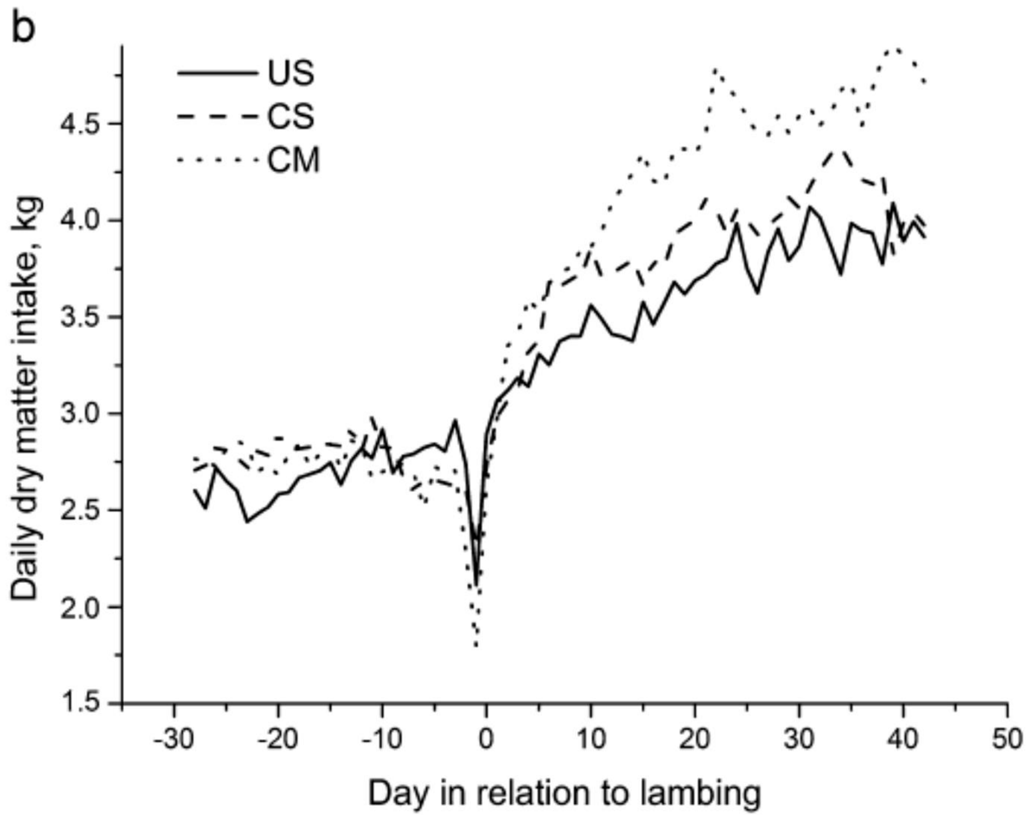
# Pregnancy

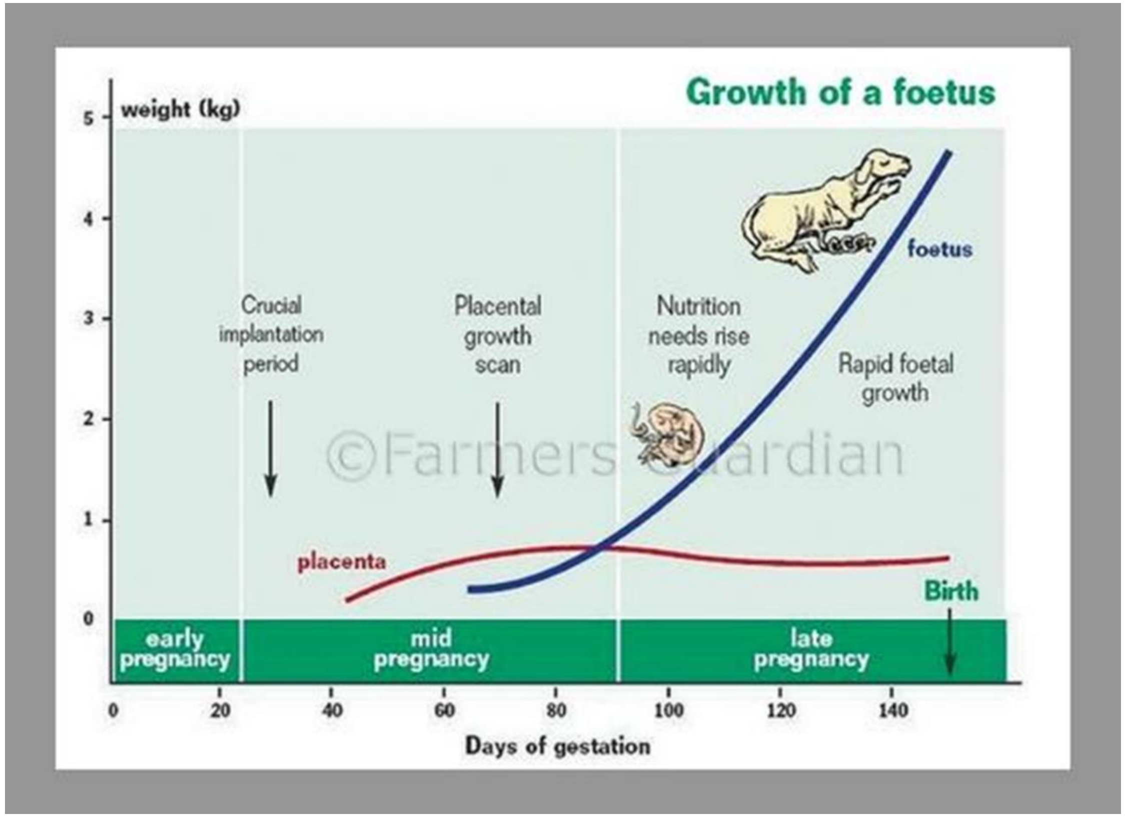



*Source: Farmers Guardian*

- The **uterus** in the final stages of pregnancy occupies a large proportion of abdominal cavity → **less space for the rumen**
- **if the animals are also too fat, much of it will be accumulated in the abdominal cavity, taking out further space to rumen**
  - **Fat produces leptin, which is anorexic hormone, reduces hunger**

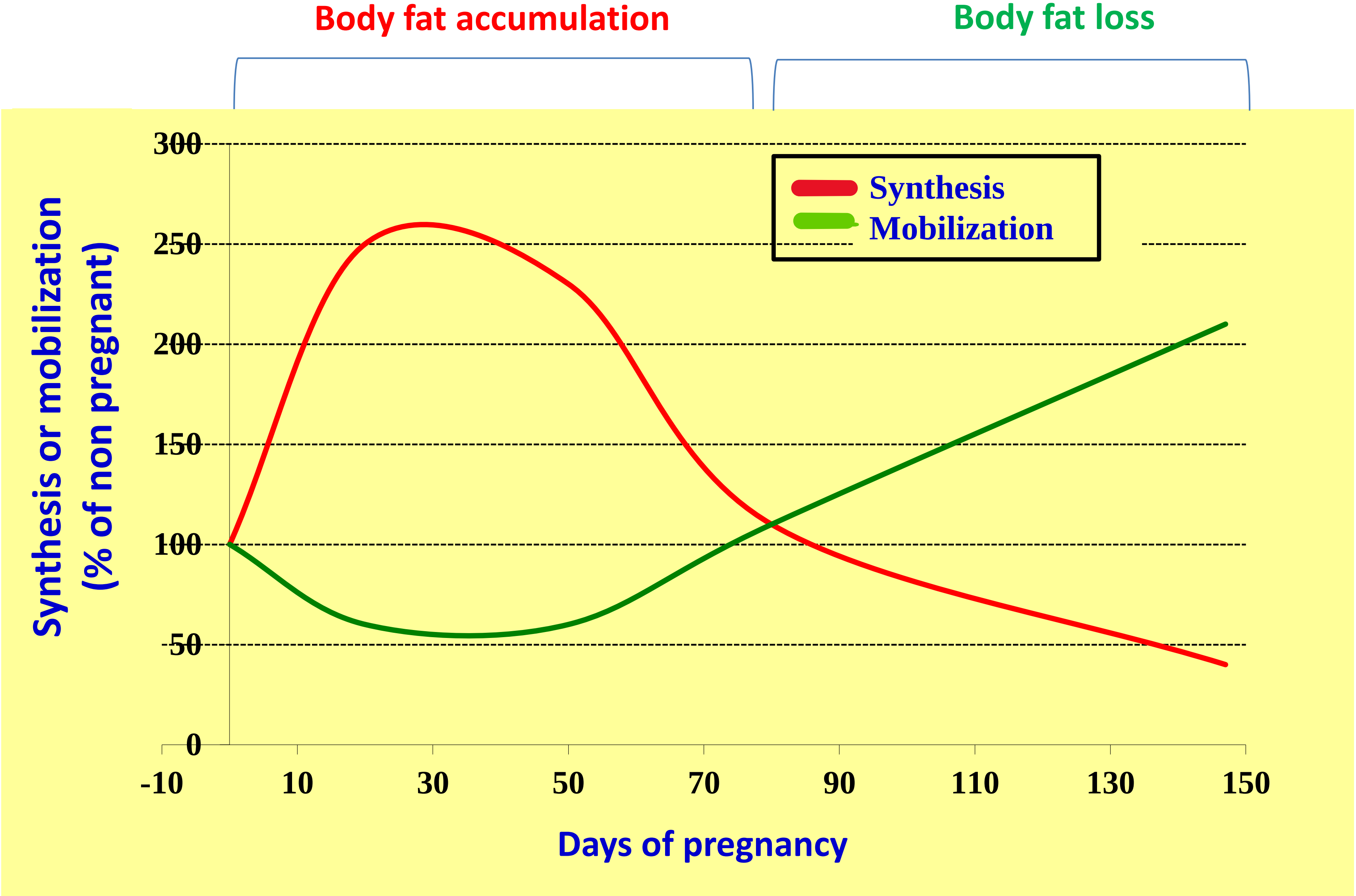
# Sheep DMI during pregnancy and early lactation
## (Helander et al., 2014)



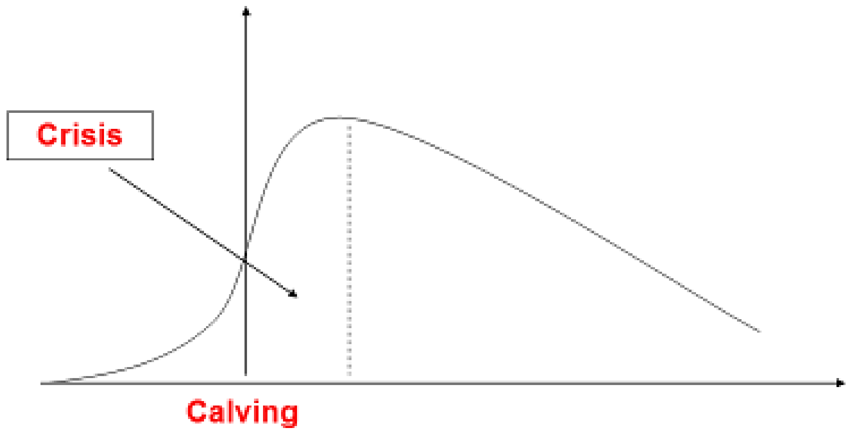




- Intake does not follow the increase in requirements
- It decreases dramatically in the last weeks of pregnancy and slowly increases after parturition, reaching optimal values only 30-40 d after parturition
- energy deficit, sheep consume more energy than they can eat. Thus, they mobilize body reserves to sustain pregnancy and lactation

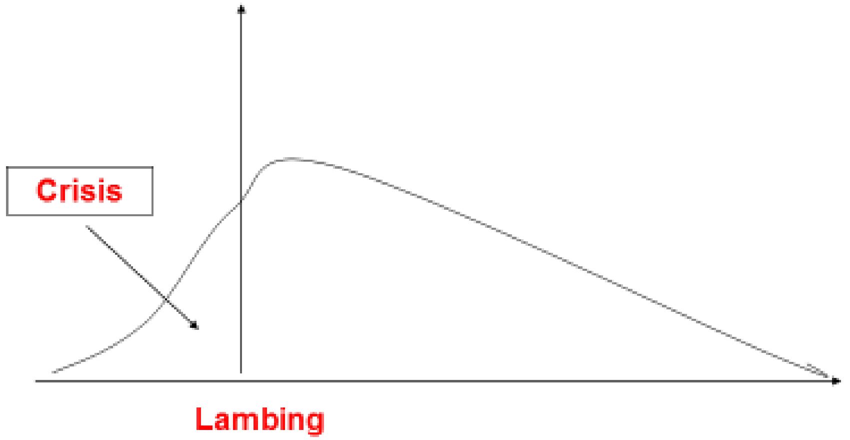
# Fat synthesis and mobilization (both always occur at the same time) during pregnancy (Bell, 1995; adapted)



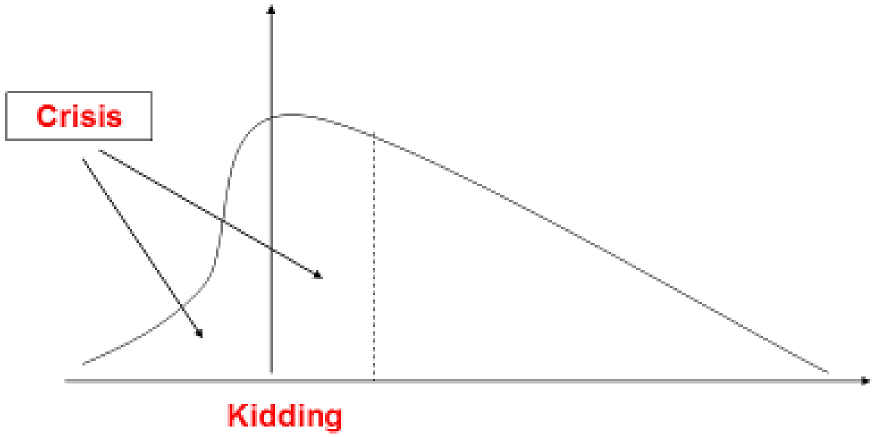
# Nutritional challenges: metabolic demand for glucose




Dairy cattle




Sheep (dairy)




Dairy goats

# Causes of mortality in a flock of 1200 adult goats (65% Saanen, 35% Alpine)

**Table 6.** Causes of mortality in a group of 1,200 adult dairy goats during 2009-2010.*

| Causes of mortality | Numbers of deaths | Proportion of all deaths (%) | Annual mortality rate (%)** |
|---|---|---|---|
| Unknown | 87 | 29.3 | 3.6 |
| Pregnancy toxemia | 55 | 18.5 | 2.3 |
| Dystocia | 47 | 15.8 | 2.0 |
| Weight loss | 27 | 9.1 | 1.1 |
| Respiratory disease | 26 | 8.8 | 1.1 |
| Metritis | 19 | 6.4 | 0.8 |
| Diarrhea disease | 14 | 4.7 | 0.6 |
| Mastitis | 10 | 3.4 | 0.4 |
| Trauma | 6 | 2 | 0.3 |
| Enterotoxemia | 4 | 1.3 | 0.2 |
| Heat stress | 2 | 0.7 | 0.1 |
| **Totals** | 297 | 100 | 12.4 |

*Only deaths in animals that were 12 months of age or older are shown.
**Calculated by dividing the number of deaths over two years by 1,200, and dividing that by 2.

Lima et al., 2012

# Causes of mortality in 45 Saanen and Alpine French farms (Mahler et al., 2001)

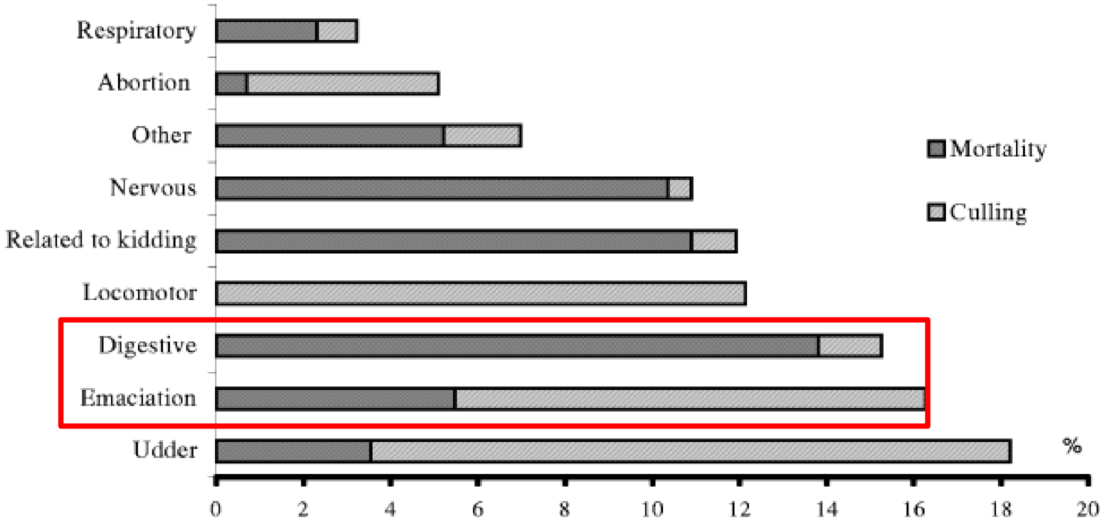



Fig. 4. Distribution of health disorders related to mortality and culling ($n = 1{,}862$).

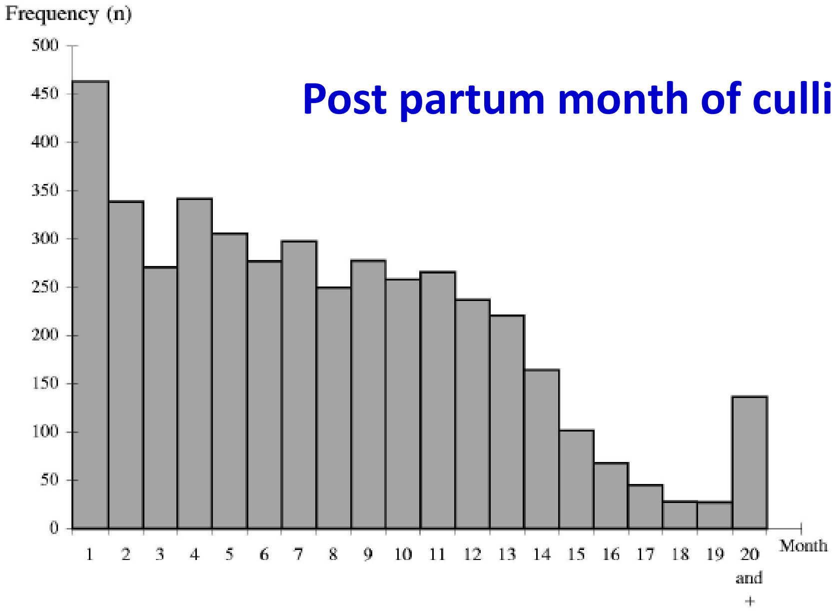



Fig. 2. Distribution of kidding-to-exit interval ($n = 4{,}379$).

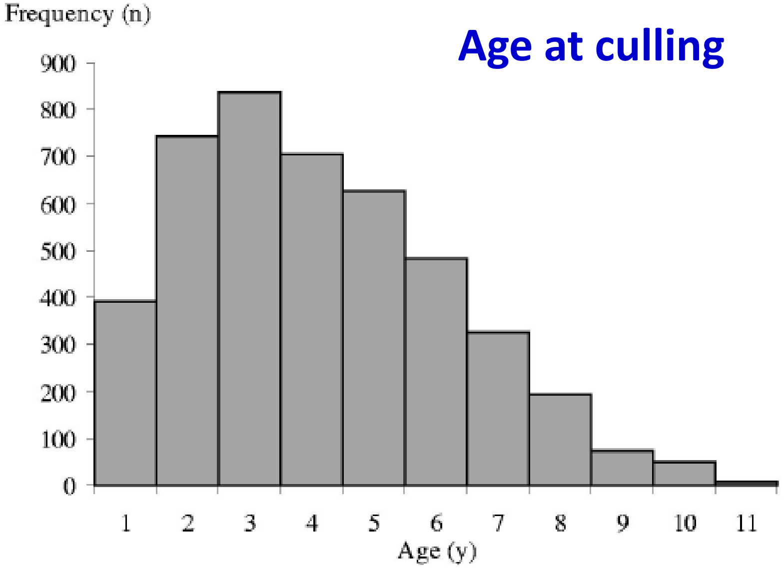



Fig. 1. Distribution of goat age at exit ($n = 4{,}441$).

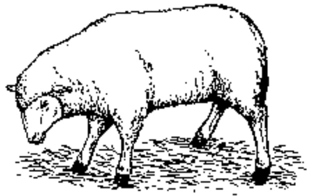
# Nutritional challenges

- **Heaviest nutritional challenge for the ewes is during late pregnancy-early lactation**
  - Nutritional status in this period affects subsequent lactation, lamb growth, and health of the animals

- **Most common nutritional disorders and diseases occur more frequently in late pregnancy-early lactation**
  - ketosis (pregnancy toxemia) and sub-ketosis
  - Hypocalcemia (milk fever)
  - Acidosis (grain overload and high sugar intake)
  - Protein unbalances
  - Immunosuppression

- Nutritional management and **proper diet formulation critical for optimal production and health**

# Ketosis



- Low blood sugar (20-40 mg/dl)
- Too fast body fat mobilization → high production of **ketone bodies** ⇒
  - β-OH butyrate
  - Acetoacetate
  - Acetone

**Acids, toxic in the blood**

| Status | Blood βOH-butyrate |
|---|---|
| Subclinical ketosis | > 0.8 mmol/l |
| Likely ketosis | > 1.2-1.6 mmol/l |
| Ketosis | > 3 mmol/l |

Fatty liver

- Signs and effects
  - Ewes are lethargic, grind teeth, walk in circles, acetone smell on breath, high death rates, difficult to recover
  - **Ketonuria** when βHB reaches 0.6-0.7 mmol
- Treatment
  - Increase blood sugar, drench with propylene glycol
- Prevention
  - Management and nutrition

# Pregnancy Toxemia in Sheep and Goats

Andrea Mongini, DVM, MS[a], Robert J. Van Saun, DVM, MS, PhD[b,*]

KEYWORDS

• Pregnancy toxemia • Small ruminants • Metabolic disease • Sheep • Goats

KEY POINTS

- Pregnancy toxemia is a metabolic disease associated with hypoglycemia and hyperketonemia in late gestation sheep and goats typically with multiple fetuses.
- Obesity or starvation during late pregnancy can predispose the ewe or doe to greater risk of pregnancy toxemia.
- Proper diagnosis and early detection of pregnancy toxemia are critical for favorable outcomes.
- Nutritional management of individuals and herds is an essential part of treatment of acute cases and prevention of future cases.

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https://doi.org/10.1016/j.cvfa.2023.02.010

# Pregnancy toxemia

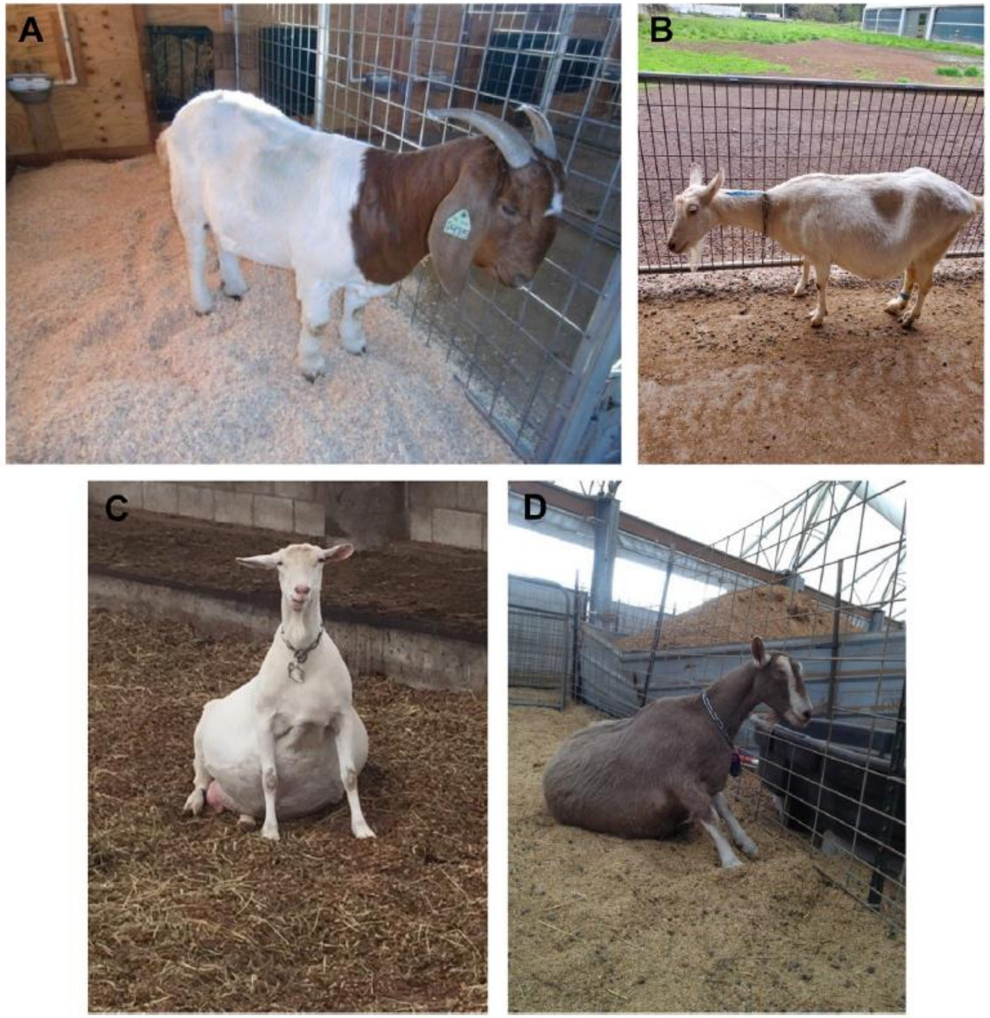


Fig. 2. Examples of pregnant does presenting in Stage 2 of pregnancy toxemia. Dams present as anorexic and may stand for limited times (*A*, *B*) or down (*C*, *D*).

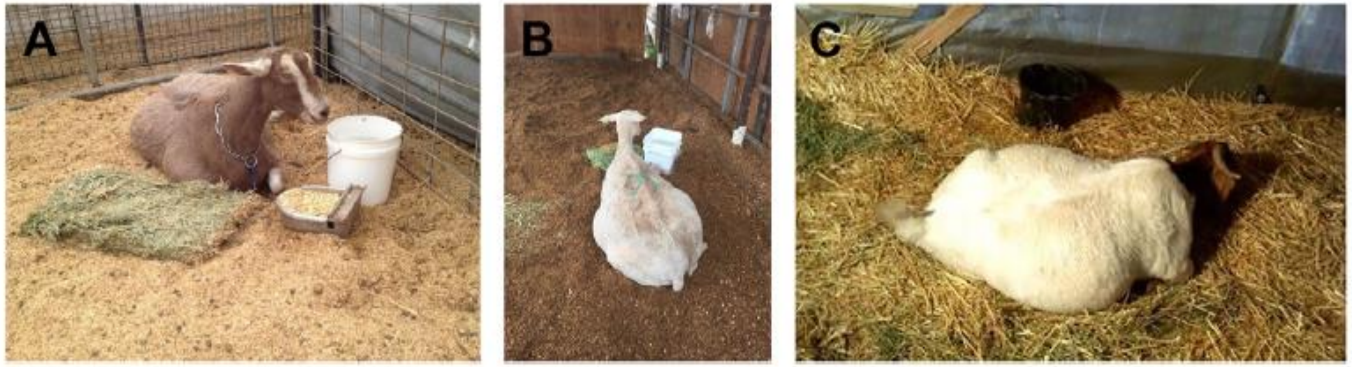


Fig. 3. Examples of pregnant does presenting in Stage 3 of pregnancy toxemia (*A–C*). Does are typically unable to rise, depressed, with labored breathing.

**Mongini & Van Saun, 2023**

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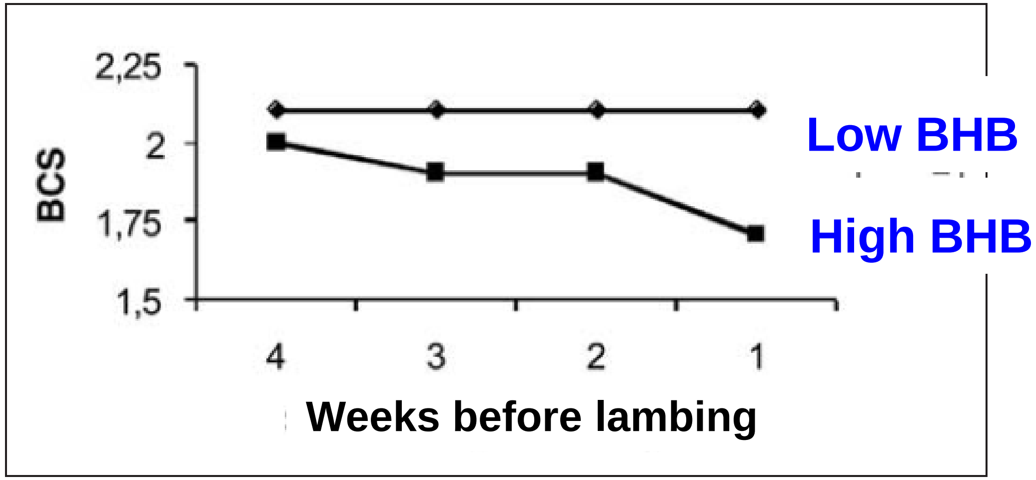
# Ketosis in sheep and goats

- **Sheep are particularly sensitive to the negative action of ketone bodies**
  - **High differences between breeds and individuals**
- **Preventive treatments often ineffective**
- **Therapies often not very effective**
- **High incidence even with adequate nutritional plans**
- **From field surveys often more than 20% of animals in subclinical ketosis or ketosis (Lacetera 2001)**
- **Often associated to hypocalcemia (milk fever)**

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




**Subclinic ketosis =**
BHB >0.86 mmol/L

| | Low BHB (<0.86 mmol/L) | High BHB (>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 in the mother and in the lamb → increases susceptibility to infectious diseases**

# Effects of ketosis in sheep & goats

**In ewes with subclinical ketosis at the end of the pregnancy** (Karagiannis et al., 2014)**:**

- **increased frequency of health problems, favoured by immunosuppression, such as pregnancy toxiemia, placental retention, metritis, clinical mastitis**
- **problems much more frequent in ewes with BCS too low (< 2.75) and too high (>3.5)**

**In ewes with with clinical ketosis (Barbagianni, 2015)**

**Increased:**

- post-partum mastitis in inoculated animals
- dystocia
- perinatal mortality
- post-partum reproductive tract disorders

**Decreased:**

- blood flow to the mammary gland

In addition, with **trematode infections, increased βHB concentration and mastitis occurence** (Mavrogianni et al., 2014)

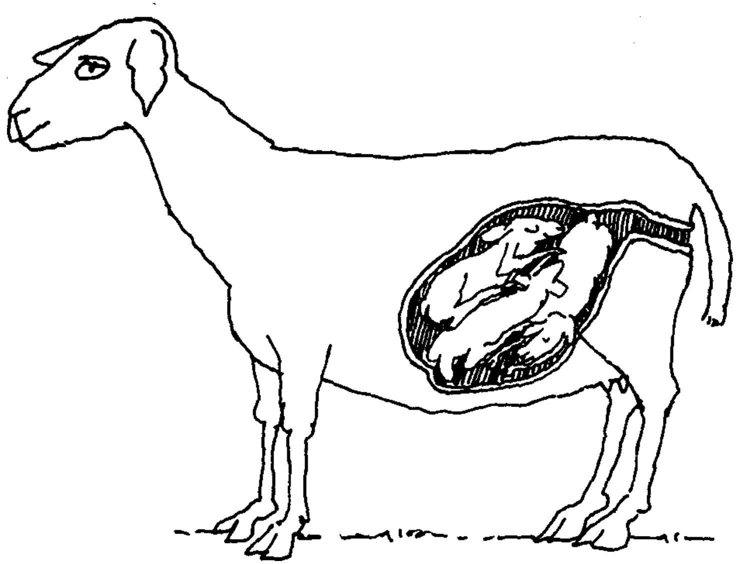
## High accuracy of hand-held electronic on farm test in dairy sheep (Panousis et al., 2012) and dairy goats (Dorè et al., 2013)


**High correlation between βHB ≥ 0.4 mmol/L at week – 4 and pregnancy toxemia in dairy goats (Dorè et al., 2015)**

**Best window for βHB in lactating goats: 3 to 16 DIM, best if associated to glucose measurement**

# Nutritional challenges during pregnancy

- **In the last 2-4 weeks of pregnancy sheep decrease their intake and requirements  grow quickly: fiber intake is the most limit factor, because of its bulkiness**
- **Some loss of body fat and protein is unavoidable, but this needs to be controlled**
  - **To reduce sanitary risks and avoid immunosuppression**
  - **To maximize milk production**
- **Too low or to high BCS at lambing reduces milk production and colostrum production**
  - **20-35% more milk at optimal BCS** in dairy ewes compared to low BCS ewes (e.g. Atti et al., 1995; Charismiadou et al., 2000)
  - **Dramatic BCS and milk production decreases in fat ewes** (BCS 4.6) at lambing due to low DMI (Noorgard et al., 2008)
- **Underfeeding in late pregnancy might reduce mammary development, lamb/kid birth weight and its survival after birth (Campion et al., 2019)**



# Feeding sheep an goats during pregnancy

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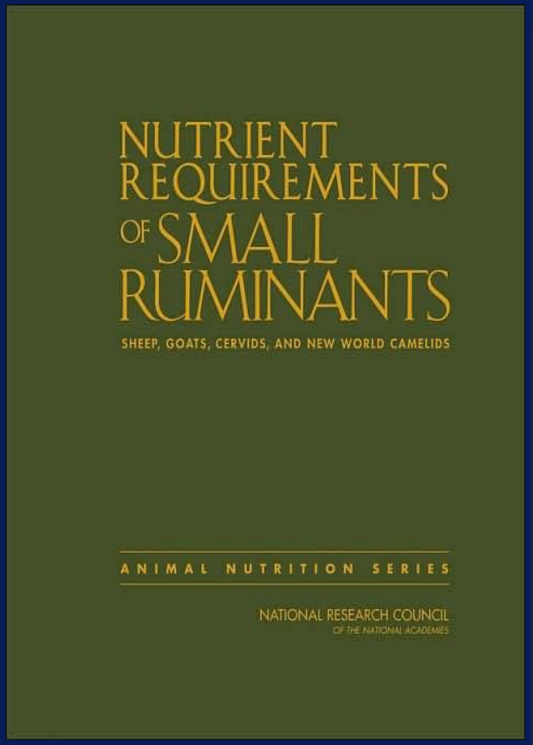
# The Small Ruminant Nutrition System

Cannas A., Tedeschi L., Fox D.G., Van Soest P.J., Pell A.N. 2004. *Journal of Animal Science*, 82:149-169
Tedeschi, L.O., Cannas, A., Fox D.G. 2010. *Small Ruminant Research*, 89, 174-184



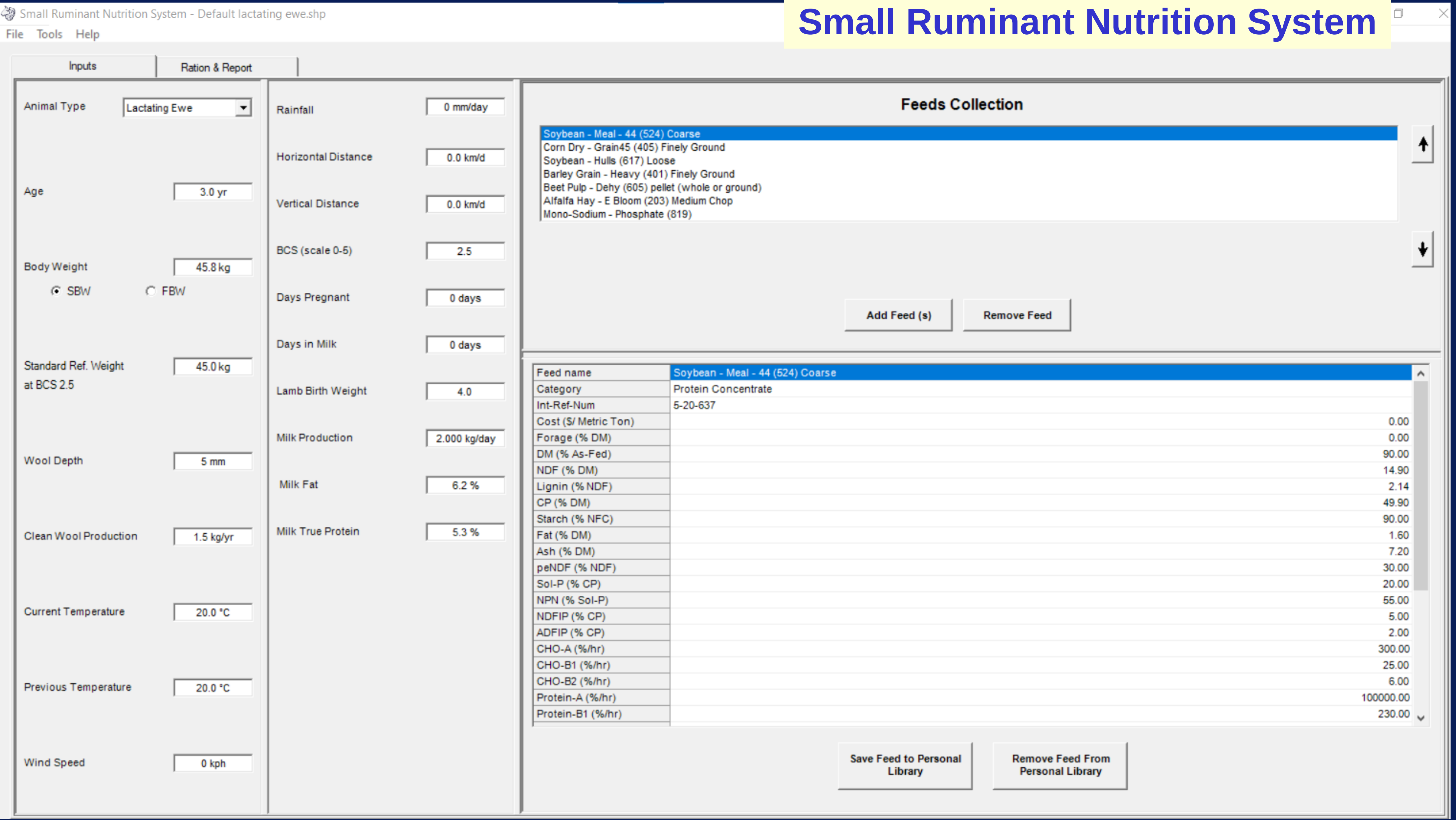

- **SRNS sowftare web site:**

  **http://nutritionmodels.com/srns.html**

- **free use for university students, very cheap for the others**

- **Multilingual: English  Portoguese, Italian, Spanish, Turkish, Korean**

# Small Ruminant Nutrition System



# Definitions: carbohydrates (CHO)

- **NDF** = **structural CHO** associated to the cell wall (CW) → plant fiber - pectins
- **Sugars and starch** = nonstructural CHO, high degradation rate, energy + reserve function in the plant
- **Pectins** = **soluble fiber** of the CW, nutritionally similar to non-structural CHO
- **NFC** = non fiber CHO: 100- $NDF_{CP\ free}$ - CP - ash- EE = **sugars + starch + pectins**
- **NSC** = non-structural carbohydrates: **sugars + starch** chemically measured
- **WSC** = water soluble carbohydrates chemically measured: **simple sugars + fructans**

# Effect of energy and fiber concentrations in pregnancy (last 60 d) on subsequent lactation

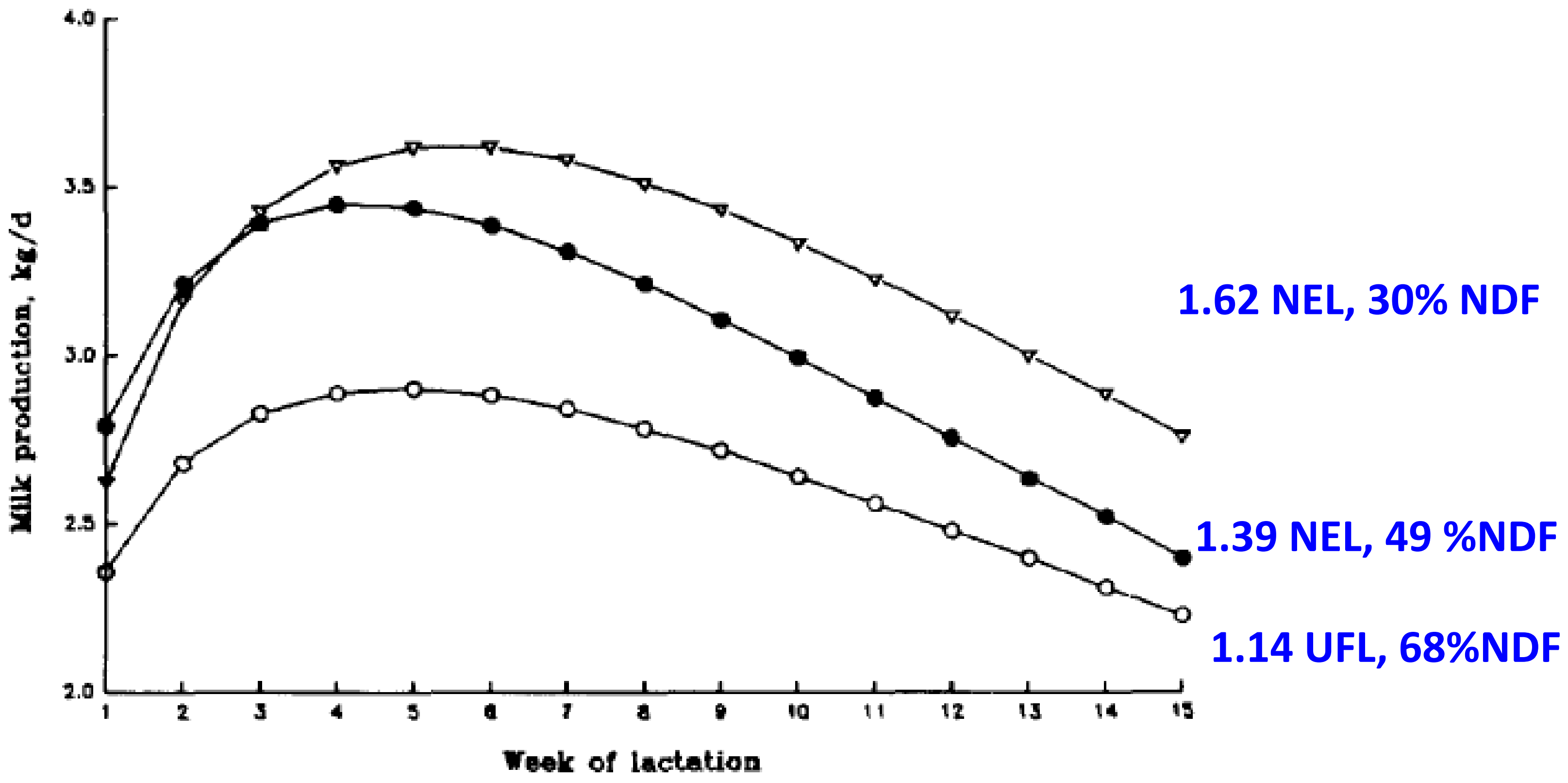



Figure 1. The effect of dietary energy intake [1.8 (○), 2.16 (●), and 2.53 (△) Mcal of metabolizable energy/kg of DM] on milk production. The $r^2$ = .891, .888, and .922, respectively, for the 1.8, 2.16, and 2.53 Mcal of metabolizable energy/kg of DM.

Sahlu et al., 1994

# NDF intake (% of BW) in ewes fed different quality of silages during pregnancy

Table 2
Calculated neutral detergent fiber intake as a percent of body weight in ewes fed differing quality silages over weeks of gestation and pregnancy status

| | NDF Intake as % of Body Weight | | |
|---|---|---|---|
| Pregnancy Week[a] | Singles | Twins | Triplets |
| 15 | 0.83 | 0.81 | 0.74 |
| 16 | 0.81 | 0.73 | 0.71 |
| 17 | 0.81 | 0.65 | 0.68 |
| 18 | 0.74 | 0.65 | 0.64 |
| 19 | 0.69 | 0.62 | 0.59 |
| 20 | 0.70 | 0.60 | 0.55 |
| Mean | 0.76 | 0.68 | 0.65 |

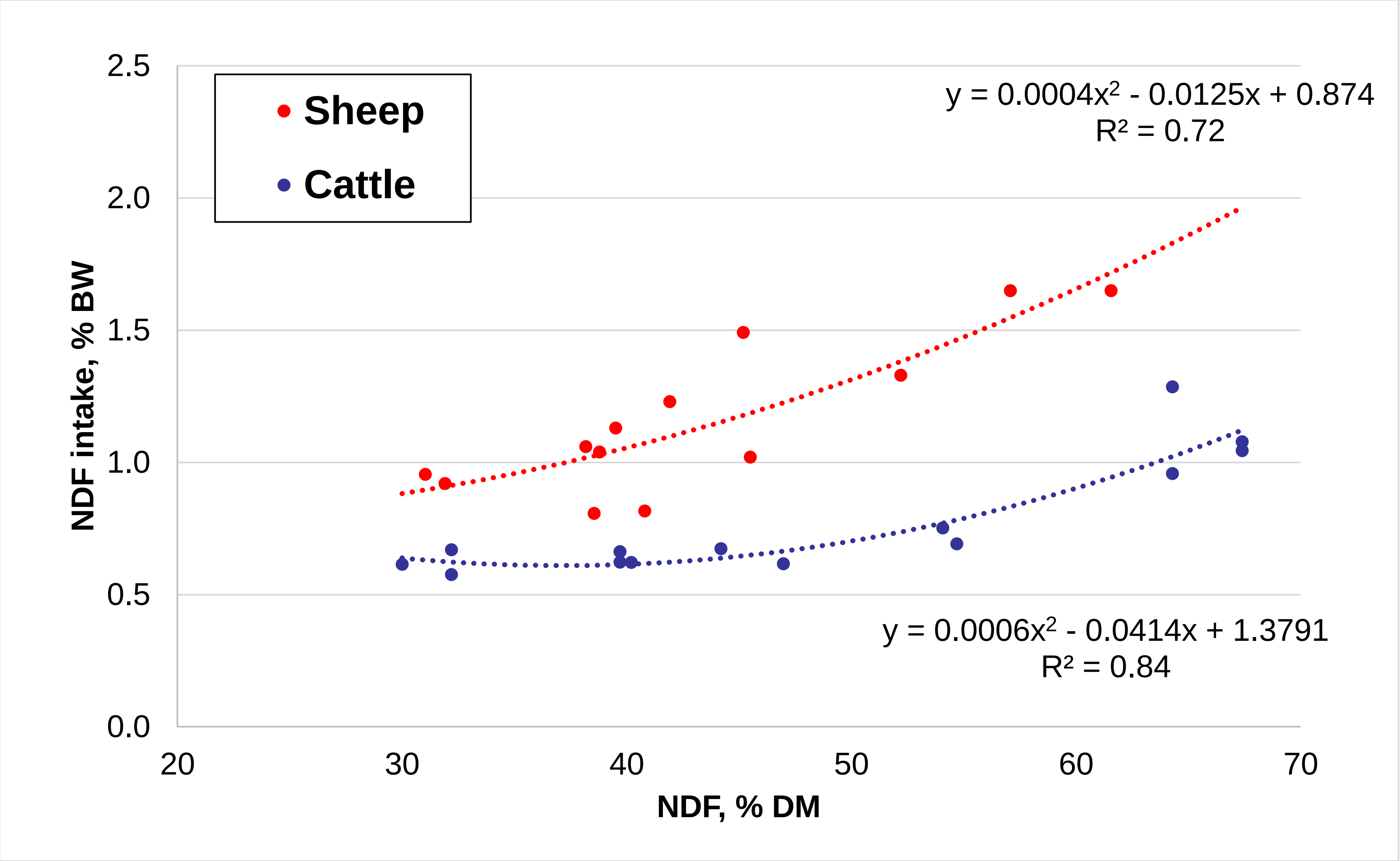
| | | NDF Intake as %BW | | |
|---|---|---|---|---|
| Forage NDF% | Week | Singles | Twins | Triplets |
| 48.5 | 15–17 | 0.82 | 0.74 | 0.71 |
| 63.8 | 15–17 | 0.78 | 0.70 | 0.70 |
| 44.9 | 18–20 | 0.83 | 0.70 | 0.70 |
| 48.5 | 18–20 | 0.71 | 0.62 | 0.59 |

[a] Silage (48.5% NDF) fed at 25% of dietary dry matter.
*From* Orr R, Newton J, Jackson CA. The intake and performance of ewes offered concentrates and grass silage in late pregnancy. Animal Science 1983;36:21-27.



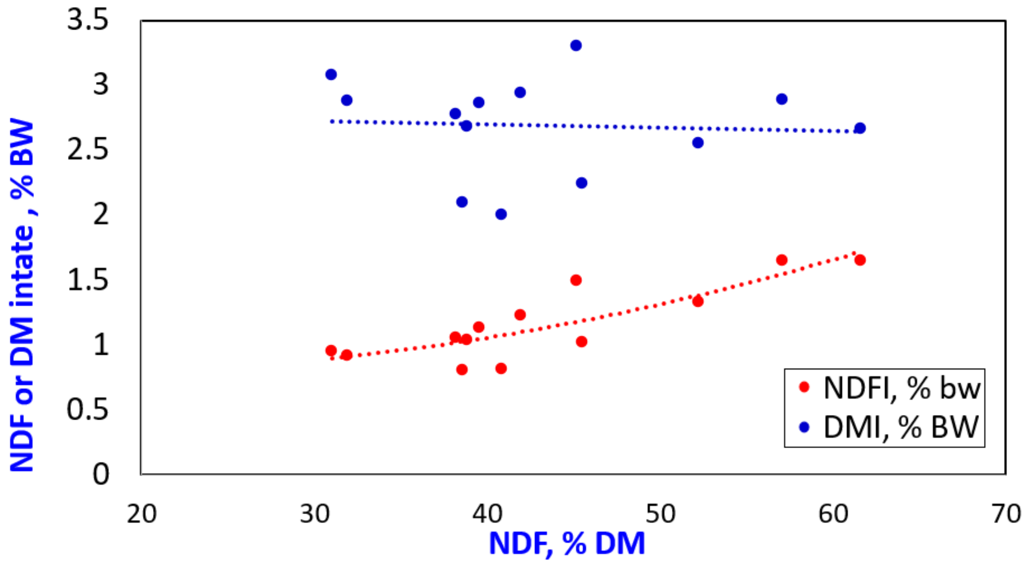
**Mongini & Van Saun, 2023**

# Diet NDF during pregnancy: sheep vs. cattle (Cannas et al., 2016)

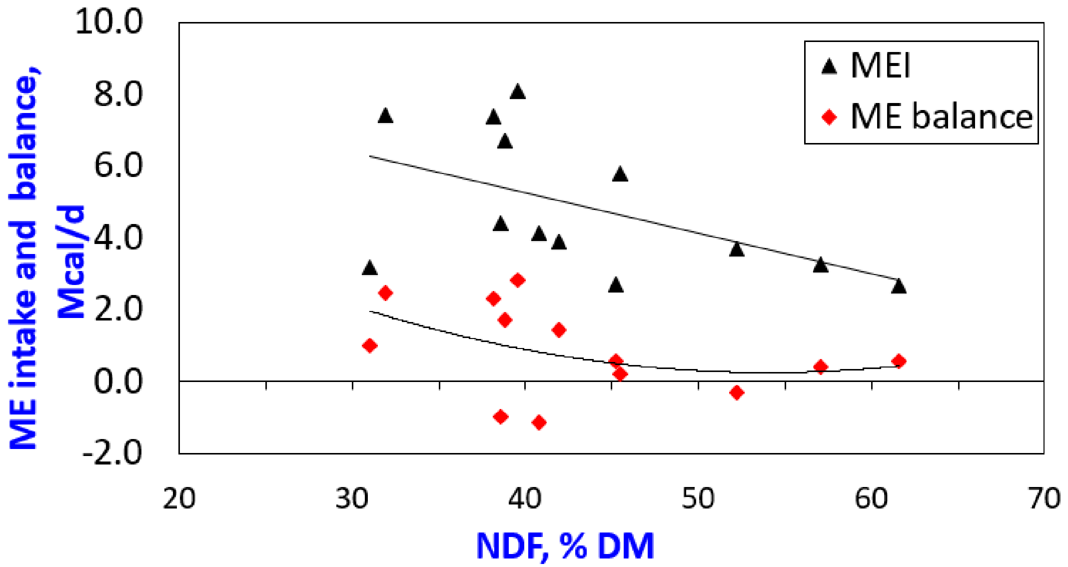


# Data of ewes in late pregnancy (-57 to -17 d DIP) in eight studies, with 13 feeding treatments (Cannas et al., 2016)

**NDF of the ration before lambing:**
**Effects on DM, NDF, and ME energy intake**




**With NDF > 40-45% sharp decline in energy intake and worsening of energy balance**



# Trial on pregnant sheep: chopped oat hay vs. chopped alfalfa hay ad libitum and 600 g/d of concentrate (M. Sini, 2023)

## DMI and NDFI

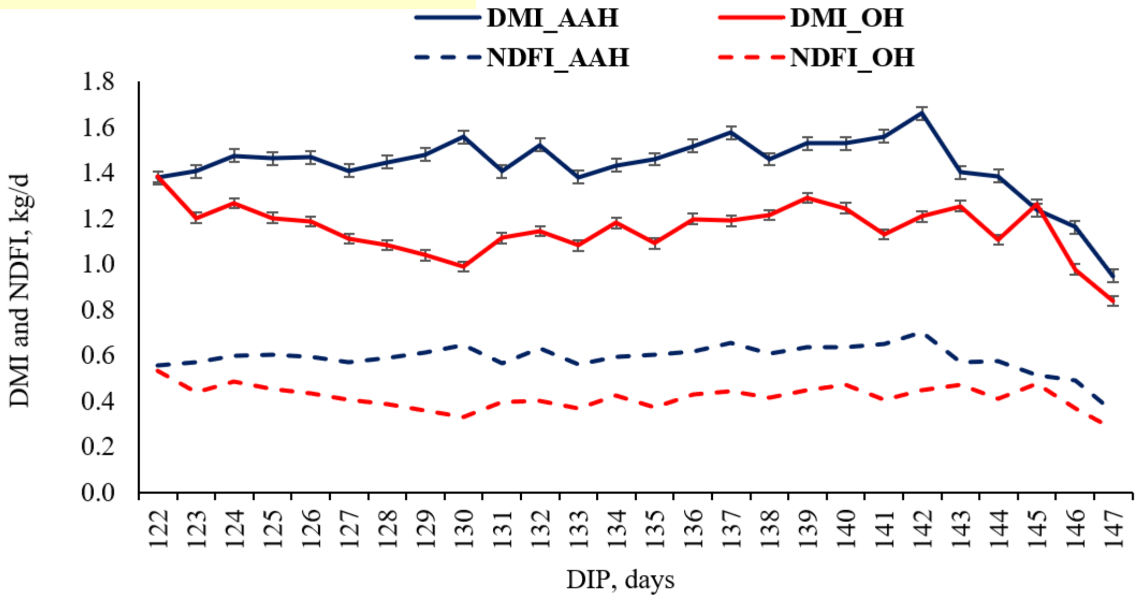
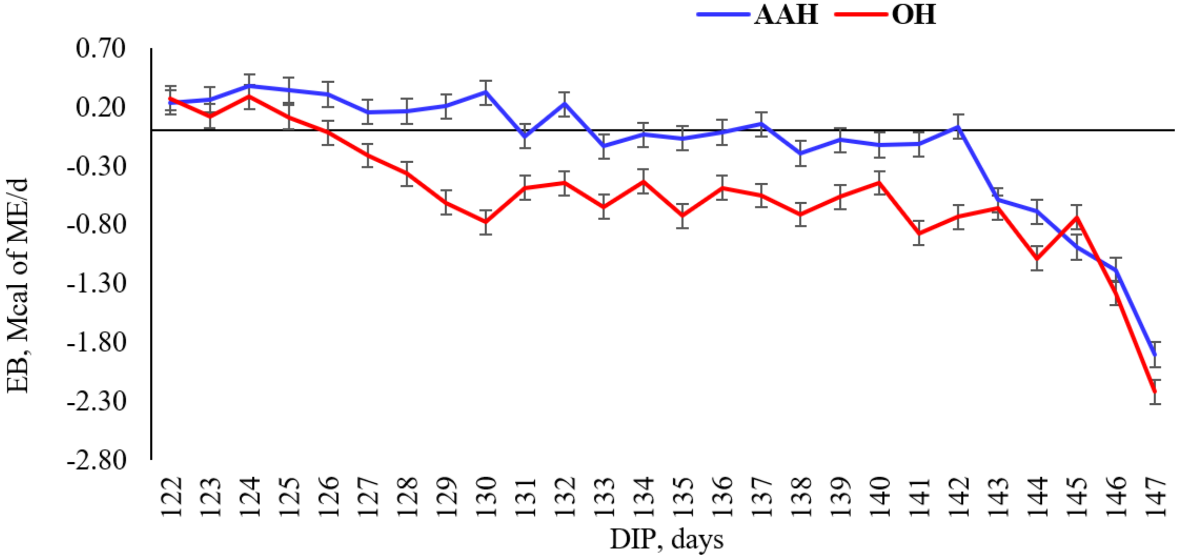
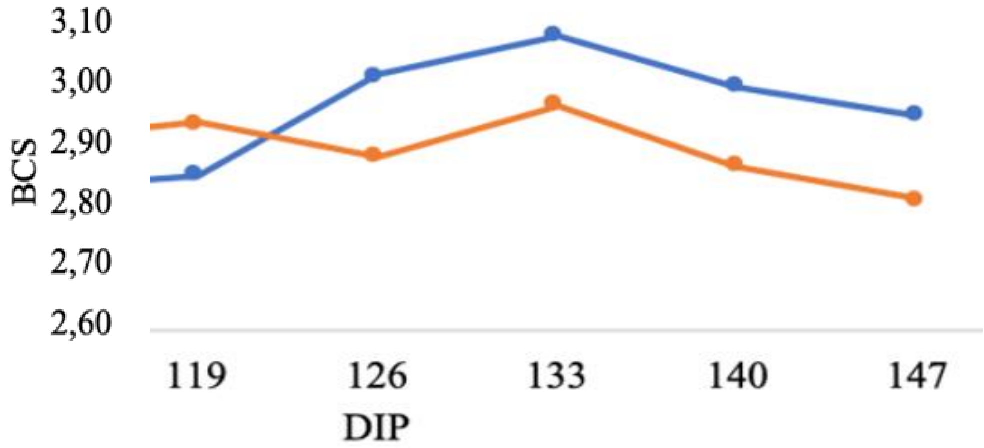



Figure 3. Dry matter (DMI) and NDF intake (NDFI) of Sarda dairy ewes when fed chopped dehydrated oat hay (OH) and dehydrated alfalfa hay (AAH) during the last month of pregnancy (DIP = days in pregnancy)

## Energy balance (EB)




## BCS



# Energy and NDF during pregnancy

- In late pregnancy diet **NDF concentration ≤ 40-45% is suggested**
  - **Higher values for high quality NDF**
  - **Lower values for prolific ewes**
- Energy and NDF concentration similar to that of lactation
- Strong association between negative energy balance, increased ketone bodies and increased infectious diseases in the mother and lamb mortality
- some animals or breeds are more susceptible to the effects negative energy balance, not clear why
- Proper nutrition during pregnancy necessary for optimal milk production and health during the lactation

# Effect of increasing PROTEIN concentrations in pregnancy (last 60 d) on subsequent lactation

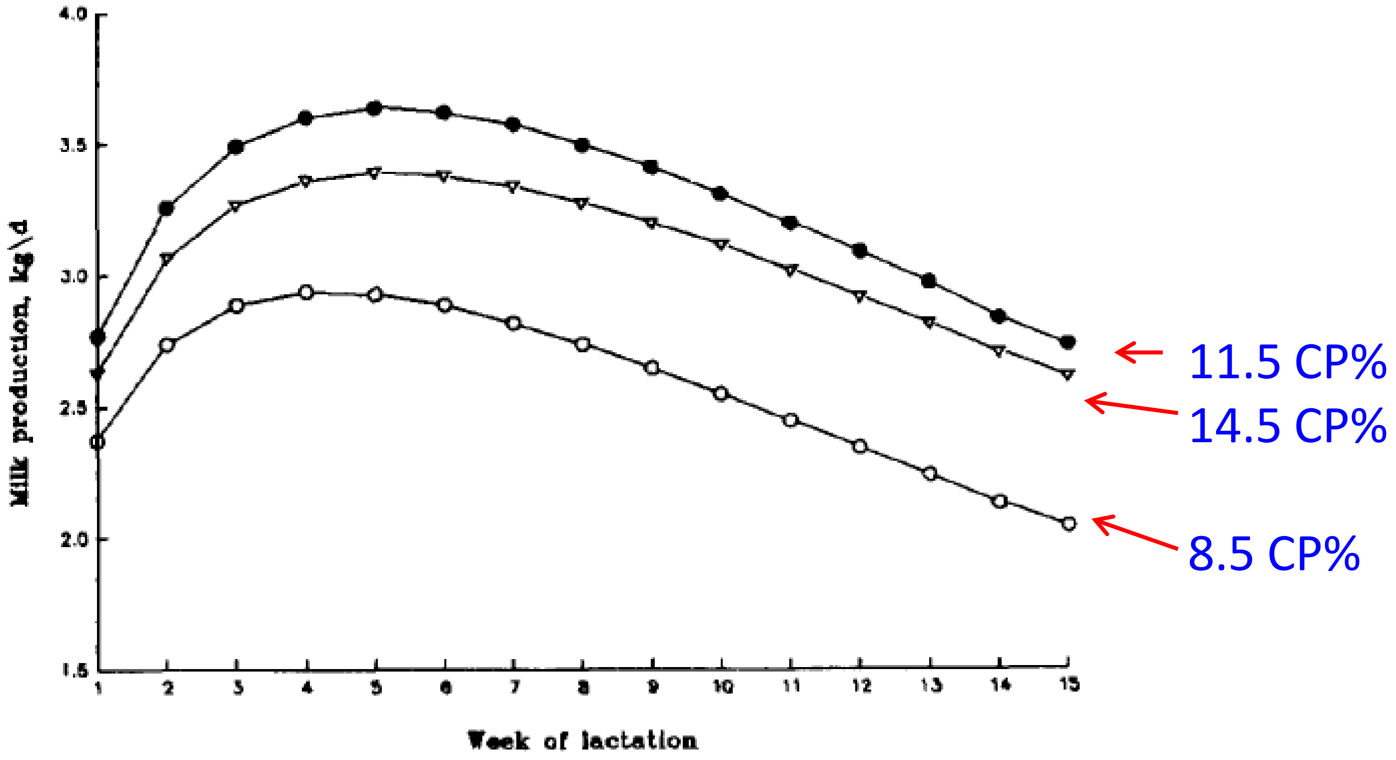



Figure 2. The effect of dietary protein intake [8.5 (○), 11.5 (●), and 14.5 (△) % CP] on milk production. The $r^2$ = .890, .912, and .903, respectively, for the diets containing 8.5, 11.5, and 14.5% CP.

Sahlu et al., 1995

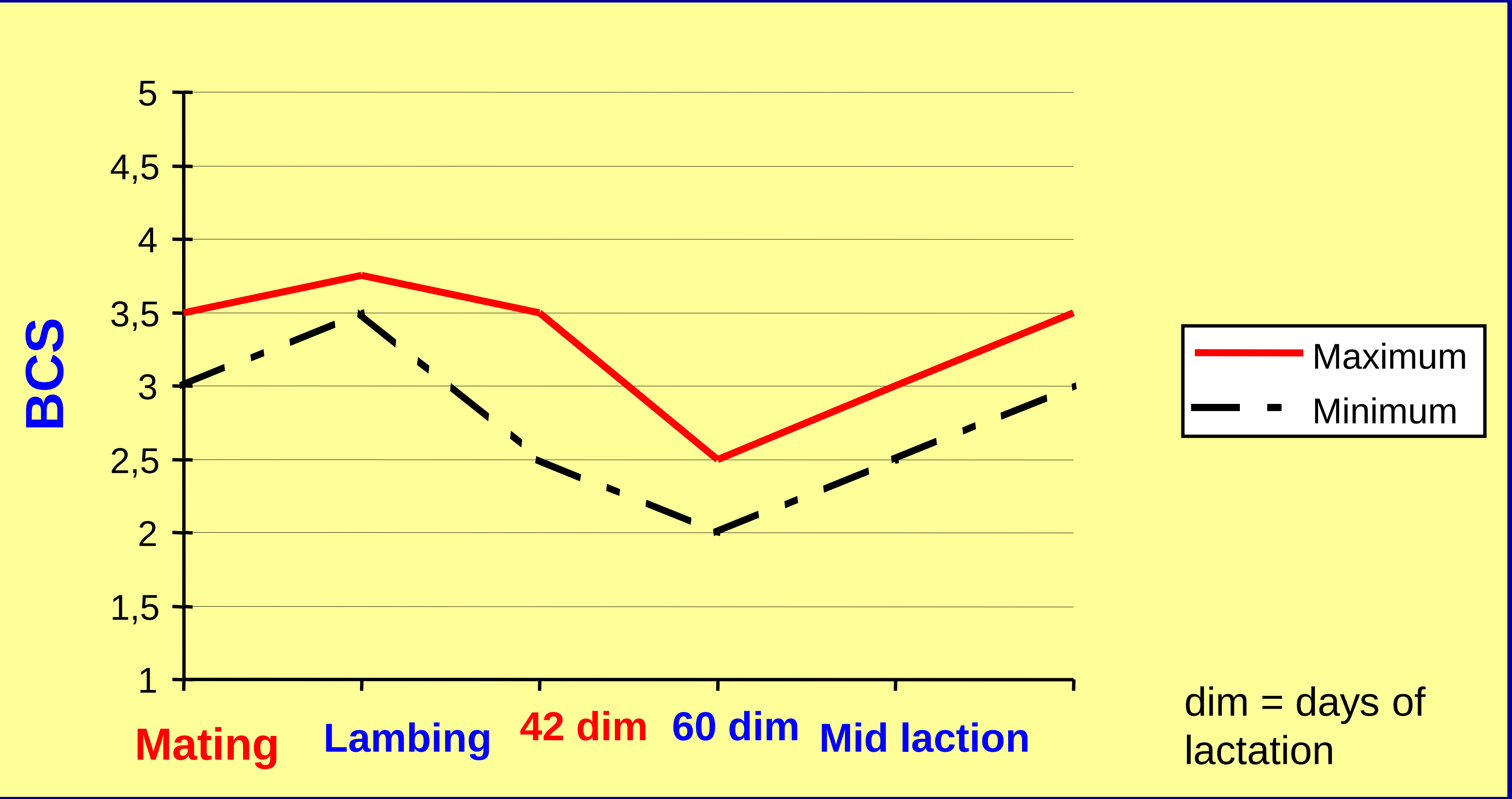
# Feeding during pregnancy

**Nutritional management for optimal production and health**

**Proper nutrition:**

- high quality-low NDF forages
- chopping forages helps: not much rumen space available, chopping reduces the filling of the rumen
- Increased supply of concentrates (steaming up) as parturition is approached
- appropriate CP supply, mineral balance, Ca:P must be in 2.0-2.25:1 ratio; also vit. A, E, selenium, Cu, Zn
- **Grouping** based on BCS, twinning rate, stage of pregnancy
- Fundamental to monitor body reserve evolution: if BCS is too high → low intake at start of lactation and low milk yield

# Optimal BCS in sheep (based on INRA)



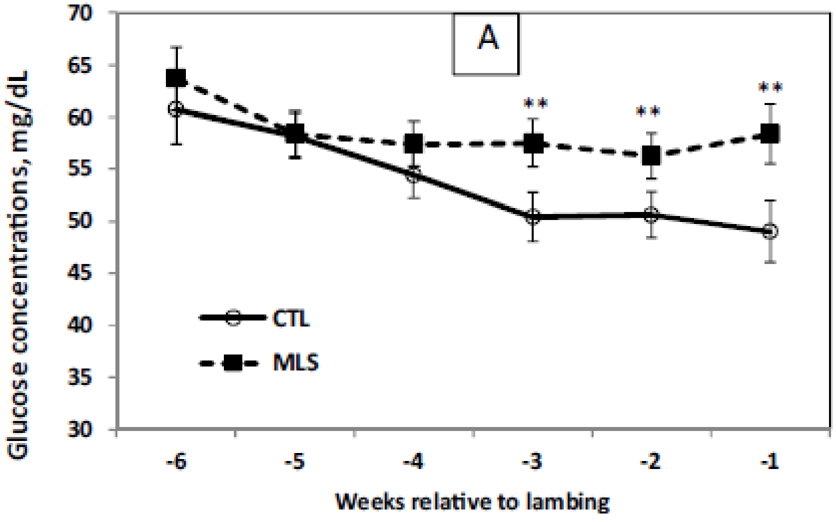

If 33% of the ewes have BCS 2, 33% have BCS 3, 33% have BCS 4, the mean **BCS = 3.00** **Perfect mean, but 2/3 of the ewes have the wrong BCS!**

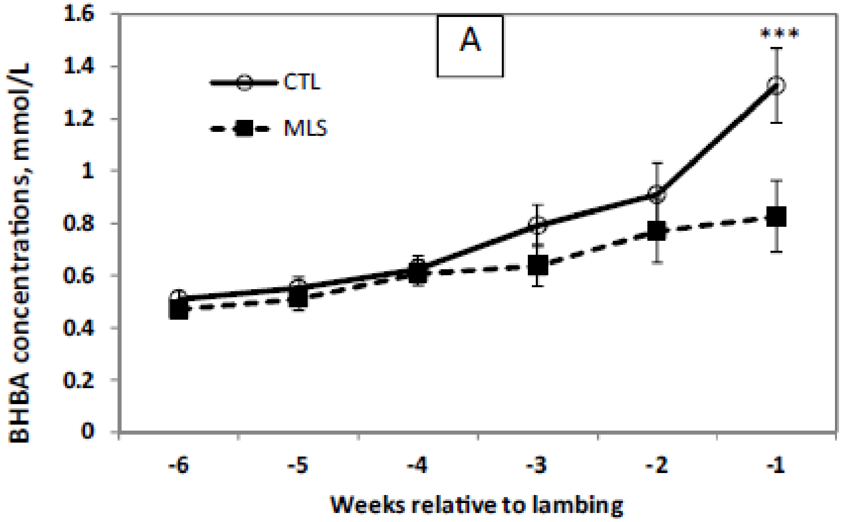
# Supplements to assist sheep and goats during the transition stage

| **Energetic compounds**<br>**↑ glucose ↓ NEFA** | **Lipotropic compounds**<br>**↑ removal and ↓ deposition of fat in the liver** |
|---|---|
| **Molasses or highly degradable CHO** | **Choline** |
| **Propylene glycol** | Betaine |
| **Glycerol** | **Methionine** |
| Propionate | Lysine |
| Monensin | Specific fatty acids |
| Niacin (vit. PP o B3) | |
| Biotin (vit. H o B7) | |
| Chromium | |

# Molasses in pregnant sheep (Moallem et al., 2016)

- **Supplementation of molasses-based supplements (100 g/d) during the last 60 d of pregnancy of prolific ewes**

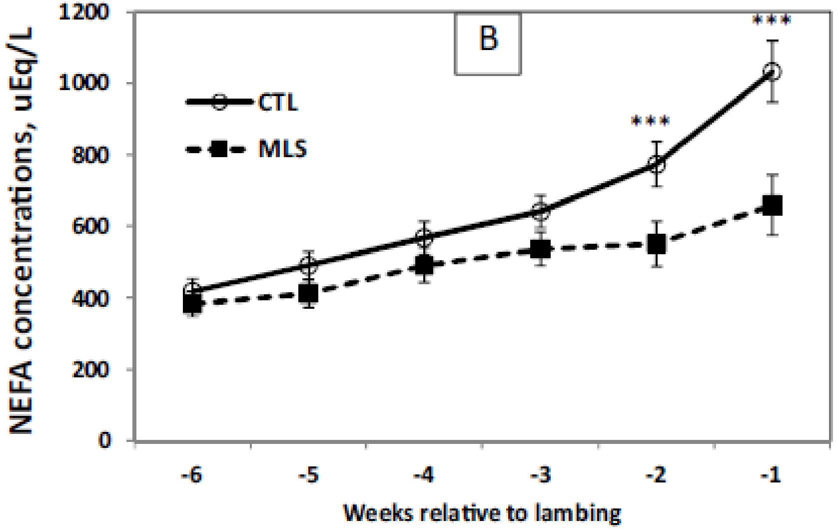



**BCS change:**

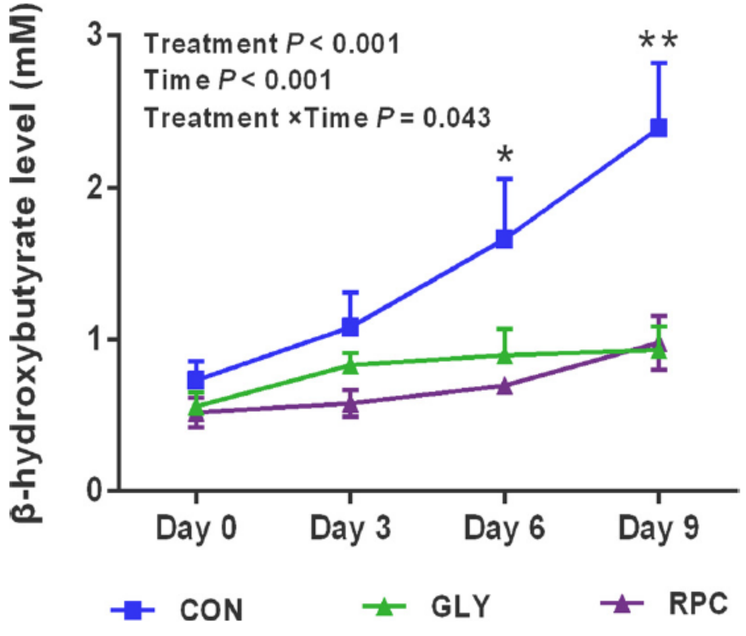
**-0.4 CTL**

**-0.15 molasses**



# Glycerol (40 mL/d) vs. RP choline chloride (10 g/d) in ewes during pregnancy (Guo et al., 2020 AFST)

- 78 kg ewes with 2-3 fetuses
- **30% feed restriction from DIP 100 to 109**




| Item | Control | Glycerol | RP Choline | *P* |
|---|---|---|---|---|
| **Blood** | | | | |
| **NEFA** (mmol/l) | 0.54 [b] | 0.56 [b] | 0.86 [a] | 0.02 |
| **Glucose** (mmol/l) | 2.51 [b] | 3.30 [a] | 3.34 [a] | 0.01 |
| **VLDL** (mmol/l) | 0.85 [b] | 0.86 [b] | 1.08 [a] | 0.04 |
| | | | | |
| **Rumen VFA, mM** | 54.6 | 58.9 | 63.4 | NS |
| **Acetate** (% of VFA) | 66.3 [a] | 48.4 [b] | 70.7 [a] | <0.001 |
| **Propionate** (% of VFA | 20.3 [b] | 32.7 [a] | 18.7 [b] | <0.001 |
| **Butyrate** (% of VFA) | 9.7 [ab] | 15.9 [a] | 7.3 [b] | 0.04 |

# **Glycerol** (40 mL/d) vs. **RP choline chloride** (10 g/d) in ewes during pregnancy (Guo et al., 2020 AFST)

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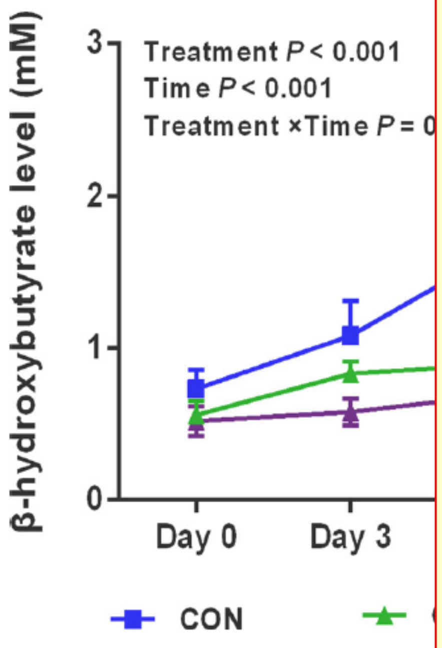


**Glycerol** mainly provided energy by participating in the gluconeogenesis process, directly (rumen absorption) and indirectly (propionate)

**Rumen-protected choline chloride** protected liver function (including fatty acid oxidation and gluconeogenesis) by transporting NEFA out of the liver, so the NEFA could then be utilized by other tissues

**Both alleviated negative NEB**

| | | | P Choline | *P* |
|---|---|---|---|---|
| | | | | |
| | | | 0.86 [a] | 0.02 |
| | | | 3.34 [a] | 0.01 |
| | | | 1.08 [a] | 0.04 |
| | | | | |
| | | | 63.4 | NS |
| | | | 70.7 [a] | <0.001 |
| | | | 18.7 [b] | <0.001 |
| **Butyrate** (% of VFA) | 9.7 [ab] | 15.9 [a] | 7.3 [b] | 0.04 |

# Rumen protected choline in goats (Pinotti et al., 2008)

- Saanen goat fed (-30 DIP to +35 DIM) CTR: control no choline or vitamin E supplementation; RPC: 4 g/d RP choline chloride; **VITE**: 200 IU/d of RP vitamin E; RPCE: choline and vitamin E
- No effects of VIT E
- Higher milk yield and milk fat concentration with RPC, no effects on BW

**Table 3** *Milk yield and composition according to treatment group from week 1 to weeks 6 of lactation*

| | Treatments | | | | | Main effects (*P* values) | | |
|---|---|---|---|---|---|---|---|---|
| | RPC | No RPC | VITE | No VITE | SEM | RPC | VITE | RPC × VITE |
| Milk (g/day) | 3159 | 2949 | 3085 | 3019 | 61.5 | 0.03 | 0.38 | 0.23 |
| 4% FCM (g/day)[1] | 3095 | 2743 | 2991 | 2910 | 93.0 | 0.02 | 0.54 | 0.18 |
| Fat (%) | 3.98 | 3.68 | 3.95 | 3.73 | 0.09 | 0.03 | 0.18 | 0.09 |
| Protein (%) | 3.69 | 3.65 | 3.68 | 3.66 | 0.15 | 0.42 | 0.63 | 0.58 |
| SCC (×1000) | 448 | 465 | 454 | 459 | 120 | 0.89 | 0.78 | 0.83 |
| Fat yield (g/day) | 125 | 104 | 119 | 108 | 6.30 | 0.02 | 0.22 | 0.10 |
| Protein yield (g/day) | 116 | 103 | 113 | 109 | 3.30 | 0.20 | 0.41 | 0.44 |

[1]4% FCM = 0.4 (g of milk) + 15 (g of fat).

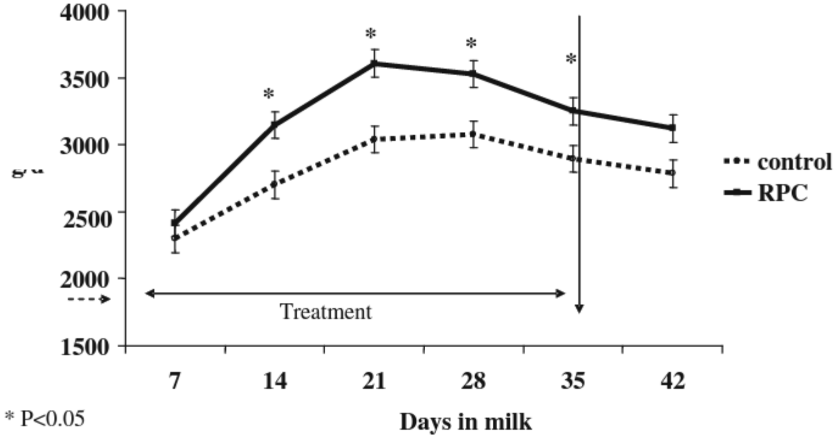


Figure 1. Milk yield through the experiment in control and RPC group

# Feeding during lactation

UNIVERSITÀ DEGLI STUDI DI SASSARI

# Energy output of sheep and goats during lactation

**Dairy goat of 65 kg BW producing 5 kg/d of milk with 3.5% fat**
**Sheep of 65 kg BW producing 3.7 kg/d of milk with 6.5% fat**

- **Same energy requirements for milk production per kg of BW of a 650 kg dairy cow that produces 50 kg/d of mil**k with 3.5% fat, but also has a 78% higher maintenance requirement per kg of PV than the cow

- The total energy requirement per kg of BW of a goat producing 5 kg/d of milk (or sheep producing 3.7 k/d of milk) is **equivalent to that of a cow producing 61 kg/d of milk**

# Sheep DM intake in the transition phase (Gallo and Tedeschi, 2021)

| Days in milk | DM intake (% of maximum lactation intake) |
|---|---|
| 0 | 55% |
| 10 | 80% |
| 20 | 95% |
| 30 | 100% |

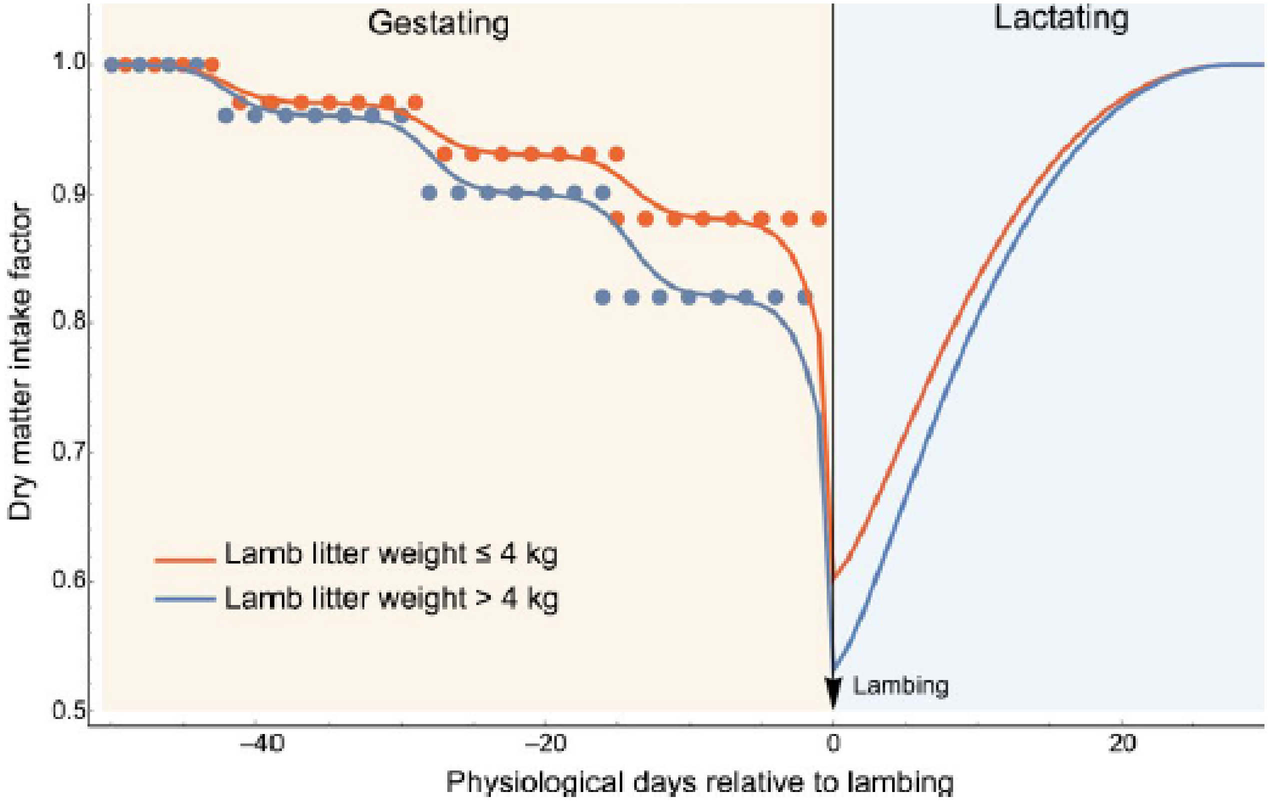


**Figure 1** – Continuous adjustment of dry matter intake for gestating (negative days) and lactating (positive days) ewes with lamb litter with weight less than 4 kg (orange line and circles) or more than 4 kg (blue line and circles) for (A) Merino- and (B) Meat-type breeds. The circles indicate the discrete weekly adjustments for gestating ewes proposed by Pulina et al. (1996) and Pulina et al. (2013). The continuous adjustment for lactating ewes is based on the Commonwealth Scientific and Industrial Research Organization (2007).

# Sheep & Goats vs. Cattle

**Compared to cows, sheep and goats:**

- **have to eat more to satisfy their maintenance requirements. This results in higher passage rate of feeds and lower fiber (forage) digestibility**

- **are more affected in their intake by particle size and fiber content of the forages**

- **have more selective feeding behavior**

# DM intake

## Level of intake, % of BW

**Lactating COWS (NRC, 1988)**

| 4.0% fat corrected milk yield, kg | BW (kg) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 500 | 550 | 600 | 650 | 700 | 750 | 800 |
| 10 | 2.40 | 2.30 | 2.20 | 2.10 | 2.00 | 1.95 | 1.90 |
| 20 | 3.20 | 3.05 | 2.90 | 2.75 | 2.60 | 2.50 | 2.40 |
| 30 | 3.90 | 3.70 | 3.50 | 3.35 | 3.20 | 3.05 | 2.90 |
| 40 | 4.60 | 4.30 | 4.00 | 3.80 | 3.60 | 3.45 | 3.30 |
| 50 | 5.40 | 5.05 | 4.70 | 4.40 | 4.10 | 3.90 | 3.70 |

**Lactating EWES (Pulina et al., 1996)**

| 6.5% fat corr. milk yield, kg | BW(kg) | | | | | |
|---|---|---|---|---|---|---|
| | 35 | 40 | 45 | 50 | 55 | 60 |
| 0 | 3.08 | 2.98 | 2.90 | 2.82 | 2.75 | 2.69 |
| 1 | 4.80 | 4.48 | 4.23 | 4.02 | 3.84 | 3.69 |
| 2 | 6.51 | 5.98 | 5.56 | 5.22 | 4.94 | 4.69 |
| 3 | | 7.48 | 6.90 | 6.42 | 6.03 | 5.69 |
| 4 | | | | 7.62 | 7.12 | 6.69 |

# Nutrition during the first part of lactation

- Milk yield and requirements grow fast
- Feed intake grows more slowly

Effects:

- the ewes eat less energy than they put in the milk
- negative energy balance
- part of the milk (up to 50%) is produced using body reserves ⇒ body weight loss

# Nutrition during the first part of lactation

Since ewes are in negative energy balance:

- dietary non-fiber carbohydrates (NFC. i.e. sugars + starch + pectins) provide readily fermentable energy

- diets rich in NFC and low in NDF ⇑ milk yield compared to diets lower in NFC

  (Susin et al.. 1995; Abdel-Rahman and Mehaia. 1996; Al Jassim et al.. 1999; Caja and Bocquier. 2000; Alexandre et al.. 2001)

# STARCH during early lactation

- In **early lactation** the diet should be rich of starch, both in ewes and goats: **20-30% of DM**
- The actual concentration depends on various factors
  - Feeding systems (TMR vs. separate supply of forages and concentrates vs. pasture+concentrate)
  - Type of starch (degradation rate varies a lot)
  - Fiber sources
  - Production level
  - Usage of buffers and yeast

# NDF intake during Lactation

# Feeding during lactation: NDF

- Diets usually balanced for energy, protein, minerals
- **What about the fiber (NDF) content of the diet??**
  - **fiber** (NDF) has **high rumen filling** effect and thus can limit intake, particularly important during lactation
    - If **too high**, intake and performances negatively affected
    - If **too low**, low rumen pH, sub or acute acidosis, milk fat depression, fattening
  - on pasture, need to maximize herbage intake, i.e. fiber intake

## Maximum dietary NDF (% of DM) and corresponding DMI (% BW) on lactating ewes fed forages and concentrates (Cannas et al., 2016)

Grass-Legume forage: 58% NDF, 1.20 NEL $kg^{-1}$ Concentrate: 12% NDF, 1.90 NEL $kg^{-1}$

| Milk, kg/d 6.5% fat, 5.8% P | 45 kg BW (2.10 NDFI%bw ) | | | | 60 kg BW (1.96 NDFI%bw ) | | | |
|---|---|---|---|---|---|---|---|---|
| | NDF % | DMI % BW | Forage % | DMI kg/d | NDF % | DMI % BW | Forage % | DMI kg/d |
| **1.0** | 54.7 | 3.8 | 93 | 1.7 | 58.0 | 3.4 | 100 | 2.0 |
| **2.0** | 41.7 | 5.0 | 65 | 2.3 | 45.9 | 4.3 | 74 | 2.6 |
| **3.0** | 33.7 | 6.2 | 47 | 2.8 | 37.9 | 5.2 | 56 | 3.1 |
| **4.0** | 28.3 | 7.4 | 35 | 3.3 | 32.3 | 6.1 | 44 | 3.7 |

| Milk, kg/d 6.5% fat, 5.8% P | 75 kg BW (1.85% NDFI%bw) | | | | 90 kg BW (1.77% NDFI%bw) | | | |
|---|---|---|---|---|---|---|---|---|
| | NDF % | DMI % BW | Forage % | DMI kg/d | NDF % | DMI % BW | Forage % | DMI kg/d |
| **1.0** | *58.0* | *3.2* | *100* | *2.4* | *58.0* | *3.0* | *100* | *2.7* |
| **2.0** | 49.1 | 3.8 | 81 | 2.9 | 51.6 | 3.4 | 86 | 3.1 |
| **3.0** | 41.2 | 4.5 | 64 | 3.4 | 43.9 | 4.0 | 69 | 3.6 |
| **4.0** | 35.5 | 5.2 | 51 | 3.9 | 38.2 | 4.6 | 57 | 4.1 |

*Italics = it would cause weight gain.*

# Optimal NDF, CP and NFC (Cannas, 2017)

**BW = 45 kg**

| | Milk yield at 6.5% fat | | | | |
|---|---|---|---|---|---|
| | **1.0** | **1.5** | **2.0** | **2.5** | **3.0** |
| **DM total** | 100 | 100 | 100 | 100 | 100 |
| **NDF** (% DM) | 55.8 | 46.1 | 41.7 | 36.3 | 33.3 |
| **CP** (%DM) | 15.9 | 16.7 | 17.7 | 18.3 | 18.6 |
| **Ash+fat** | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 |
| **NFC (%DM)** | 16.3 | 25.2 | 28.6 | 33.4 | 36.1 |

**NFC= starch, sugars and pectins = 100-NDF-CP-EE-ash**

# Feeding in single group and energy balance

**High genetic and phenotypic variability within flock:**

- High variability of production
- Only one ration is used
- It is impossible to feed all the sheep correctly

- **The most productive sheep are underfed**
    - body reserves decrease
    - milk production drops

- **Less productive sheep are overfed**
    - too fat
    - GH decreases, milk production drops
    - Risks of acidosis

# Energy balance (BE) and weight losses

Dairy ewes in strongly negative BE tend to reduce milk production faster than dairy cows

- sheep were less selected for milk production than dairy cows or goats
- Ancestral characteristics aimed at protecting life are most evident
- this is also evident in cattle in breeds not selected for milk production

- Low fertility in too fat or too thin ewes

# Group feeding and energy balance

Single group feeding of sheep is a major cause of low lactation persistency and nutritional disorders

**Solutions:**

- the flock should be divided into groups of sheep with similar production or BCS
- each group should have a different ration
- monitoring of BCS and milk fat to protein ratio during the lactation

**Options for differentiated rations:**

- keep separate groups in the farm
- Keep animals together and separate them (manually or mechanically) before milking
- Use milking equipment with individual feeders

**Total mixed rations vs. pasture + supplement feedings**

**What type of CHO after the peak of lactation?**

**Starch vs. digestible fiber**

# Do sheep and goats differ in the use of starch during lactation?

In **ewes**:

- **Positive** effect of **starch in early lactation** (20-30% of DM) (Susin et al., 1995; Al Jassim et al.. 1999; Caja and Bocquier. 2000; Alexandre et al., 2001, Cannas et al., 2002; Bovera et al., 2004)
- **Negative effect** (fattening, decreased milk production) of starch **in mid-late lactation** (max **10-15% of DM**)
- **Positive** effects of feeds rich in **highly digestible fiber** (e.g. beet pulps, soybean hulls and high quality forages) (Cavani et al., 1990; Cannas et al., 1998 and 2013; Bovera et al., 2004, Zenou and Miron, 2005; Sini et al., 2023)

In **goats**:

- **Positive effect of starch** (20-35% of DM) **both in early and mid-late lactation** (Fedele et al., 2002; Cannas et al., 2007; Serment et al., 2011; Ibáñez et al., 2015)

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# Metabolic and hormonal control of energy utilization and partitioning from early to mid lactation in Sarda ewes and Saanen goats

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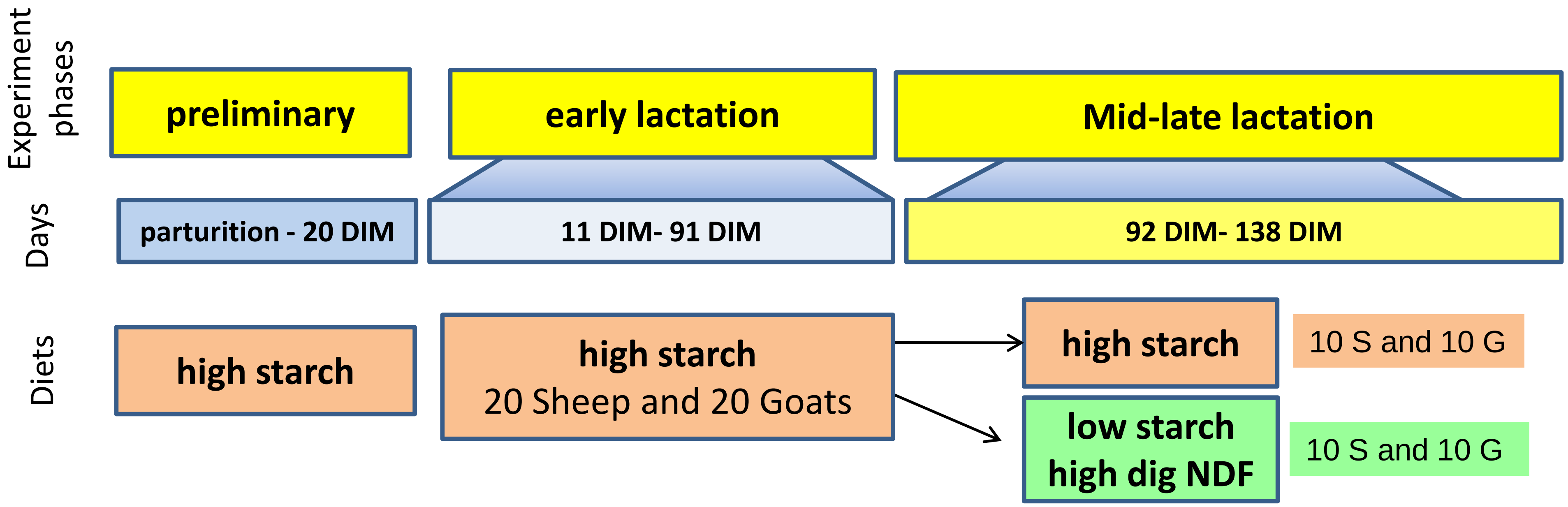

# High starch diet in comparison to Low starch diet in mid lactation

In **goats**

↑ milk production, ↓ milk fat concentration

In **sheep**

↓ Fat corrected milk yield, milk fat and protein concentration, milk fat and protein yield, ↑ BCS

- **Energy partitioning** during mid lactation differed between dairy goats and dairy ewes: **starch rich diets favored milk production in goats, accumulation of body reserves in ewes**
- **In goats vs. sheep**: higher **GH** and lower **glucose** and **insulin**
- **no effects of starch level on hormonal and metabolic status**

**Goats seem to be GLUCOSE dependent, sheep ACETATE dependent**

# Selection, particle size and S&G feeding with TMR

# Sheep and goats vs. cattle

Sheep ruminate more finely the diet compared to to cattle:

- particle size in the feces is smaller
- grains are finely ground during rumination
  - their rumen digestibility is higher than in cows
- rich diets (high in concentrates) tend to be digested better by  sheep than by cattle

Sheep are much more selective than cattle

# Use of diets with small particle size in sheep

- **Pelleted TMR for dairy ewes (developed by Rossi e al., 1991)** are currently produced by several companies
  - high intake and milk yield without nutritional disorders
  - Easy to supply

- **Replacement of 67% of hay NDF by soybean hulls increased DMI by 43% and milk yield by 46% (Araujo et al., 2008)**

# TMR particle size guidelines for sheep

1) **In cattle TMRs, too small particle size of forages → acidosis, milk fat depression**

2) **In sheep TMRs, too large particle size of forages → acidosis, milk fat depression**

- **if forages are coarsely chopped in the TMR:**
  - Sheep are very selective and can eat all concentrates first →acidosis, MFD
  - Low intake of the forages of the TMR ⇓ milk yield
  - chopping of forages ⇑ intake and milk yield
  - with TMR wagons it is practically impossible to make TMR with too small particle size for sheep

# What will they eat first ??

# TMR with fairly small paricle size

# Commercial dry total mixed rations for sheep

From a UK veterinarian: - this is a meat flock of 1200 ewes in the last 5 weeks before lambing - they were being fed too much long forage and were really selecting out the grains and soya. I reduced the ratio of forage and advised they chopped the ration more.

# 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

## Indicative CP concentrations for ewes during lactation (% of DM) (Serra et al., 1998)

| Milk with 5% protein vera (kg/d) | BW (kg) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
| 0,5 | 16,6 | 15,8 | 15,1 | 14,8 | 14,5 | 14,0 | 13,7 | 13,3 | 12,9 |
| 1,0 | 17,7 | 16,9 | 16,5 | 15,9 | 15,6 | 15,0 | 14,5 | 14,3 | 13,9 |
| 1,5 | 18,5 | 17,7 | 17,4 | 16,7 | 16,4 | 15,9 | 15,7 | 15,2 | 14,8 |
| 2,0 | 19,1 | 18,7 | 18,1 | 17,7 | 17,2 | 16,6 | 16,4 | 15,9 | 15,7 |
| 2,5 | | | 18,9 | 18,3 | 17,8 | 17,5 | 17,0 | 16,6 | 16,4 |
| 3,0 | | | | | 18,6 | 18,0 | 17,6 | 17,3 | 16,9 |
| 3,5 | | | | | | | 18,3 | 17,8 | 17,6 |

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

| IN THE 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 Nitrogen (MUN) = milk urea x 0.4667

# Thank you for the attention