FEEDING DAIRY SHEEP: NUTRITIONAL CHALLENGES AND OPPORTUNITIES

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Nutritional challenges in late pregnancy-early lactation

It is well known that milk production depends not only on the nutritional management of the animals during lactation, but also on their nutritional management during pregnancy, with special importance for its last part, as summarized by Cannas et al. (2002). Since sheep are much more prolific than cows and have a shorter pregnancy, their nutritional strain in late pregnancy is much more intense than that of cows. Indeed, comparing cow and sheep it appears that the combined effect of sheep's shorter pregnancy and higher prolificacy brings, in the critical last month of pregnancy, to a growth rate of the fetuses per kg of body weight (BW) of the mother that is 4 times higher in sheep with twins and almost 6 times higher in sheep with triplets compared to cows (Table 1). This is an amazing nutritional challenge, causing exponential increases in nutrient requirements, and in particular energy requirements, in a short time, since 80-90% of fetal growth occurs in the last 50-60 days of pregnancy. Unfortunately, during this period the capacity of sheep to eat fiber does not increase, because rumen expansion is limited by the space occupied by the uterus and probably by subtler hormonal changes that occur in the preparation of lambing. Indeed, in the last 2 to 3 weeks of pregnancy dietary intake not only does not increase, as it would be necessary to cover the growing energy requirements, but it actually decreases dramatically (Helander et al., 2014; Olsen, 2016).

In late pregnancy, then, it is necessary to supply increasing amounts of concentrates as lambing is approached. This is because concentrates have a very low filling effect in the rumen, a very important factor in animals already constrained by uterine and conceptus development.

Table 1. The length of pregnancy and the fetal growth rate in late pregnancy of cow and ewes.

Species	BW mother, kg	Pregnancy lenghth, d	Total birth weight, kg	BW/ mother BW, %	Fetal growth rate, last 30 d of pregnancy, g/d × kg mother BW
Cow	650	283	40	6.1	0.5
Ewe with twins	65	147	7	10.8	2.0
Ewe with triplets	65	147	10	15.3	2.8

The appropriate amount and source of concentrates in this period can be estimated by using nutritional software and it will vary greatly based on the forage sources used, the BW of the mother, the number of fetuses and the stage of pregnancy. In addition, if pregnancy occurs during winter it is necessary to account for the fact that cold stress might markedly increase maintenance energy requirements, especially in Nordic regions. One problem of concentrate allocations is that if the ewes are not grouped based on the stage of pregnancy and twinning rate, it is not easy to supply appropriate amounts of concentrates, with a high risk of underfeeding or overfeeding certain animals. This is particularly true for large sheep farms or when lambing is not synchronized and is spread over many weeks. As a result, many ewes may become too thin or too fat when they approach lambing.

Proper nutrition during pregnancy favors the development of the secretory tissue of the mammary gland, probably as a result of the action of the placental lactogen hormone secreted by the placenta, whose development occurs mostly during mid-pregnancy, and also due to the stimulus derived in late pregnancy by adequate nutrition. The overall effect is an increase in the number of mammary secretory cells and, thus, a higher potential milk yield (Bizelis et al., 2000; Charismiadou et al., 2000).

Proper nutrition during pregnancy also influences milk yield because it allows the accumulation of sufficient body fat and protein reserves, which can be mobilized in the first months of lactation. For example, Atti et al. (1995) observed that milk yield was 30% lower in the first 9 weeks of lactation for ewes lambing at BCS 1.75 compared to ewes lambing at BCS 3. The negative effects on milk yield due to underfeeding are thus probably a combined effect of the lower development of the secretory tissue of the mammary gland and decreased availability of energy from body reserves in early lactation, especially in the first month. Indeed, after lambing intake is usually very low and it slowly increases, peaking only at 30 to 45 days in milk (DIM). In the meanwhile, energy intake very often does not cover all requirements and the ewes need to mobilize body reserves, especially fat, to sustain milk production.

Sheep too fat during late pregnancy may have also various metabolic constrains and disorders. First, their intake is negatively affected by the fat that accumulates at a visceral level and competes for space with the rumen (Forbes, 1969). In addition, leptin, a hormone produced by the fat tissue has been shown to decrease the appetite of fat animals. The results of over-fattening affects not only pregnancy but also lactation (Nørgaard et al., 2008). Indeed, these authors showed that, comparing ewes with very high (4.6) or intermediate (3.8) BCS at lambing, the high BCS ewes produced more colostrum 3 h after birth but very quickly lost milk production and BCS, probably due to their very low intake (not measured) in early lactation, while the ewes with a lower, and more optimal, BCS at lambing produced much more milk and lost much less BCS (Table 2). The very fast BCS loss of the ewes with high BCS at lambing markedly increases the risks of sub-ketosis or ketosis, as discussed later. These risks are higher in ewes with twins compared to those with singles (Schlumbohm and Harmeyer, 2008).

Table 2. Effect of high BCS at lambing on milk yield and BCS variations during early lactation (from Nørgaard et al., 2008)

Item	At lambing	5 d in milk	30 d in milk
BCS high	4.6	4.2	3.4
Milk production, kg/d	0.616[1]	2.22	1.22
BCS medium	3.8	3.5	3.2
Milk production, kg/d	0.294[1]	2.56	2.48

[1] Colostrum 3 h after birth.

It is well known that too fast body reserve mobilization during pregnancy can induce ketosis in the ewes, a serious and often deadly metabolic disorder caused by the accumulation of ketone bodies (β-OH butyrate, acetoacetate, acetone) in the blood. Ketone bodies are directly produced by the mobilized fat when the mobilization is too fast and there is a shortage of glucose in the blood. In ewes this disorder usually occurs more frequently in late pregnancy, and in ewes with twins and triplets compared to ewes with singles so it is also sometimes known as “twin lambs disease.” Ketosis in sheep is usually called pregnancy toxemia, since it generally occurs during pregnancy. While clinical pregnancy toxemia is fortunately not very common, its mild, subclinical form, called sub-ketosis, is very frequent and can affect up to 40% of the animals. Sub-ketosis cannot be recognized by any clinical symptom but only measuring blood ketone bodies. In general, β-OH butyrate (βHB) is the ketone body measured in the blood to identify subclinical ketosis. This can be done not only in certified laboratories but also on-site, by using portable, very accurate, and easy to use equipment, which has been successfully tested both in sheep (Panousis et al., 2012) and in dairy goats (Dorè et al., 2013). Dorè et al. (2015) suggested that, in dairy goats, measurements of βHB 40 days before parturition can predict future pregnancy toxemia. Indeed, subclinical ketosis can be a predictor of ketosis (i.e. pregnancy toxemia) but it is also associated with a status of immunosuppression in sheep (Lacetera et al., 2001, 2002) as in dairy cattle (Suthar et al., 2013). Lacetera et al. (2001, 2002) classified sheep in subclinical ketosis, having βHB level higher than 0.86 mmol/L and lower than 1.2 mmol/L, and compared them with ewes of the same flock with normal values, finding that the ewes in subclinical ketosis had half of the blood immunoglobulin G of those in normal status and produced a colostrum with 5 times less immunoglobulin G (Table 3). This striking effect of subclinical ketosis on immune defenses suggests that both the mothers and the lambs suckling their colostrum would be more prone to infectious diseases.

Table 3. Immunoglobulin G in the blood and in the colostrum of ewes with low and subclinical high β-OH butyrate (βHB) values. Adapted from Lacetera et al. (2001, 2002).

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

* P<0.05: ** P<0.01

This hypothesis was confirmed by a study on 231 dairy ewes conducted in Greece in a high production flock monitored every day in the transition period, from 15 days before parturition to 30 DIM (Karagiannis et al., 2014). They observed that the percentage of health problems in this transition period was much higher for the ewes too thin (BCS < 2.75) or too fat (BCS >3.5) at day 30 days before lambing (Table 4). In addition, the ewes that had health problems had also higher blood βHB and NEFA than those without clinical problems, suggesting 1) a causative correlation between health problems and body fat mobilization, and 2) that the immunosuppression caused by too fast body fat mobilization was the cause of this phenomenon. The health problems observed were (in parenthesis the percentage in respect to the ewes monitored): pregnancy toxemia (2.6%), placental retention (1.4%), metritis (8.6%), clinical mastitis (4.8%), culling for other diseases or low milk yield (8.2%). Interestingly both too thin and too fat ewes had a higher incidence of health problems during the transition and higher ketone bodies. Probably, too thin ewes were in that status because they had already lost many reserves and too fat ewes were instead starting this process. Indeed, it is well know that fat animals eat less, especially in late pregnancy, as mentioned before (Forbes et al., 1969, Nørgaard et al., 2008).

These findings are in line with the increased odds of metritis, clinical ketosis, lameness, and displaced abomasum in dairy cows in subclinical ketosis (Suthar et al., 2013) and to the association of pregnancy toxemia to increased incidence of mastitis, dystocia, perinatal mortality and post-partum reproductive tract disorders and decreased resistance to gastrointestinal parasites (Barbagianni et al., 2015a,b,c).

Table 4. The relationship between BCS, blood βHB and NEFA and health status of dairy ewes in the transition period (late pregnancy to early lactation); adapted from Karagiannis et al. (2014).

	Health problems	
BCS	NO	YES
Thin: BCS <2.75	69%	31%
Normal: BCS 2-5-3.5	88%	12%
Fat: BCS >3.5	67%	33%
βHB at – 30 d, mmol/L	0.849	1.118
NEFA – 30 d, mmol/L	0.345	0.494

Overfeeding during late pregnancy and fast accumulation of body fat in that stage were also associated with accumulation of an excess of fat in the visceral of the mothers and fetal growth restriction, which was 11% lower at day 130 of pregnancy compared to normally fed ewes (Caton et al., 2009).

All this information suggests that dietary formulation during pregnancy and lactation should be carefully done and monitored. However, while there is a vast research on energy and protein requirements of the ewes during these stages, with even some models based on the same structure of the Cornell model for cattle (Cannas et al., 2004; Tedeschi et al., 2010), none of the existing feeding systems reports optimal dietary fiber (Neutral Detergent Fiber, NDF) concentrations and of nonstructural carbohydrates (sugars and starch) optimal for sheep.

Thus, it becomes difficult to translate energy requirements in practical diets. Indeed, it is impossible to formulate appropriate diets without having reference values for their fiber (i.e. NDF) concentration, since it is well known that a diet too rich in NDF would be not completely eaten and a diet too poor in fiber would cause a decrease in ruminal pH and thus, likely, sub-acidosis or acidosis.

For this reason, the next paragraphs will present some information on optimal NDF levels in the diets of pregnant and lactating ewes.

Dietary NDF level during pregnancy

As said before, during pregnancy the capacity of sheep to eat fiber does not follow the increase in requirements but it actually decreases in the last 2 to 3 weeks of pregnancy (Helander et al., 2014; Olsen, 2016). A factor is certainly the development of the uterus and the accumulation of body fat, as clearly described in the model of Tedeschi et al. (2013) for cattle.

The definition of the optimal NDF intake in pregnant ewes is then very important, considering all the risks associated to low dry matter intake (DMI) at this stage.

An important study on this aspect was presented by Olsen (2016), who summarized the results of 5 different studies carried out in Scandinavian countries on pregnant ewes of large body size (95.6 ± 3.0 kg, measured 4 weeks before term) with twins or triplets (Table 5). Despite the different quality of the forages and concentrates used and the various doses of concentrate supplied in the studies, the level of NDF intake (% of BW) varied very little, being equal to 1.03 ± 0.08, as average and standard deviation of the 5 experiments (Table 5). The coefficient of variation (CV) was low, being 7.35% of the mean. The daily NDF intake also varied little, being equal to 993 ± 99 g/d of NDF intake. In contrast, the variability in DMI (as % of BW) and ME daily intake was larger, with CV of 9.8% and of 12.3% of their respective means. In the same study a progressive decrease of NDF intake was observed in the last 3 weeks of pregnancy, with a total decrease in NDF of about 10 to 15%. These data strongly suggest that NDF was constrained by the body size of the ewes more than other factors, such as requirements of diet energy concentration.

Table 5. Body weight, NDF and DM, and ME intake in ewes in late pregnancy in five different studies (Olsen et al., 2016).

Study #	BW kg	NDFI % BW	NDFI kg/d	DMI kg/d	DMI % BW	ME intake Mcal/d
1	100.0	11.3	1.13	2.86	2.9	8.13
2	94.0	1.04	0.98	2.52	2.7	6.74
3	92.6	0.92	0.85	2.67	2.9	7.46
4	95.1	1.06	1.01	2.64	2.8	7.41
5	97.7	1.02	1.00	2.19	2.2	5.81
Mean	95.9	1.03	0.99	2.6	2.7	7.1
St. Dev.	3.0	0.08	0.99	0.25	0.3	0.88
CV, %[1]	3.1	7.35	9.96	9.62	9.8	12.3

[1] Coefficient of variability, i.e. standard deviation/mean in percent.

In some Brazilian Santa Ines ewes of 52.5 kg of mean BW (day 90 of pregnancy), Macedo Junior et al. (2012) found that the level of intake of NDF during pregnancy changed little, with higher values for ewes carrying single fetuses than twin fetuses (NDF intake of 1.65% vs. 1.28% of BW, for ewes with singles and twins, respectively; mean value of 1.46% of BW; Figure 1). On an absolute value, there was an average increase in NDF intake during pregnancy (0.75 vs. 0.85 kg/d at 90 and 130 days of pregnancy, respectively).

Interestingly, as later discussed for the lactation stage, the comparison of the two studies showed that during pregnancy the level of intake of NDF (% of BW) was higher for the sheep breeds of small body size than for those of heavier BW. These results can be helpful as guidelines to formulate diets with appropriate NDF concentration during pregnancy, even though it is clear that there is a need to develop more data for pregnant ewes.

Dietary NDF level during lactation

Optimal dietary NDF concentrations have been little studied both in sheep and goats. Some reference values were given by Cannas (2004), based upon studies carried out on Sicilian lactating ewes of about 55 kg of BW fed on pasture and supplemented with hay, silage and concentrate.

The optimal NDF concentrations reported are probably too low, since in the dataset used the DMI measured in the ewes was lower than that usually observed in dairy sheep. This was because the ewes were kept on pasture 5 to 6 h per day and this might have limited their pasture intake, making the overall diet more concentrated and poorer in NDF than needed.

For this reason, we have been working to refine those values for ewes of different body size (Cannas et al., 2016). The approach used was to adapt to sheep the Mertens (1987) model, from which most dairy cattle values are derived.

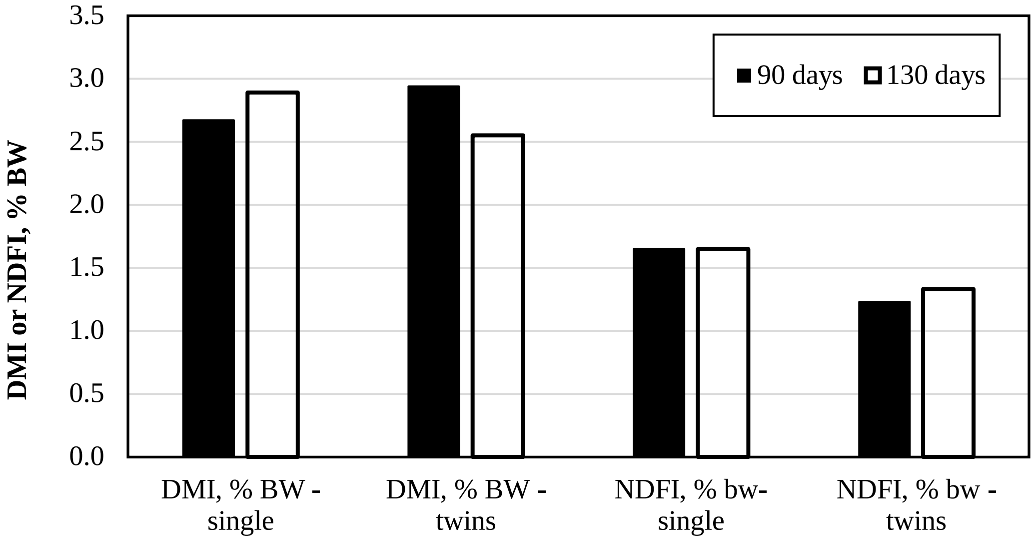

Figure 1. The level of intake of DM and NDF (% of BW) in ewes during 90 and 130 days of pregnancy with singles and twins (adapted, Macedo Junior et al., 2012).

Mertens (1987) defined maximum concentrations of dietary NDF that would not cause DMI reduction in dairy cows due to diet's filling effect in the rumen. In his work, optimal NDF concentrations of the diet were obtained considering an optimal daily level of NDF intake as a percent of body weight (NDFI%BW) of 1.2%. The actual value used was 1.1% per day, to include safety margins. Although there are no indications regarding optimal NDFI%BW for small ruminants, lactating ewes usually have an NDFI%BW markedly higher than 1.1% per day, e.g. 2.28% per day for 42-kg ewes (Molle et al. 2014; 2016) and 1.76% per day for 92-kg ewes (Olsen 2016). Sheep also have considerably greater DMI as % of BW than cattle (Van Soest 1994), and if 1.1% NDFI%BW per day is used to balance the sheep diets, the dietary concentrations of NDF would be too low to allow proper rumen function. Thus, we developed a model to predict optimal NDFI%BW and dietary NDF concentration for lactating ewes using the equations of Mertens (1987). The 1.1% NDFI%BW per day of Mertens (1987) was scaled to sheep assuming it varied as a function of adult weight, A, raised to the power of -0.25 ($A^{-0.25}$), which is the result of the ratio of adult energy maintenance requirements across species, which scales at $A^{0.75}$ (Kleiber, 1932; Taylor, 1980), and the reticolorumen volume, which scales with A^{1} (Van Soest 1994). This approach is consistent with the scaling by $A^{-0.27}$ of feed rumen passage rate reported by Illius and Gordon (1991). In the rest of this paper, A is referred to as BW to correspond with common terminology; the point being that scaling cannot be used for immature BW (Thonney et al., 1976). As a result, the NDFI%BW that would not restrict DMI due to rumen fill decreased exponentially (NDFI%BW per day = $5.4442\times BW^{-0.25}$), ranging from 2.10% per day for 45-kg ewes to 1.77% per day for 90-kg ewes. By using these values of NDFI%BW, the maximum dietary concentrations of NDF to avoid rumen fill restriction on DMI were then calculated for sheep of different mature BW and milk production (Table 6).

These values were evaluated by using the 50 individual measurements of DMI, diet composition, and milk production of lactating ewes of Molle et al. (2014; 2016), showing a fairly close agreement between predicted and observed dietary NDF concentrations and very close agreement between predicted and observed DMI (Cannas et al., 2016).

Table 6. Optimal dietary NDF (% of DM) and corresponding DM intake (DMI, % BW) on ewes fed forages and concentrates (values in the table based on a grass-legume forage mix with 58% NDF and 1.20 Mcal NEL/kg and a concentrate with 12% NDF and 1.90 Mcal NEL kg)[1].

Milk, kg/d	45 kg BW (2.10 NDFI%BW)[2]				60 kg BW (1.96 NDFI%BW)			
6.5% fat, 5.8% P	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
1.5	47.3	4.4	77	2.0	51.3	3.8	85	2.3
2.0	41.7	5.0	65	2.3	45.9	4.3	74	2.6
2.5	37.3	5.6	55	2.5	41.5	4.7	64	2.8
3.0	33.7	6.2	47	2.8	37.9	5.2	56	3.1
3.5	30.7	6.8	41	3.1	34.9	5.6	50	3.4
4.0	28.3	7.4	35	3.3	32.3	6.1	44	3.7
Milk, kg/d	75 kg BW (1.85% NDFI%BW)				90 kg BW (1.77% NDFI%BW)			
6.5% fat, 5.8% P	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
1.5	54.3	3.4	92	2.6	56.6	3.1	97	2.8
2.0	49.1	3.8	81	2.9	51.6	3.4	86	3.1
2.5	44.8	4.1	71	3.1	47.5	3.7	77	3.3
3.0	41.2	4.5	64	3.4	43.9	4.0	69	3.6
3.5	38.2	4.8	57	3.6	40.9	4.3	63	3.9
4.0	35.5	5.2	51	3.9	38.2	4.6	57	4.1

[1] Forage indicates the percentage of forages in the ration, being the rest made by concentrate. Values estimated assuming no BW loss or gain, except for values in Italics, which would cause weight gain. Some of the very high milk production levels reported are possible only on single animals, not as a mean value for a flock.

[2] NDFI%BW = NDF intake as % of BW.

The values reported in Table 6 were calculated assuming that optimal dietary NDF (% of DM) and corresponding DM intake are those that maximize fiber intake capacity, which is mainly influenced by their body size and it is proportionally higher in small than large ewes, since the latter have a faster rumen passage rate of the fiber than the former and, therefore, keep feedstuffs in the rumen for a shorter time. This is a well-studied nutritional strategy of ruminants of small body size (Van Soest, 1994).

The values reported in Table 6 were calculated assuming that the diets were all made by a grass-legume forage mix (with 58% NDF and 1.20 Mcal NEL/kg) and a concentrate (with 12% NDF and 1.90 Mcal NEL kg), used in different proportions. The approach used can be easily extrapolated to forages and concentrates of different compositions. Some practical considerations for this approach are listed below.

1. The DMI as a proportion of BW increases as milk production increases. At equal production levels, this value is higher in ewes of small body size than in larger ewes. However, in absolute terms DMI (i.e. kg x day) is higher in ewes of larger body size

2. Optimal dietary NDF decreases as milk production increases. At equal production levels, this value is higher in large than in small ewes. Thus, large ewes can use a higher proportion of forage in the diet at equal production levels. For ewes of small body size, at the very high production level the percentage of the forage in the diet can be so low to pose risks of rumen acidosis. In this case, part of the starchy concentrates should be substituted by sources of very digestible fiber and pectins, such as beet pulp or soyhulls. Dietary NDF concentration would increase above the values suggested in Table 6 but probably DMI would increase as well, with beneficial effects on rumen health and milk production (Araujo et al., 2008).
3. The NDF values of Table 6 are in part affected by the quality of the forage. With forages of better quality (lower NDF content and higher NEL concentration) than those used to develop the table, a larger proportion of the diet can be made by forages, thus fewer concentrates are needed. The contrary occurs for low quality forages.

The approach used to develop these reference NDF values did not consider the effects of the quality of NDF, in terms of its content of fermentable fiber and lignin. Future developments will consider the quality of NDF as a factor to be accounted for. The important issue of the proportion of fermentable and indigestible NDF in the diet will be covered in more details in next paragraph.

Effect of Fermentable NDF on Feed Intake

Details about the effect of the proportion of dietary potentially-fermentable fiber (pfNDF; digestible NDF as a proportion of dietary dry matter) on expected maintenance of rumen function and its positive relationship to feed intake were presented at the 20th DSANA Symposium (Thonney, 2014). The briefest version can be summarized in one short sentence: “Ruminants need fermentable fiber.” Surprisingly, this seems to be a mystery to many ruminant nutritionists. The longer short version is: 1) that ruminant species developed on diets composed primarily of fiber; 2) that only the fiber that can be fermented by bacteria and protozoa in the rumen or lower gut is important in sheep nutrition; 3) that the main end products of NDF fermentation (volatile fatty acids or VFAs; primarily acetic acid, propionic acid, and butyric acid) help to maintain ruminal function, are absorbed directly across the rumen wall, and serve as the primary substrates for glucose and fatty acids needed for metabolism; 4) that too high a proportion of dietary indigestible NDF limits feed intake; while 5) feed intake continuously increases as dietary pfNDF increases. Thus, optimizing the dietary concentration of pfNDF will increase feed intake and minimize nutritional challenges during late pregnancy and early lactation.

The proportion of NDF that is digestible varies with the digestibility of specific feed ingredients and declines with the faster rate of passage associated with higher levels of feed intake. Therefore, instead of total dietary NDF, diets should be balanced on pfNDF, where pfNDF is stated in concentration units determined at 1× maintenance levels of intake. pfNDF at 1× maintenance levels of intake can be calculated easily from the numerous values for digestibility of feed ingredients (dry matter digestibility, DMD) determined over the last 150 years at maintenance levels of intake.

The calculation of pfNDF is:

Eq 1: Indigestible dry matter: 1 – DMD
Eq 2: Indigestible NDF (INDF): Results from Eq 1 – metabolic fecal losses

where metabolic fecal losses vary from 10% of dietary dry matter for grains to 15% for poor quality forages (Van Soest, 1994). Subtract INDF from NDF to obtain pfNDF.

While research is in progress (see paper in these proceedings by Niko Kochendoerfer) to refine the minimum dietary pfNDF concentrations for lactating ewes, preliminary research and experience balancing diets for commercial farms suggests that at least 30% of the dry matter should be pfNDF. An example of two complete feeds for lactating ewes is shown in Table 7 with the specifications for the mineral-vitamin premix in Table 8.

Table 7. Ingredients in a non-forage diet for 70-kg lactating ewes (% as fed basis).

Ingredient	With vegetable oil	Pelleted
Soy bean hulls	44.0	33.5
Corn	41.2	36.9
Soybean meal	10.4	6.5
Wheat middlings		20.0
Vegetable oil	2.0	
Cornell mineral-vitamin premix (Table 8)	1.0	1.0
Ammonium chloride	0.7	0.7
Calcium carbonate	0.5	1.2
Salt	0.2	0.2

Table 8. Cornell sheep mineral and vitamin premix specifications (1% of diet DM).

	Concentration		
Nutrient or ingredient[1]	Diet	Premix	Unit
Salt	0.50	50	%
Distillers grains (carrier)	0.459	45.9	%
Feed-grade oil	0.005	0.5	%
Manganese	25	2,500	ppm
Vitamin E	93.7	9,370	IU/kg
Selenium	0.30	30	ppm
Zinc	20	2,000	ppm
Iodine	0.80	80	ppm
Vitamin A	2,645.5	264,552	IU/kg
Vitamin D	330.7	33,069	IU/kg
Cobalt	0.2	20	ppm
Molybdenum	0.7	70	ppm

[1] The first two items are ingredients that make up 95.9% of the premix on an as-fed basis. The other items are supplied by ingredients that make up the other 4.1% of the premix.

Diets with these ingredients are dusty unless they include vegetable oil, molasses, or are pelleted. Wheat middlings help to make pellets that hold together. Dusty diets reduce palatability and can cause inhalation pneumonia. Holding the diet together with vegetable oil, molasses, or by pelleting also prevents sorting so that ewes consume balanced diets.

Forages with high concentrations of pfNDF can also improve intake of ewes during late pregnancy and early lactation. What forages have high concentrations of pfNDF? Surprisingly to many farmers and nutritionists, alfalfa is not one of them unless it is cut very early and stored as silage. Early cut grass has much higher concentrations of pfNDF and it is especially palatable when properly ensiled. Early spring pasture may contain so much water that ewes cannot consume sufficient amounts to supply suggested dry matter levels of feed components. Properly managed, rotationally grazed pasture supplies high levels of pfNDF.

Table 9. Dietary components for 70-kg ewes in early lactation.

Item	Suggested component levels	With vegetable oil	Pelleted
DDM, % DM	75	80.0	81.4
Major dietary components, % DM (may not sum to 100% due to rounding error)			
CP	16	16.1	16.0
pfNDF (minimum)	30	30.6	30.0
INDF (maximum)	10	5.9	5.5
NSCHO	34	38.9	41.1
EE	5	5.0	2.9
Ash	5	4.2	2.1
Macro minerals, % DM			
Ca	0.52	0.56	0.81
P	0.29	0.26	0.41
K	0.80	1.03	1.05
Mg	0.18	0.20	0.24
S[1]	0.26	0.13	0.14
Micro minerals, ppm of DM			
I	0.80	0.89	0.89
Fe	50	229.80	211.10
Cu	10	4.9	5.75
Mo	0.5	1.8	1.91
Co	0.20	0.22	0.22
Mn	40	42.33	66.80
Zn	33	54.72	66.09
Se	0.3	0.30	0.53
Vitamins			
A, kIU/kg DM	1.13	1.33	1.33
D, kIU/kg DM	0.15	0.17	0.17
E, IU/kg DM	43	47.26	47.3

[1] S in analyzed feed has always been sufficient with these ingredients.

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