REVIEW ARTICLE

Prediction of feed intake in the Italian dairy sheep

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ABSTRACT

Recommendations on feed intake for sheep are based on assessments of genetic types, feeding systems and environmental conditions that are very different from Italian ones. These considerations underline the need for intake data or models that derive from local trials. For this reason intake data of lactating and dry ewes, pregnant ewes, rams and growing lambs have been collected from selected literature based on sheep feeding trials mainly conducted on dairy breeds in Italy or in other Mediterranean countries. Equations and intake tables differentiated according to the physiological and productive categories, as well as feeding typology are reported. Particular consideration is given to pasture intake with supplementation, reporting three equations developed for three qualitative levels of the pasture, recognizable from the CP content of herbage: < 10% DM; ≥ 10% and ≤ 16% DM; >16% DM. The equations include animal and pasture variables and supplementation, expressed as grams of CP given with feeds other than pasture. Only when pasture CP content is lower than 10% DM, supplement is not included in the equation, as no or negative substitution effect is expected.

Key words: Feed intake, Dairy sheep, Mediterranean environment.

RIASSUNTO

STIMA DELL’INGESTIONE ALIMENTARE DI OVINI DA LATTE ITALIANI

I sistemi di stima dell’ingestione volontaria degli ovini attualmente adottati derivano da studi effettuati su tipi genetici, condizioni alimentari e sistemi di allevamento molto diversi rispetto a quelli italiani. Da tali considerazioni si evidenzia la necessità di disporre di dati o di modelli di ingestione che derivano da sperimentazioni locali. A tale scopo sono stati raccolti dati bibliografici relativi all’ingestione di pecore in lattazione e in asciutta, di pecore in gravidanza, di arieti e di agnelliti in accrescimento, riferibili a tipi genetici da latte allevati in Italia o in paesi dell’area mediterranea. Vengono proposte equazioni e tabelle di riferimento, per stadio fisiologico e per tipologia alimentare. Ampio spazio viene riservato all’ingestione al pascolo in presenza di integrazione alimentare, proponendo tre equazioni di stima per tre livelli qualitativi del pascolo, definiti dal contenuto in proteina grezza dell’erba (< 10% SS; ≥ 10% e ≤ 16% SS; >16% SS). Le equazioni includono variabili relative agli animali, al pascolo e al supplemento (espresso in grammi di PG fornita in stalla). L’equazione da adottare quando il pascolo presenta un contenuto di PG<10% SS non include il supplemento in quanto in tali condizioni l’effetto di sostituzione atteso è pari e, in alcuni casi, anche inferiore a 0.

Parole chiave: Ingestione alimentare, Ovini da latte, Ambiente mediterraneo
Introduction

After estimating the nutritive requirements and before determining the ration, the feed intake capacity must be estimated. This factor sets fundamental limits on the subsequent stages of establishing a ration: quantity of energy, protein, mineral, etc. should be administered within the limits of dry matter that the animal is capable of consuming. Obviously the greater the intake capacity, the more nutrients can be “diluted”, which means more roughages can be used with a probable reduction in the cost of the ration.

In sheep feeding the intake factor has been discussed in detail in literature worldwide. Highly authoritative international scientific bodies (NRC, 1985; INRA, 1988; CSIRO, 1990), that can be referred to for a detailed analysis, report intake tables, estimation equations or particular intake units of measure (UEM), that refer to standard animals, fed with standard feeds.

Recommendations from the above-mentioned systems, however, are based on assessments of genetic types, environmental conditions and, last but not least, grazing systems at times very different from Italian ones. The last factor above plays a fundamental role in determining intake: part of Italian dairy sheep farms practice short grazing which lasts about 5-8 hours a day and consists in letting the sheep graze after morning milking and then returning the sheep to the pens before afternoon milking.

These considerations underline the need for intake data or estimation systems that derive from local trials, as highlighted by Elsen et al. (1988) in a wide literature review on intake models at pasture for sheep of various genetic types and in diverse geo-climatic conditions. Therefore, the following paragraphs refer to assessments, equations and intake tables differentiated according to the physiological and/or productive categories, with the aim to develop intake guidelines specifically regarding dairy sheep farmed in Italy, or in the Mediterranean area.

Lactating ewes

Most equations defined for calculating intake, in varying environmental conditions, include body weight and milk production among the variables. In fact, intake should be closely linked to the sheep nutrient requirements. However, variations in production levels resulting from the physiological trend of the lactation curve are not always associated to corresponding intake changes. Table 1 demonstrates how dry matter intake remains high even when milk production diminishes as a consequence of lactation that progresses. This is probably linked to the physiological tendency of sheep, in the intermediate and final stages of lactation, to regain body reserves that were used in the first weeks after partum.

In this regard, Pulina et al. (1996) defined an equation for estimating intake indoors for Italian milk sheep breeds, that not only considers animal weight and milk production, but also daily weight changes that, in adult animals, can only be a consequence of deposit or mobilization of body reserves.

Table 1. Dry matter intake and milk production

| Week of lactation | Breed | Intake g DM/d | Milk production g/d |
|-------------------|-------|--------------|---------------------|
| 3                 | Comisana ¹ | 2670         | 2026                |
| 8                 | Comisana ³ | 2634         | 1025                |
| 14                | Comisana ³ | 2149         | 693                 |
| 7-9               | Massese ² | 2200         | 1068                |
| 12-14             | Massese ² | 2200         | 588                 |
| 16-18             | Massese ² | 2050         | 346                 |
| 6                 | Comisana ³ | 1323         | 1077                |
| 10                | Comisana ³ | 1373         | 783                 |
| 14                | Comisana ³ | 1820         | 488                 |
| 18                | Comisana ³ | 1428         | 424                 |
| 5 to dry off      | Sarda ⁴  | 2539         | 1095                |
| 4 to dry off      | Sarda ⁴  | 2079         | 1005                |
| 3 to dry off      | Sarda ⁴  | 2521         | 976                 |
| 2 to dry off      | Sarda ⁴  | 2042         | 856                 |
| 1 to dry off      | Sarda ⁴  | 2153         | 721                 |

¹Pauselli et al., 1993; ²Trimarchi et al., 1981; ³D’Urso et al., 1993; ⁴Pulina et al., 1993.
DMI = -0.545 + 0.095 MW + 0.65 NM + 0.0025 BWC \hspace{1em} (1)

where:

- DMI = intake of DM in kg/head/d;
- MW = metabolic weight in kg;
- NM = normalized daily milk production (6.5% fat and 5.8% protein) in kg (Pulina et al., 1989);
- BWC = body weight changes in g/d.

The equation allows dry matter intake estimation without, however, taking into consideration the qualitative characteristics of the diet. In milk sheep with a diet consisting mainly of forage, fill effect is one of the main causes of intake changes. Most attempts at estimating forage intake by sheep, based on their chemical-nutritive composition, have highlighted the important role of content in cell walls, well represented in NDF percentage (Van Soest, 1994), in that it affects the ruminal retention time of the diet. Table 2 reports some intake estimation equations in relation to the NDF, developed by various authors. For each equation a simulation has been made, including NDF values from 37 to 60% of the diet. According to these simulations, for each percentage increase in NDF, the reduction of intake (in %) has been calculated. A mean value of the four estimated intake reductions was then calculated for each NDF level of the diet. The following equation was derived from the linear regression analysis between mean reduction of intake (%) and diet NDF percentage (n = 25; r^2 = 0.98): intake reduction (%) = 0.3102 + (0.0148*NDF diet).

In previous research carried out on lactating Comisana and Pinzirita ewes (Avondo and Cannas, 2001), we observed that dry matter intake, for medium-high production levels, is greatest when the diet NDF level is equal to 37% of dry matter. On the basis of these results, a coefficient (k) was calculated, that would be multiplied by the intake value obtained with the equation (1), when the NDF value of the diet is greater than 37% of dry matter: k = 1 - [(0.003102+0.000148*NDF diet)/(% NDF diet– 37)].

Rams

Intake data availability from Italian research on rams, both in reproduction and maintenance, is quite modest. However, to prepare feeding guidelines specifically for Mediterranean dairy sheep, intake data for the above-mentioned category should be based on these few data, rather than referring to Northern European literature. Rassu et al. (2001) observed that ram intake estimated by INRA, the most widely adopted feeding requirement system in Italy, are notably lower than their observations in Sarda rams.

Table 3 reports intake data from Italian trials on Comisana and Sarda rams in various feeding conditions. It is possible to note a weak but significant (P<0.05) positive correlation between DM intake and body weight (r^2 = 0.34). The inclusion of the independent variable “percentage of forage in the diet” in a multiple regression analysis provided a significant positive correlation with an increase of the r^2 value from 0.34 to 0.77. This result seems to support the negative influence of concentrate in the diet on total intake. An experiment carried out to study the effect of crude protein level of concentrate on the feeding behaviour of Comisana rams (Avondo and Lutri, 2004) has found that animals tend to reduce intake to avoid excess protein. Similar self-regulating behavioural mechanisms for nutrient intake have often been observed in animals farmed both indoors and at pasture (Kyriazakis and Oldham, 1993; Forbes, 1995; Forbes and Mayes, 2002).

### Table 2.

Equations for intake estimation (g/kg MW) in relation to diet NDF content

| Forage category | Regression equations |
|-----------------|----------------------|
| All forage \(^1\) | I = 107.4 - 0.644 NDF (%) |
| Various hays \(^1\) | I = 117.4 - 0.760 NDF (%) |
| Various hays \(^2\) | I = 96.5 - 0.38 NDF (%) - 0.0000004 NDF* (%) |
| Mixed hays \(^2\) | I = 136.5 - 0.12 NDF (g/kg DM) |

\(^1\) Macchioni et al., 1990; \(^2\) Lanari et al., 1993; \(^3\) Dulphy et al., 1990
Growing animals

Analysing intake data from Italian breed lambs (male and female) and comparing them to the intake of wool and meat breed lambs, it can be observed that, for equal body weights, intake is rather similar. With the aim to develop an intake model for growing sheep, 142 mean intake values from Italian literature (Lanza et al., 1988a, 1988b, 1991, 2003; Pennisi et al., 1988; Casamassima et al., 1993; Frisenna et al., 1995; Biondi et al., 1996a, 1996b; Priolo et al., 2000; Rizzi et al., 2002) and personal data have been collected. Some differences in the intake of lambs can be observed between diets based on ground or pelleted complete diets and more traditional diets based on hays and concentrates. For this reason, the intake data have been separated into two sets, on the basis of diet typology. The regression analysis for the two data sets resulted in the following equations:

1) traditional diets based on hays and concentrates ($n = 66; r^2 = 0.77$)
   
   \[ DMI = -720.32 + 107.84 \times BW - 1.46 \times BW^2 \]

2) ground or pelleted complete diets ($n = 76; r^2 = 0.81$)
   
   \[ DMI = 357.08 + 25.95 \times BW \]

Maintenance and gestation

In the Mediterranean areas, the dry period starts in summer. During this season it is highly common practice to leave sheep to pasture on cereal stubble. Indeed, in many cases this diet represents the only resource available in this period, characterised by extremely dry weather.

| Diet                          | Breed       | BW kg | Forage in the diet % DM | Diet crude protein content % | Intake g DM/d | Bibliographic source        |
|-------------------------------|-------------|-------|--------------------------|-----------------------------|---------------|-----------------------------|
| Italian ryegrass and mixed concentrate | Sarda       | 72.4  | 53                       | 11.8                        | 1656          | Rassu et al., 2002          |
|                               |             | 78.8  | 43                       | 12.0                        | 1606          |                             |
| Italian ryegrass and lupin     | Sarda       | 67.5  | 60                       | 16.6                        | 1461          | "                           |
|                               |             | 78.5  | 56                       | 17.1                        | 1542          |                             |
| Alfalfa and mixed concentrate  | Sarda       | 65.8  | 60                       | 18.0                        | 1766          | "                           |
|                               |             | 78.5  | 56                       | 18.0                        | 1904          |                             |
| Mixed hay and mixed concentrate | Comisana   | 80.8  | 90                       | 8.6                         | 2435          | Avondo et al., 2004         |
|                               |             | 79.5  | 90                       | 8.8                         | 2505          |                             |
|                               |             | 81.8  | 90                       | 8.2                         | 2484          |                             |
| Sorghum hay and mixed concentrate | Comisana | 80.4  | 90                       | 14.3                        | 2234          | "                           |
|                               |             | 80.5  | 90                       | 15.2                        | 2094          |                             |
|                               |             | 80.9  | 90                       | 14.1                        | 2172          |                             |
| Medicago arborea               | Comisana    | 48.4  | 100                      | 21.7                        | 1874          | Bonanno et al., 1998        |
|                               |             | 67.7  | 100                      | 21.7                        | 2483          |                             |
| Atriplex halimus and straw     | Comisana    | 45.9  | 100                      | 13.6                        | 1235          | Alicata et al., 2002        |
|                               |             | 46.4  | 100                      | 13.6                        | 1439          |                             |
Nonetheless, animals are still capable of high selective activity in favour of basal leaves and, above all, grains that have fallen on the ground during harvesting (Mulholland and Coombe, 1979; Outmani et al., 1991; Caballero et al., 1992). This selective behaviour enables the sheep to feed on a diet that is more than adequate for their nutritive requirements.

Table 4 reports intake data calculated from bibliographic sources regarding dry sheep fed with various diets. Note that for each diet typology, data is very similar among animals at maintenance and during gestation, despite the source of data being varied, deriving from trials on genetically different types. Table 5 reports the tendency of gestating ewes to reduce intake in the final weeks of gestation.

This reduction is widely documented and can only partially be related to fill effect caused as the foetus grows. This is confirmed by the reduction in intake observed in animals fed with diets mainly based on concentrate. A more plausible explanation of reduced appetite would be the increased placental oestrogen secretion that occurs in the final weeks of gestation (Forbes, 1995).

Trabalza-Marinucci et al. (1992) have developed an equation, reported below, to estimate sarda sheep intake in the last month of gestation that also takes into account the substitution effect caused by the supplement:

\[
VHDMI = 513.11 + 56.78 \times MW + 110.59 \times BWG - 1.62 \times CONI
\]

where:
- \(VHDMI\) = hay intake (g DM d\(^{-1}\))
- \(MW\) = metabolic weight (kg);
- \(BWG\) = weight increase during gestation (kg);
- \(CONI\) = supplement intake (g DM d\(^{-1}\)).

On testing the above equation using data available on Comisana ewes, an overestimate of intake, on average equal to 18%, can be observed. This can almost certainly be attributed to the different diet typology and feeding system adopted (hay given indoors vs. cereal stubble given at pasture).

**Intake at pasture (short grazing and supplement)**

A model has been defined to estimate pasture intake of lactating ewes in Mediterranean semi-extensive systems (Avondo et al., 2002). The database used to process regression analysis is reported in Table 6. Data were collected during 9 experimental trials conducted over 8 years in various areas of Sicily and in different feed supplement conditions.
The two equations developed are reported below for two pasture qualitative levels defined by the crude protein content:

i) for pasture with crude protein content ≤ 16% DM (n = 357; r² = 0.45; Significance of all variables in the model: P<0.01):
Pasture DM intake (g/d) = 335.6 + 113.5 Herbage Biomass (t DM/Ha) + 0.28 Normalized milk (g/d) - 0.56 Supplement (g CP/d):

ii) for pasture with crude protein content > 16% DM (n = 313; r² = 0.54; Significance of all variables in the model, P<0.01):
Pasture DM intake (g/d) = 997.1 + 73.9 Herbage Biomass (t DM/Ha) - 27.4 Herbage Height (cm) + 20.4 Herbage DM (%) + 0.16 Normalized milk (g/d) - 1.24 Supplement (g CP/d).

A subsequent processing of the same data was performed with a further subdivision of data, taking into consideration the different role played by the supplement with pasture protein levels below 10% of DM:

iii) for pasture with crude protein content ≥ 10% and ≤ 16% DM (n = 225; r² = 0.35; Significance of all variables in the model, P<0.01):
Pasture DM intake (g/d) = 420.4 + 95.9 Herbage Biomass (t DM/Ha) + 0.33 Normalized milk (g/d) - 1.24 Supplement (g CP/d):

iv) for pasture with crude protein content < 10% DM (n = 112; r² = 0.65; Significance of all variables in the model, P<0.01):
Pasture DM intake (g/d) = 118.38 + 165.8 Herbage Biomass (t DM/Ha) + 0.253 Normalized milk (g/d).

As herbage intake is low with very poor pasture, the supplement generally exercises no substitution effect, even causing an increase in pasture intake; this parameter was therefore not included in the equation.

Should detailed information on the pasture not be available, reference can be made to the classification reported in Table 7, based on characteristics observed on visual inspection. This classification is determined on the basis of herbage intake results and dietary behaviour of lactating ewes collected in conditions that vary in height and density of herbage, biomass, biological stage, and biomass heterogeneity. All these variables together can provide highly valid information on pasture usability.

Pasture intake is the result of interaction between the animal and herbage at its disposal. The different pasture typologies reported in the

| Parameters | Value range | n. |
|------------|-------------|----|
| Body weigh | kg          | 26.8 – 77.3 | 676 |
| Normalized milk | g/d | 111 – 2100 | 676 |
| Pasture characteristics: | | |
| Biomass | t DM/Ha | 0.45 – 6.1 | 40 |
| Height | cm | 3.4 – 51.0 | 32 |
| Crude protein | % DM | 5.6 – 29.2 | 60 |
| NDF | " | 24.2 – 71.2 | 60 |
| DM | % | 11.4 – 46.4 | 60 |
| Supplement characteristics: | | |
| Supplement | g DM/d | 0 – 1055 | 20 |
| Supplement | g CP/d | 0 – 149 | 20 |
| Supplement | g NDF/d | 0 – 426 | 20 |

Avondo et al., 2002.

Table 6. Data bank used to define a model to estimate intake
FEED INTAKE IN MEDITERRANEAN DAIRY SHEEP

Table 7. Description of four pasture typologies, classified on the basis of characteristics observed on visual inspection (and relative data obtained from measurements or chemical analysis).

| Pasture type | Biomass | Density | Biological stage | Height | Herbage distribution |
|--------------|---------|---------|------------------|--------|---------------------|
| 1: excellent | High (>3.0 t DM/Ha) | High Dense and compact herbage | Tender (light green) herbage (CP>16% DM) | Low and uniform (6-10 cm) | No uncovered areas |
| 2: good | Medium (2.0-3.0 t DM/Ha) | Medium Less compact herbage | Tender (light green) herbage (CP>16% DM) | Medium-low (not over 20) | Nearly no uncovered areas |
| 3: mediocre | High (not lower than 3.5-4 t DM/Ha) | Medium-low | Less tender (dark green) herbage (CP>10 and <16% DM) | Medium-high (20-35 cm) | Uncovered areas, uneven height |
| 4: poor | Low (<2 t DM/Ha) | Low Scarce herbage | Herbage in senescence (yellow) (CP<10% DM) | High (>35 cm) or medium-high | Biomass unevenly distributed with large uncovered areas |

Table offer the animal diverse feeding possibilities. On pasture type 1 (and to a lesser extent on pasture type 2), young and compact herbage allows the sheep to take large bites that are easy to chew and desirable in taste. On pastures type 3 and 4, due to the presence of lignified herbage, the animal takes small bites after having searched out the most tender parts. The result of this selective activity is a significant improvement in the qualitative characteristics of the diet with respect to the available herbage and is associated with a notable reduction in dry matter intake with respect to the better typologies of pasture. Animal selectivity nearly always favours matter that is richer in protein. This aspect must be taken into consideration when formulating feed supplements. Indeed, in the presence of a mediocre quality pasture, a high protein supplement is often administered (supplements up to 20% CP) without considering that it is exactly in these herbage conditions that the selective activity in favour of higher protein parts of herbage is very high, allowing the sheep to intake significantly better diets, from this point of view, than would be expected.

The feed supplement provided indoors can cause a marked effect on pasture intake, giving rise to a substitution effect. The latter is determined by the relationship between pasture intake changes and the quantity of supplement administered. The substitution effect is an indicator of the utilisation efficiency of the supplement. This normally has a value between 0 and 1: it is 0 when pasture intake remains unchanged following supplement administration (in this case overall intake is at its maximum); it is equal to 1 when pasture intake falls by an equal amount as the amount administered indoors. It is evident that the greater the substitution effect, the lower the efficacy of the supplement.

Table 8 reports the mean expected intake, with different supplement levels, per kg of milk produced and indicates the percentage increases expected for protein content of the diet selected at pasture, compared to the herbage protein content. This table represents a guide when equations for pasture intake estimation are not applicable.
because no data on pasture (biomass, herbage height, crude protein level, etc.) are available. In these cases, consulting Table 7, it is possible to assign a quality score to the pasture on the basis of visual estimation. After scoring the pasture, consulting Table 8 makes it possible to get indications of the expected herbage intake.

Conclusions

Intake guidelines are provided for dairy sheep in different physiological stages and feeding systems. An empirical model, based on visual estimation of the pasture, is also proposed to estimate pasture intake and crude protein level of the selected diet when a supplement is given to lactating ewes. The reliability of the models and reference tables reported is supported by genetic, environmental and feeding system analogies between the intake data - collected by selecting bibliographic sources almost exclusively from experimentation made on dairy breeds in Mediterranean environment - and the farm conditions where these models would be applied.

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Table 8. Expected pasture intake and selective activity, for milk production equal to 1 kg/d

| Pasture type   | Quantity of supplement administered kg/d | Pasture intake kg DM/d | Variation in protein content of the diet selected compared to herbage content % |
|----------------|------------------------------------------|------------------------|--------------------------------------------------------------------------------|
| 1: excellent   | 0.3                                      | 1.5-2.0                | < +10                                                                            |
| 2: good        | 0.3                                      | 1.2-1.6                | +5 ÷ +20                                                                         |
| 3: mediocre    | 0.3                                      | 1.0-1.3                | +25 ÷ +40                                                                       |
| 4: poor        | 0.3                                      | 0.5-0.8                | > +60                                                                            |
| 1: excellent   | 0.5                                      | 1.3-1.5                | < +10                                                                            |
| 2: good        | 0.5                                      | 1.1-1.3                | +5 ÷ +20                                                                         |
| 3: mediocre    | 0.5                                      | 0.9-1.2                | +25 ÷ +40                                                                       |
| 4: poor        | 0.5                                      | 0.5-0.8                | > +60                                                                            |
| 1: excellent   | 1.0                                      | 1.0-1.4                | < +5                                                                             |
| 2: good        | 1.0                                      | 0.8-1.3                | +5 ÷ +10                                                                         |
| 3: mediocre    | 1.0                                      | 0.8-1.2                | +15 ÷ +30                                                                        |
| 4: poor        | 1.0                                      | 0.5-0.8                | > +40                                                                            |
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