Interactions between nutrition and reproduction in sheep and goats with particular reference to the use of alternative feed sources

Rekik M., Lassoued N., Ben Salem H., Mahouachi M.

in

Priolo A. (ed.), Biondi L. (ed.), Ben Salem H. (ed.), Morand-Fehr P. (ed.).
Advanced nutrition and feeding strategies to improve sheep and goat

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 74

2007
pages 375-383

Interactions between nutrition and reproduction in sheep and goats with particular reference to the use of alternative feed sources

M. Rekik*[1], N. Lassoued, H. Ben Salem** and M. Mahouachi*****
*Ecole Nationale de Médecine Vétérinaire, 2020 Sidi Thabet, Tunisia
**INRA-Tunisie, Laboratoire des Productions Animales et Fourragères, Rue Hédi Karray, 2049 Ariana, Tunisia
***Ecole Supérieure d'Agriculture du Kef, 7100 Le Kef, Tunisia

SUMMARY – This paper is intended to focus on some aspects of interactions between nutrition and reproduction in small ruminants particularly under low input systems of arid and semi-arid regions. Most of the published work shows important effects of the level of nutrition on reproductive traits of males and females. Onset of puberty, ovulation rate, embryo survival, depth of anoestrus and response to the male effect in the female as well as testicular size, sperm production and abnormalities in the male were all shown to be modified through short, medium and long term dietary changes. There is a wealth of information on such findings mostly originating from breeds under temperate latitudes. However, available results from small ruminants populations that have been selected under more difficult climates or having different levels of productivity seem to suggest different patterns of interactions between genotype and nutrition. Improvement of the feeding level conventionally achieved through the use of concentrates, hence expensive feedstuffs, could not be cost-effective at the farmer's level under low input systems. Alternative feeding strategies are therefore needed in these arid environments where food supply varies greatly from season to season and from year to year due to highly unpredictable patterns of rainfall. This paper reports on some experiences where alternative feed sources were shown to alter reproductive traits in small ruminants. Amongst these experiences, the use of feed blocks could represent a promising nutritional tool to boost reproduction when animals graze poor pastures. Alternatively, the use of multi-purpose shrubs or several agricultural by-products might also be considered within feeding strategies targeted to improve reproductive efficiency. However, more research in this area is needed to elucidate the specific effects of anti-nutritional factors on reproduction of sheep and goats.

Keywords: Reproduction, nutrition, small ruminants, breed differences, alternative feed sources.

RESUME – *"Interactions entre nutrition et reproduction chez les ovins et caprins, en particulier concernant l'utilisation de sources alimentaires alternatives".* Le propos de cet article est d'appréhender certains aspects des interactions entre nutrition et reproduction chez les petits ruminants en particulier en systèmes à faibles intrants des régions arides et semi-arides. La plupart des travaux publiés montrent d'importants effets du niveau de nutrition sur les caractéristiques reproductives des mâles et femelles. L'apparition de la puberté, le taux d'ovulation, la survie embryonnaire, l'intensité de l'anœstrus et la réponse à l'effet mâle chez la femelle, ainsi que la taille testiculaire, la production de sperme et les anomalies chez le mâle s'avéraient tous modifiés par des changements de régime alimentaire à court, moyen et long terme. Il existe une très vaste information sur ces investigations principalement pour ce qui est des races sous latitudes tempérées. Toutefois, les résultats disponibles sur les populations de petits ruminants qui ont été sélectionnées en climats plus difficiles, ou présentant des niveaux de productivité différents, semblent suggérer des tendances différentes quant aux interactions entre génotype et nutrition. *L'amélioration du niveau d'alimentation, qui se fait traditionnellement par l'emploi de concentrés, donc d'aliments onéreux, ne pouvait pas être rentable pour l'éleveur des systèmes à faibles intrants. Il est donc nécessaire de faire appel à des stratégies alimentaire alternatives dans ces milieux arides où l'approvisionnement alimentaire varie fortement d'une saison à l'autre et d'une année à l'autre en raison de l'imprévisibilité des précipitations. Cet article rapporte quelques expériences où il a été observé que des sources alimentaires alternatives modifiaient les caractéristiques reproductives chez les petits ruminants. Parmi ces expériences, l'utilisation de blocs alimentaires semble prometteuse pour stimuler la reproduction lorsque les animaux sont sur pâturages pauvres. Une autre alternative serait l'utilisation d'arbustes polyvalents ou d'un certain nombre de sous-produits agricoles, qui pourraient entrer dans les stratégies alimentaires visant à améliorer l'efficience reproductive. Cependant, d'autres recherches sont encore nécessaires dans ce domaine pour tirer au clair les effets spécifiques des facteurs antinutritionnels sur la reproduction des ovins et caprins.*

Mots-clés : *Reproduction, nutrition, petits ruminants, différences entre races, sources alimentaires alternatives.*

[1]Corresponding author: Tel. 21671552200, Fax: 21671552441, e-mail: rekik.mourad@iresa.agrinet.tn

Introduction

Over the last two decades, several major reviews have addressed the topic between nutrition and reproduction with a particular interest in sheep and goats (Robinson, 1990; Smith, 1991; Brown, 1994; O'Callaghan and Boland, 1999; Martin *et al*., 2004). While these reviews have mainly focussed on the female sheep, a relatively small body of information on males or goats is available in the literature. Several established facts of the effect of nutrition on the different components of reproduction can be drawn out of the published studies, some of which are reported in the following:

(i) Pre-natal under-nutrition has a more negative effect in females than in males on later reproductive development and adult function (Rae *et al*., 2002).
(ii) In males, reproductive function in young animals appears to be more susceptible to dietary restrictions of energy and protein than in adult and may lead to permanent histological changes at the level of the testis (Brown, 1994).
(iii) In females, the most prominent effect is around the time of mating on the wave-like pattern of follicle development, embryo survival and twinning rate (Viñoles, 2003).
(iv) Changes in levels of dietary intake are associated to changes in gonadotropin secretion, hence of the functioning of the gonads, which also respond to dietary-induced blood-borne metabolic hormones and substrates (Rhind, 1992; O'Callaghan and Boland, 1999).
(v) In Mediterranean regions, breeds of sheep and goats have a reproductive pattern that varies much greatly in relation to food availability than other environmental inputs (Folch *et al*., 2000).

However and in many cases, these reviews refer to very variable inconsistent results and some of these discrepancies can be explained by the use of different breeds, the nature of the nutritional resources, hence of management and also by differences in the experimental designs. It is also important to point out that most of the available data on interactions between nutrition and reproduction in small ruminants is obtained in temperate conditions with feed resources high in available nutrients that promote feed intake and using breeds with moderate to elevated levels of twinning allowing dietary-induced changes in litter size to be depicted.

These conditions are different of those commonly encountered in low input systems of the Mediterranean region. This paper therefore aims at comparing if the reproductive response to dietary changes of the breeds in these low input systems is consistent with the widely accepted models in the literature and at assessing, in comparison to conventional supplementation, the effect of some alternative feed resources (AFR) on the reproductive efficiency of sheep and goats thriving in low input systems. Several relevant papers and documents were considered but we admit that we are not aware of all what has been published about the topic in the considered geographic area.

Relationship between nutrition, live weight and the reproductive response

It is classically admitted that in both the mid and the long terms, variations in growth and fluctuations in live weight are a mediator of the effects of nutrition on reproduction. In temperate breeds, this relationship is clearly described by Foster and Nagatani (1999). In the harsh environments of the Mediterranean region extending to other countries of West and Central Asia, sheep and goat breeds are assumed to be late maturing and therefore attempts to breed them early were not fully investigated. Lassoued and Atti (1996) in central Tunisia have shown that, if unsupplemented between 6 (weaning time) and 12 months of age, ewe lambs of the Barbarine breed reach a live weight of approximately 28 kg, less 6 kg than their supplemented counterparts and only 44% attained puberty in comparison to 84% of their supplemented counterparts. The same authors demonstrated that if the ewe lambs continued to be unsupplemented until 18 months of age corresponding to their first spring mating season, their live weight averaged 32 kg and only 23% conceived at the end of the mating season. However, their counterparts correctly nourished during the same period reached a higher live weight of approximately 44 kg prior to mating and 70% successfully mated. These results are consistent with early findings obtained in temperate environments and they demonstrate the strategic use of supplementation to achieve normal growth of young female sheep and therefore satisfactory reproductive results. The adequacy of live weight at the time of mating under rangeland conditions and its relationship with lambing rate of Awassi sheep is described by Thomson and Bahady (1988) through a quadratic polynomial equation $Y = 0.03423\ X - 0.00024\ X^2 - 0.16276$ where Y is lambing rate and X the ewe live weight at mating in kg.

Unfortunately similar published trends in the male are unavailable when low input systems of the Mediterranean region are considered. It seems however from work by Mahouachi *et al*. (2002, unpublished work) using males of the Queue Fine de l'Ouest (QFO) Tunisian breed of sheep, that alternating feeding level from high (1.6 of the Metabolisable Energy for Maintenance, MEM) to low (1.0 MEM) level was associated with a marked reduction in the ejaculate volume and not concentration. In addition and over a 24-hour bleeding period, mean testosterone concentrations were higher ($P<0.05$) during application of the high in comparison to the low feeding levels with respective values of 119±37.4 and 78±15.6 pg/ml.

Another component of the effect of live weight on reproduction is the direction of live weight change prior to mating. Following a preliminary report on the effect of live weight change on the success of artificial insemination in Barbarine ewes (Rekik *et al*., 2003), we designed an experiment using two autochthonous breeds namely the Barbarine and the QFO to further investigate this aspect. For 11 weeks prior to artificial insemination, ewes of both breeds either received a high feeding level (HH) to achieve rapid live weight gain, a moderate feeding level (MM) to achieve a steady live weight increase or a 5-week period of feeding restriction to achieve live weight loss followed by a 6-week period of high feeding level (LH) to reverse trends in live weight variation. All the sheep were artificially inseminated after synchronisation with progestagen-impregnated sponges and the ram effect. In both breeds, the results (Table 1) show that a relatively short period of food restriction is not detrimental to conception rates if animals are correctly fed to achieve a positive change in live weight prior to mating.

Table 1. The influence of the direction of live weight change on the success of artificial insemination in two Tunisian breeds of sheep

Breed	Treatment	Conception rate (%)	Average litter size
Barbarine	MM	50	1.13
	LH	58	1.11
	HH	47	1.12
Queue Fine de l'Ouest	MM	72	1.12
	LH	76	1.14
	HH	76	1.31

Nevertheless, nutritionally imposed treatments may have marked effects on reproduction before any changes in live weight are depicted. This is particularly true in the case of short-term dietary changes and Smith and Stewart (1990) postulated an immediate nutrient effect on the different reproductive traits. In this respect and when studying the effect of strategic supplementary feeding with groundnut seed cake on ewe productivity under range conditions of Sudan, El-Hag *et al*. (1998) recorded a significant improvement in lambing rates and a marked reduction in abortion rates of supplemented ewes in comparison to those managed on rangeland. Reduction in abortion rate was estimated to be higher than 40% of those ewes conceiving. It appears however that the reproductive response to improved planes of nutrition is breed dependent and according to Lassoued *et al*. (2004), the higher is the inherent prolificacy level of the breed, the higher is its reproductive response in terms of ovulation rate and litter size to improved levels of nutrition prior to and during mating. As a result and at least in semi-arid Tunisia, the use of concentrates as an expensive resort to supplement low prolific animals of the local breeds prior to mating may not lead to improvement in their reproductive traits (Rekik *et al*., 2005) and the authors suggested that alternative feed resources need to be envisaged as a more sustainable strategy in low input systems. Indeed, the high cost of concentrates associated to limited availability hamper their wide scale use, especially by small farmers (Ben Salem and Nefzaoui, 2003).

Interactions between nutrition and reproduction when small ruminants are fed alternative feed resources

Alternative feed resources refer to those local feeds, which could replace partially or totally

conventional feedstuffs either forages or concentrate feeds without reducing livestock performance but should reduce the feeding cost. In low input systems of the Mediterranean region, alternative feed resources can be native pastures or rangelands, crop residues mainly straw and stubbles or locally available agro-industrial by-products (olive cake, molasses, tomato pulp, etc). In comparison to the use of conventional feed particularly concentrates, the option of using alternative feed resources is more economic, more ecological as it integrates the animal to its environment and can improve soil and water conservation in the case of shrubs. In addition and under low rainfall areas, this option is more sustainable than grains cropping or purchasing.

Looking at the use of AFR from a different angle, several constraints are associated with their use and these can be summarised as follows:

(i) The low nutritive value and the imbalanced nutrient profile in energy, proteins and minerals as in the case of cereal straw and stubbles as well as olive cake,

(ii) The high content in anti-nutritional factors such as tannins, saponins, alkaloids, oxalates as in the case of shrubs like acacia, pistacia and cactus.

(iii) The use only during short periods due to high moisture content as in the case of most agro-industrial by-products.

In contrast to the wealth of information dealing with the subject of interactions between nutrition and reproduction with a particular reference to conventional feed resources (grasses, concentrates), research findings specifically related to the use of alternative feed resources are very scarce. We shall in the following report on our experience in Tunisia on results linking nutrition to reproduction using diets in which alternative feed resources are incorporated. When available, data obtained in other countries with similar natural constraints will also be reported.

Reproductive traits of Tunisian local sheep and goats supplemented with or grazing *Acacia cyanophylla* Lindl. foliage

Acacia cyanophylla Lindl. is a widespread shrub species in Tunisia and despite the low nutritive value of its foliage (Degen *et al*., 1997; Ben Salem *et al*., 2002), it produces a high quantity of biomass which is relatively rich in crude protein throughout the year (Ben Salem, 1998). However, abundant tannins in this plant species form insoluble complexes with the proteins rendering them unavailable for the rumen micro flora and consequently the host animal. The use of PEG, a synthetic polymer, has proven to provide satisfactory results in deactivating acacia tannins (Ben Salem *et al*., 1999) hence improving the efficiency of utilisation of this shrub by animals (Makkar, 2003). A wealth of information on the nutritive value of acacia-based or supplemented diets and lamb growth is available. However, the effect of acacia feeding on reproductive performance of ewes and goats was not investigated and we are not aware of any reports on the subject from other countries where acacia is grown and used in animal feeding.

In a first experiment, supplementing QFO ewes fed wheat straw with concentrate and air-dried acacia foliage with and without polyethylene glycol (PEG) resulted in very similar reproductive results being unusually low for ovulation rate and litter size (Table 2). The authors (Rekik *et al*., 2005) concluded that the mechanisms, whereby the likely increased absorption of protein in the ewes receiving PEG should have caused an elevation of ovulation rate and consequently litter size, were perhaps blocked by other metabolic signals arising from a rapid decrease of the ewes' body condition prior to and during mating. Alternatively, other secondary compounds in acacia including oxalates, cyanides, saponins, amines and alkaloids (Ben Salem, unpublished results) and not determined in this study, could have affected reproductive traits in this study by lowering to minimum levels ovulation rate and litter size. Nevertheless, there is no evidence in the literature linking the effect of anti-nutritional factors, other than tannins, and reproduction in sheep.

Table 2. Body condition score, ovarian activity after a progestagen-synchronised oestrus and lambing traits of ewes fed on barley straw, concentrate and acacia foliage with (PEG) and without (C) PEG (Rekik *et al.,* 2005)

	Diets		Prob. > F
	C	PEG	
Number of ewes	24	24	
Body condition score (35†)	1.61±0.34	1.64±0.30	NS
Body condition score (65†)	1.27±0.43	1.31±0.29	NS
Ewes in oestrus (%)	20/24 (83.3)	24/24 (100)	$P < 0.05$
Ewes cycling (%)	21/24 (87.5)	24/24 (100)	$P = 0.08$
Ovulation rate (± s.d.)	1.05±0.22	1.0±0	NS
Lambing rate at induced oestrus (%)	19/24 (79.1)	17/24 (70.8)	NS
Lambing rate after mating period (%)	22/24 (91.6)	24/24 (100)	NS
Litter size at birth (%)	1±0	1±0	NS

†days after the application of the feeding regimes. NS: not significant ($P > 0.05$).

To test the hypothesis that factors other that tannins in acacia may influence reproductive traits of ewes prior to mating, a second experiment using Barbarine ewes during fall mating was carried out and in which a further group of ewes receiving no acacia was included. The results (Table 3) suggest that after 75 days of feeding acacia, the PEG is no longer effective in reversing the decline of ovulation rate associated with acacia only. While these results again support the idea that other factors than tannins in acacia may be acting in the long term to depress ovulation rate, the inherent low ovulation rate of the sheep breeds used is perhaps preventing clear-cut differences to be depicted.

Table 3. Ovulation rate of Barbarine ewes fed different diets

Feeding regime†	Ovulation rate	
	45 days after start of the nutritional treatment	75 days after the start of the nutritional treatmenr
Hay and barley (n=34)	1.16	1.12
Acacia (n=33)	1.06	1.06
Acacia + PEG (n=33)	1.18	1.04

†Balanced for total digestible proteins and energy supply.

We also investigated the effect of acacia feeding on reproductive traits of goats using females of the local breed during postpartum. Daily PEG supplementation of goats browsing acacia increased daily intake of the shrub as well as protein digestibility, hence amino acids availability. The results (Table 4) clearly show that PEG administration was effective in improving ovulation rate at the second postpartum ovulation which in average occurred 27 days after kidding.

Effect of the level of incorporation of wasted dates on the reproductive traits of the prolific D'Man ewes

Dates production is an important agricultural activity in many parts of North Africa, the Middle East and several other Arabian countries. Unsuitable dates for human consumption are usually incorporated by farmers in the diets distributed to ruminants. There is very little published information on the use of date palm by-products in animal feeding except reports by El-Hag *et al*. (2002) who have succeeded in using wasted dates as an energy-rich ingredient in multi-nutritional blocks given to growing sheep and goats. Tunisia is a typical case where annually, about 20% of the national dates

harvest in the south is rejected by the national market and the export companies. The feedstuff is available throughout the year and can substitute for more expensive carbohydrate sources but with a high content of readily soluble sugars that can interfere with the rumen environment.

Table 4. Effect of PEG administration on reproductive parameters of native goats grazing acacia and supplemented with hay and concentrate

	Diets		Prob. > F or X^2
	C	PEG	
Number of goats	27	27	
Number of goats resuming ovulation (%)	21/27 (77.8)	20/27 (74.1)	N.S.
Ovulation rate (mean±s.e.) at the second postpartum ovulation (n)	1.25±0.45 (12)	1.76±0.60 (13)	P<0.05
Number (proportion) of goats with an ovulation rate > 1	3 (25)	9 (69.2)	P<0.05)
Number of goats manifesting oestrus (%)	18/27 (66.7)	17/27 (62.9)	N.S.
Days (mean±s.e.) separating first oestrus from application of nutritional treatment	21.6±7.41	19.8±8.05	N.S

On the ground, these large quantities of wasted dates are in most situations used by farmers in livestock feeding but we ignore the effect of such a practice on the animals' performances. This is particularly true when reproduction is considered, and worldwide we are not aware of any published work on the effect of dates in the diets on reproductive performances of small ruminants.

Since the introduction and the rapid growth of the population of the prolific D'Man sheep in the oasis of southern Tunisia (Lassoued and Rekik, 2001), we considered ewes of this species as a good biological model to investigate interactions between nutrition and reproduction when diets are composed of wasted dates. A series of trials were carried out in this respect and we report here some preliminary results.

In a first trial, three levels of dates incorporation in a hay-based diet were tested. Levels of dates incorporation were set to 25, 50 and 75% of the diet corresponding to daily quantities of 320, 650 and 970 g of wasted dates per ewe. The diets were balanced for nitrogen content using urea and between treatment groups, animals were balanced for live weight and initial ovulation rate. Digestibility trials (Fig. 1) show that in the three treatment groups, dry matter digestibility was comparable and at least equal to 77 % in animals of the treatment group receiving 75% of dates in their diet.

The main reproductive trait measured and here reported is ovulation rate. Following the initial ovulation rate at the start of the experiment, repeated measurement of this trait was carried out at days 27, 48 and 86 after the start of application of the nutritional treatment. At each of these occasions, animals were synchronised using progestagen impregnated sponges containing 30 mg of fluorogestone acetate left *in-situ* for 14 days and ovulation rate was determined by laparoscopy at day 8 after sponges withdrawal. Variations of ovulation rate in three treatment groups are reported in Fig. 2.

The results clearly show that when wasted dates are incorporated at levels higher than 25% in the diet, ovulation rate of the ewes showed a marked decrease by day 86 of the application of the nutritional treatment. Relatively to the initial ovulation rate, such a decline reached 26 and 30.1% in respectively the 50% and 75% levels of dates incorporation. The decline in ovulation rate started to occur earlier in ewes of the treatment group receiving 75% of dates in their diet but it was very similar to levels of ovulation rate in ewes of the treatment group receiving 50% of dates by approximately 50 days after the application of the nutritional treatment. In the absence of differences in live weight and body score condition between animals in the three treatment groups (data not shown), variations in ovulation rate could be related to either the presence of a specific substance in dates or to some other metabolic signals resulting from differences in rumen metabolism as a consequence of incorporating more dates in the diet of the ewes. However, more experimental evidence is needed to strengthen the above assumptions.

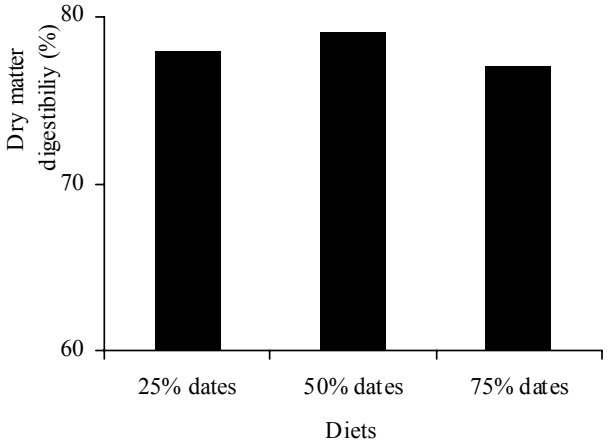

Fig. 1. Dry matter digestibility of the diets.

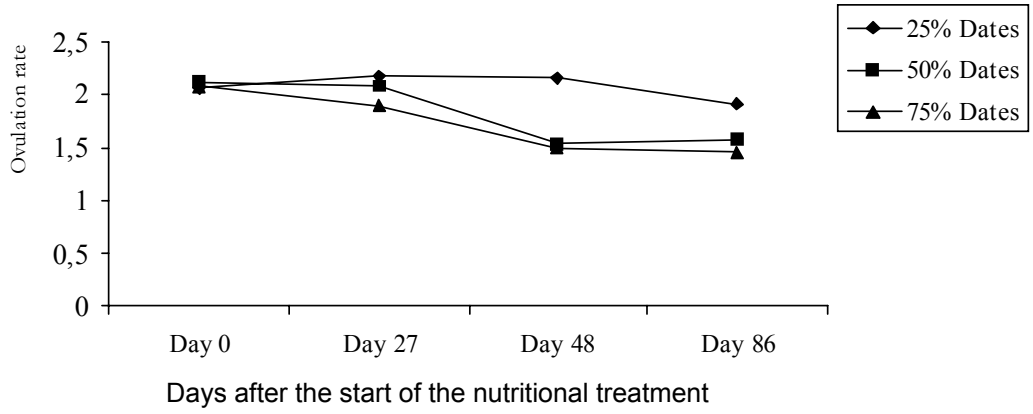

Fig. 2. Ovulation rate of D'Man ewes receiving diets with different levels of wasted dates incorporation.

Reproductive traits of small ruminants when supplemented with multi-nutritional feed blocks

In their review, Ben Salem and Nefzaoui (2003) defined the feed blocks as a solidified mixture of agro-industrial by-products, urea, a binder and salt used as a preserver. The role of feed blocks is to provide the animal continuously and simultaneously with minerals, vitamins, energy and protein or non-protein nitrogen. It has been shown in many studies that feed blocks improve digestion of low quality roughages by stall-fed or grazing animals. Very few studies have addressed the topic of nutrition and reproduction interactions when sheep and goats are supplemented with feed blocks and Ben Salem and Nefzaoui (2003) in their review on feed blocks, did report some of the available data in this area. We do not intend to review the same data again and readers are invited to consult the paper by Ben Salem and Nefzaoui (2003) for an exhaustive inventory of results linking nutrition and reproduction with reference to feed blocks. We only report here results by Al-Haboby *et al*. (1999) in Iraq using sheep grazing stubbles and supplemented or not with poultry litter and cotton seed cake-based blocks. Significant improvements in conception rate and % twinning were obtained when ewes are supplemented prior to and during mating with feed blocks (Table 5). In this case, improvements in the reproductive traits were most likely the result of an overall increase in nutrients provision particularly proteins when feed blocks are used as a supplement.

Table 5. Reproductive traits of Awassi sheep grazing stubbles and supplemented or not with multinutrient blocks (Al-Haboby *et al*., 1999)

	Nutritional regime	
	Stubble grazing	Stubble grazing + blocks supplementation
Body condition score at mating	2.31	2.72
Conception rate (%)	81	96
% twinning	12	27

Conclusion

Most of the available information on the interactions between nutrition and reproduction emanates from studies carried out under temperate conditions. Comparatively, there is a limited body of results gathered in the low input systems of the Mediterranean region where food scarcity and its erratic pattern of production are likely to interfere with management of reproduction. In these regions, where a wide range of alternative feed resources are available, we ignore how reproductive traits can be modified when sheep and goats are fed these resources. Some preliminary results on the use of shrubs seem to indicate involvement of a range of anti-nutritional compounds interfering with both the energy and the nitrogen balances. Pushing further these studies towards the metabolic hormones and their relationship with the reproductive hormones may lead to a better understanding of the mechanisms whereby alternative feed resources influence expression of the reproductive traits.

References

Al-Haboby, A.H., Salman, A.D. and Abdul Kareem, T.A. (1999). Influence of protein supplementation on reproductive traits of Awassi sheep grazing cereal stubble. *Small Rum. Res*., 34: 33-40.

Ben Salem, H. (1998). *Effets de* l'Acacia cyanophylla *Lindl. sur l'ingestion et la digestion des régimes destinés aux ovins. Rôle des tanins et perspectives d'amélioration de sa valeur alimentaire*. Thèse Doctorat de l'Université de Dijon (France). 252 p.

Ben Salem, H., Atti, N., Priolo, A. and Nefzaoui, A. (2002). Polyethylene glycol in concentrate or feed blocks to deactivate condensed tannins in *Acacia cyanophylla* Lindl. foliage. 1. Effects on intake, digestion and growth by Barbarine lambs. *Anim. Sci.,* 75: 127-135.

Ben Salem, H. and Nefzaoui, A. (2003). Feed blocks as alternative supplements for sheep and goats. *Small Rum. Res*., 49: 275-288.

Ben Salem, H., Nefzaoui, A., Ben Salem, L. and Tisserand, J.L. (1999). Different means of administering polyethylene glycol to sheep: Effect on the nutritive value of *Acacia cyanophylla* Lindl. foliage. *Anim. Sci*., 68: 809-818.

Brown, B.W. (1994). A review of nutritional influence on reproduction in boars, bulls and rams. *Reprod. Nutr. Dev.,* 34: 89-114.

Degen, A.A., Blanke, A., Becker, K., Benjamin, R.W. and Makkar, H.P.S. (1997). The nutritive value of *Acacia saligna* and *Acacia salicina* for goats and sheep. *Anim. Sci*., 64: 253-259.

El-Hag, M.G., Al-Merza, M.A. and Al-Salti, B. (2002). Growth in the Sultanate of Oman of small ruminants given date by-products-urea multinutrient blocks. Asian-Aust. *J. Anim. Sci*., 15(5): 671-674.

El-Hag, F.M., Fadlalla, B. and Elmadih, M.A. (1998). Effect of strategic supplementary feeding on ewe productivity under range conditions in North Kordofan, Sudan. *Small Rum. Res*., 30: 67-71.

Folch, J., Lassoued, N., Khaldi, G., Hanocq, E., Bodin, L., Jurado, J.J. and Chemineau, P. (2000). Plasticity of sheep and goat reproduction in the Mediterranean basin. *Proceedings of the joint ANPA-EAAP-CIHEAM-FAO symposium on livestock production and climatic uncertainty in the Mediterranean,* Agadir (Morocco), 22-24 October 1998. EAAP publication No. 94, pp. 237-245.

Foster, D.L. and Nagatani, S. (1999). Physiological perspectives on leptin as a regulator of reproduction: Role in timing puberty. *Biol. Reprod*., 60: 205-215.

Lassoued, N. and Atti, N. (1996). *Maîtrise des techniques de l'élevage ovin en conditions difficiles. Rapport final du projet PNM, N° PS94BIRD6*. Secrétariat à la Recherche Scientifique et à la Technologie, Tunisia.

Lassoued, N. and Rekik, M. (2001). Differences in reproductive efficiency between female sheep of the Queue Fine de l'Ouest purebred and their first cross with the D'Man. *Anim. Res*., 50: 373-381.

Lassoued, N., Rekik, M., Mahouachi, M. and Ben Hamouda, M. (2004). The effect of nutrition prior to and during mating on ovulation rate, reproductive wastage, and lambing rate in three sheep breeds. *Small Rum. Res*., 52: 117-125.

Makkar, H.P.S. (2003). Effects and fate of tannins in ruminant animals, adaptation to tannins, and strategies to overcome detrimental effects of feeding tannin-rich feeds. *Small Rum. Res*., 49: 241-256.

Martin, G.B., Milton, G.T.B, Davidson, R.H., Banchero Hunzicker, G.E., Lindsay, D.R. and Blache, D. (2004). Natural methods for increasing reproductive efficiency in small ruminants. *Anim. Repro. Sci.,* 82-83: 231-246.

O'Callaghan, D. and Boland, M.P. (1999). Nutritional effects on ovulation, embryo development and the establishment of pregnancy in ruminants. *Anim. Sci*., 68: 299-314.

Rae, M.T., Kyle, C.E., Miller, D.W., Hammond, A.J., Brooks, A.N. and Rhind, M.S. (2002). The effects of undernutrition, in utero, on reproductive function in adult male and female sheep. *Anim. Reprod. Sci*., 72, Issues 1-2: 63-71.

Rekik, M., Lassoued, N., Ben Salem, H. and Tounsi, I. (2005). Reproductive traits of Queue Fine de l'Ouest ewes fed on wheat straw supplemented with concentrate and *Acacia cyanophylla* Lindl. foliage with and without PEG. *Small Rum. Res*. (in press).

Rekik, M., Lassoued, N., Saadoun, L., Arous, M. and Ben Sassi, M. (2003). Using the ram effect as an alternative to eCG before artificial insemination of Barbarine ewes. *Journal of Animal and Veterinary Advances*, 2(4): 225-230.

Rhind, S.M. (1992). Nutrition: Its effects on reproductive performance and its hormonal control in female sheep and goats. In: *Progress in sheep and goat research*, Speedy, A.W. (ed.). C.A.B. International, pp. 25-51.

Robinson, J.J. (1990). Nutrition in the reproduction of farm animals. *Nutrition Research Reviews*, 3: 253-276.

Smith, J.F. (1991). A review of recent developments on the effect of nutrition on ovulation rate (the flushing effect) with particular reference to research at Ruakura. *Proceedings of the New Zealand Society of Animal Production,* 51: 15-23.

Smith, J.F. and Stewart, R.D. (1990). Effects of nutrition on the ovulation rate of ewes. In: *Reproductive physiology of Merino sheep. Concepts and Consequences*, Oldham, C.M., Martin, G.B. and Purvis, I.W. (eds). School of Agriculture (Animal Science), The University of Western Australia. Nedlands, pp. 85-101.

Thomson, E.F. and Bahady, F.A. (1988). A note on the effect of live weight at mating on fertility of Awassi ewes in semi-arid northwest Syria. *Anim. Prod*., 47: 505-508.

Viñoles, C. (2003). *Effect of nutrition on follicle development and ovulation rate in the ewe*. Doctoral Thesis. Swedish University of Agricultural Sciences, Uppsala.