Assessment of nutritional characteristics of conventional and non-conventional feedstuffs for small ruminants using physical, chemical and in vitro methods

Giger-Reverdin S., Duvaux-Ponter C., Sauvant D., Rihani N., Sos-Dahbi E., Baraka A.

in

Ben Salem H. (ed.), Nefzaoui A. (ed.), Morand-Fehr P. (ed.).
Nutrition and feeding strategies of sheep and goats under harsh climates

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 59

2004
pages 111-118

Assessment of nutritional characteristics of conventional and non-conventional feedstuffs for small ruminants using physical, chemical and *in vitro* methods

S. Giger-Reverdin*, N. Rihani, E. Sos-Dahbi**, C. Duvaux-Ponter*, A. Baraka** and D. Sauvant***
*Physiologie de la Nutrition et Alimentation, Unité Mixte de Recherche, INRA-INA Paris-Grignon, 16 rue Claude Bernard, 75231 Paris Cedex 05, France
**Département des Sciences Animales, Institut Agronomique et Vétérinaire Hassan II, BP 6202, Rabat-Instituts, 10101 Rabat, Morocco

SUMMARY – The assessment of nutritional characteristics of conventional and non-conventional feedstuffs for small ruminants is of particular practical importance as these animals very often use local forages and by-products. Besides chemical assays, several easy-to-perform physical methods (bulk density, water holding capacity, initial pH, intrinsic buffering capacity) have been used for a set of 45 samples obtained from two different countries (France and Morocco) and covering a wide range of compositions. Short-term *in vitro* gas production was also measured. There were no differences between conventional and non-conventional feedstuffs for the relationships between the physical and chemical parameters. These relationships were poor, implying that the physical parameters might give additional information on feed characteristics. The proposed physical methods could be of interest to predict the fill value, and the *in vitro* gas method should estimate the potential acidogenicity of feedstuffs.

Key words: Feed, methods of analysis, feeding value, small ruminants.

RESUME – *"Caractérisation nutritionnelle des aliments conventionnels et non conventionnels destinés aux petits ruminants par des méthodes physiques, chimiques et* in vitro*". L'estimation des caractéristiques nutritionnelles des aliments conventionnels et non-conventionnels destinés aux petits ruminants présente une importance pratique particulière, car ces animaux valorisent très souvent des fourrages et des sous-produits locaux. En plus des analyses chimiques classiques, quelques méthodes physiques (densité, capacité de rétention en eau, pH initial, pouvoir tampon intrinsèque) ont été proposées et discutées pour un ensemble de 45 matières premières. Celles-ci ont été recueillies dans 2 pays différents (France et Maroc) et couvrent une large gamme de composition. La production de gaz à court terme a aussi été mesurée* in vitro*. Dans les relations entre les nouveaux paramètres et l'analyse chimique, les aliments non-conventionnels ne se distinguent pas des conventionnels. Les relations sont peu précises, ce qui signifie que les nouveaux paramètres apportent des informations originales pour caractériser les aliments. Les méthodes physiques proposées pourraient être intéressantes pour prédire la valeur d'encombrement des aliments, et la méthode* in vitro*, le pouvoir acidogène potentiel.*

Mots-clés : *Aliments, méthodes d'analyse, valeur nutritive, petits ruminants.*

Introduction

Small ruminants, such as sheep and goats, usually use local forages and by-products efficiently. Even though feedstuffs may differ greatly from one location to another, the estimation of their nutritive value remains an important goal.

Among the methods used to predict the nutritive value of feedstuffs, chemical assays are the most frequently used. Other methods that characterise either the physical properties of feeds or their *in vitro* degradability may also be of interest.

The aim of this work was to test the relationships between the usual chemical assays, and measurements obtained using physical and *in vitro* methods, for the conventional and non-conventional feedstuffs.

Material and methods

Feedstuffs

Forty-five feedstuffs commonly used to feed small ruminants (conventional: forages and concentrates; non-conventional: crop residues and agro-industrial by-products) were tested in this study. About half of them were obtained from France (24) and the rest (21) from Morocco. They can be grouped into seven main classes (Table 1).

Table 1. List of feedstuffs

	Conventional feedstuffs	Non-conventional feedstuffs
Cereals	Barley	
	Maize	
	Oats	
	Sorghum	
	Wheat	
Cereal by-products	Brewers grains	
	Corn gluten feed	
	Corn gluten meal	
	Rice bran	
	Wheat bran	
Legumes	Faba beans	
	Lupine seed	
	Peas	
Oilseed meals	Coconut meal	
	Palm kernel meal	
	Rapeseed meal	
	Soybean meal	
	Sunflower meal	
Agro-industrial by-products	Citrus pulp	Almond hulls
	Soya bean hulls	Argan pulp
	Sugar beet pulp	Carob pulp
		Olive cake
Crop residues		Artichokes leaves
		Peanut haulms
		Sugar beet tops and leaves
		Sugar cane leaves
		Sugar cane tops
Roughages	Alfalfa hay	Fababean straw
	Dehydrated alfalfa	Wheat straw
	Berseem hay	
	Corn silage	
	Corn stover	
	Oats forage	

Out of the feedstuffs used, the following seven were studied in both countries: brewers grain, wheat bran, sunflower meal, citrus pulp, sugar beet pulp, alfalfa hay and corn silage.

Methods of analysis

Each team performed the analysis on its own samples using the same methods as follows:

(i) Standard chemical methods were used: dry matter (DM; AFNOR, 1982), ash (AFNOR, 1977) and crude protein (CP; ISO, 1997). Cell wall content was estimated by the neutral detergent fibre (NDF) method of van Soest and Wine (1967) as modified by AFNOR (1997). Lignocellulose (ADF) and lignin (ADL) were obtained using a sequential approach (AFNOR, 1997) on the NDF residue as proposed by Giger *et al*. (1987).

(ii) Physical methods as described by Giger-Reverdin (2000) and Giger-Reverdin *et al*. (2002). Bulk density was obtained after a modification of the method of Montgomery and Baumgardt (1965). It was defined as the mass of the substrate (expressed in mg) contained in a 100 ml glass graduated cylinder after three sequential automatic swirling divided by the volume occupied (expressed in ml). Water holding capacity (WHC) was an adaptation of one of the methods of Robertson and Eastwood (1981) and corresponded to the quantity of water retained by a sample after soaking for 24 h in distilled water. Initial pH was defined as the pH of a solution containing a 10 g sample in 600 ml distilled water. The intrinsic buffering capacity (BC) was equal to the inverse of the value, at the initial pH, of the derivative function that characterises the changes in pH after the addition of acetic acid from the initial pH to pH 4.

(iii) *In vitro* gas production was measured using the gas method proposed by Menke and Steingass (1988), modified by Maaroufi *et al*. (1999) to perform a dynamic description of the amounts of gas produced.

Results and discussion

For the seven feeds tested in both locations, a two factors ANOVA was performed, and "feed" and "country" effects tested. The country effect was non significant for almost all the parameters tested in this study, and at the level of significance for the water holding capacity ($P < 0.043$, $n = 7$). Moroccan feedstuffs seemed to retain a little more water than French ones (17%). This means that for similar feedstuffs, the measurements conducted at two locations using the physical methods could be considered nearly equivalent.

On the whole set of data, Moroccan feeds, which are mainly of a non-conventional nature, differed from the French ones for the chemical parameters (Table 2). They were significantly more fibrous and contained less protein and more ash.

Table 2. Statistics on the feedstuffs

	France		Morocco		Country effect
	Mean	Standard deviation	Mean	Standard deviation	
Chemical parameters (kg/kg DM)					
NDF	0.343	0.214	0.472	0.433	0.035
ADF	0.195	0.142	0.295	0.126	0.016
ADL	0.034	0.030	0.084	0.064	0.001
CP	0.212	0.152	0.120	0.080	0.017
Ash	0.055	0.028	0.099	0.061	0.002
Physical parameters					
Bulk density	0.541	0.157	0.463	0.229	NS[†]
Water holding capacity (l/kg DM)	3.38	1.57	4.94	1.30	0.001
Initial pH	5.63	0.80	5.61	0.86	NS
Initial pH (pH > 4.5)	5.93	0.46	5.85	0.64	NS
Buffering capacity (pH > 4.5)	1.08	0.62	1.18	0.62	NS
Gas production (ml gas/200 mg DM)					
3 hours	7.7	3.4	5.4	3.4	0.029
6 hours	17.3	8.4	13.3	8.5	NS

[†]NS = non significant.

Moroccan and French feedstuffs were, on the average, similar in bulk density. This parameter was related negatively to NDF content (Fig. 1).

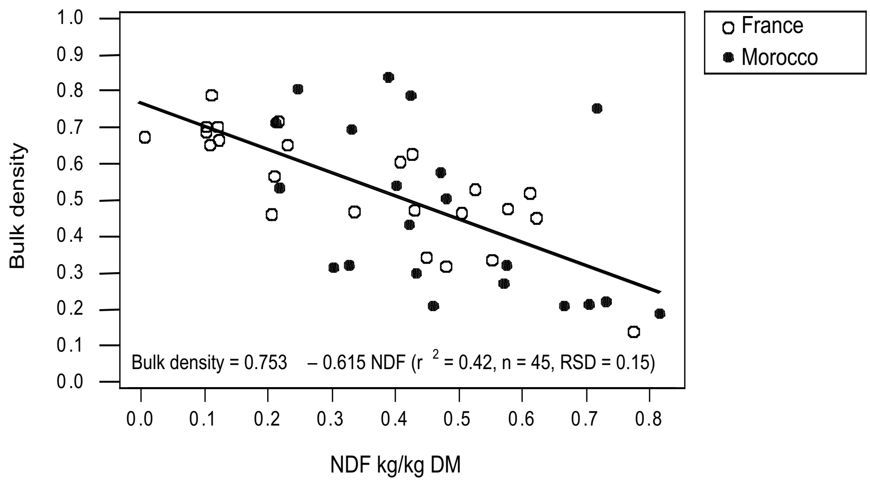

Fig. 1. Relationship between bulk density and NDF.

Most of the residual variation of the equation can be explained by ADL and ash contents:

Bulk density = 0.793 – 0.700 NDF + 1.43 ADL – 1.16 ash [1]
(r^2 = 0.57, n = 45, RSD = 0.13)

In general, roughages and non-conventional feedstuffs had a low density and a high NDF content, while cereals or grain legumes had low levels of cell wall constituents and high bulk density values. The bulk densities were lower than 0.84 (lesser than that of water). An accurate estimate of this parameter is quite important, as it influences passage rate in the rumen, and thus DM intake (Montgomery and Baumgardt, 1965; Seoane *et al*., 1981; Ehle, 1984; Wattiaux, 1990). This is of particular importance for low quality non-conventional feeds having high fill values. The main drawback of this method was that the measurement was done on sieved samples that may not precisely represent the actual particle size distribution of the raw material.

Moroccan feeds retained statistically more water than the French ones. Most of the variation in the WHC was explained by NDF content (Fig. 2).

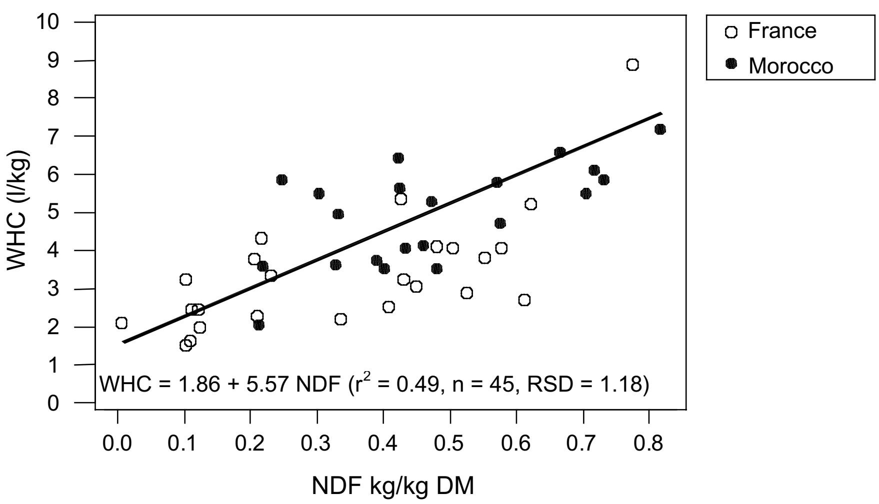

Fig. 2. Relationship between the water holding capacity of feedstuffs and the NDF content.

This relationship is in agreement with the literature (Singh and Narang, 1991). Water holding capacity can be more accurately predicted by a combination of both NDF and ash contents:

WHC = 1.42 + 5.06 NDF + 8.57 ash [2]
(r^2 = 0.56, n = 45, RSD = 1.11)

Nevertheless, if the coefficient obtained on 7 feeds analysed in both countries is applied to the whole set of Moroccan samples, the relationship is improved:

WHC = 1.85 + 4.79 NDF [2']
(r^2 = 0.48, n = 45, RSD = 1.04)

The WHC of a feedstuff represents its ability to immobilise water within its fibre matrix (Singh and Narang, 1991). Among the methods proposed to measure it, centrifugation at high speed (McConnell *et al*., 1974; Robertson and Eastwood, 1981; Seoane *et al*., 1981; Singh and Narang, 1991) or by filtration (Robertson and Eastwood, 1981), the latter seems to be the most accurate. It is easier to perform and follows more closely the conditions likely to be found in the ruminant digestive tract, and thus mimics better the physiological reality (Robertson and Eastwood, 1981). Feedstuffs with a high WHC have generally low bulk density values. This could be explained by the fact that feedstuffs with low bulk density could have numerous gas pockets that might retain water, such as water in excess within the rumen.

French and Moroccan feedstuffs did not differ for initial pH on the whole set of samples (5.63 vs 5.61). Two of the feeds (French corn silage and the Moroccan argan pulp) had an initial pH lower than 4.0. For these feeds, the intrinsic buffering capacity could not be calculated. Moreover, 5 other feedstuffs had an initial pH between 4.0 and 4.3 (2 brewer's grains, corn gluten feed, corn gluten meal and Moroccan corn silage). For these feeds, intrinsic buffering capacity was either very high (4.5 for the corn gluten meal and 19.6 for the corn gluten feed) or the adjustment did not fit. For the 38 remaining feedstuffs, which had a pH higher than 4.5 (5.93 for France vs 5.85 for Morocco), no significant differences in the intrinsic buffering capacity were found between the two sets of samples. A decrease in the intrinsic buffering capacity with the initial pH was also noted (Fig. 3).

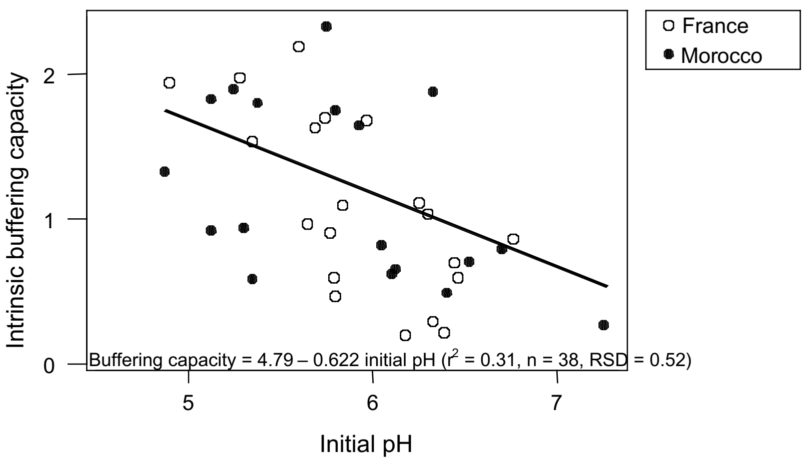

Fig. 3. Relationship between the intrinsic buffering capacity of feedstuffs and their initial pH.

Feedstuffs with a high protein content exhibited higher buffering capacities than the others. A combination of initial pH, CP and ash might explain most of the observed variations:

Intrinsic buffering capacity = 5.33 – 0.834 initial pH + 1.95 CP + 5.00 ash [3]
(r^2 = 0.59, n = 38, RSD = 0.41)

This relationship is interesting since it confirms our previous data (Giger-Reverdin *et al*., 2002) with unconventional feedstuffs, such as almond hulls, artichokes leaves, carob pulp, peanut haulms or olive cake that had never been tested before.

In the very first hours of incubation, Moroccan feedstuffs were degraded more slowly, but this difference was no longer significant after 6 hours of incubation. Gas production was highly correlated with NDF (Figs 4 and 5).

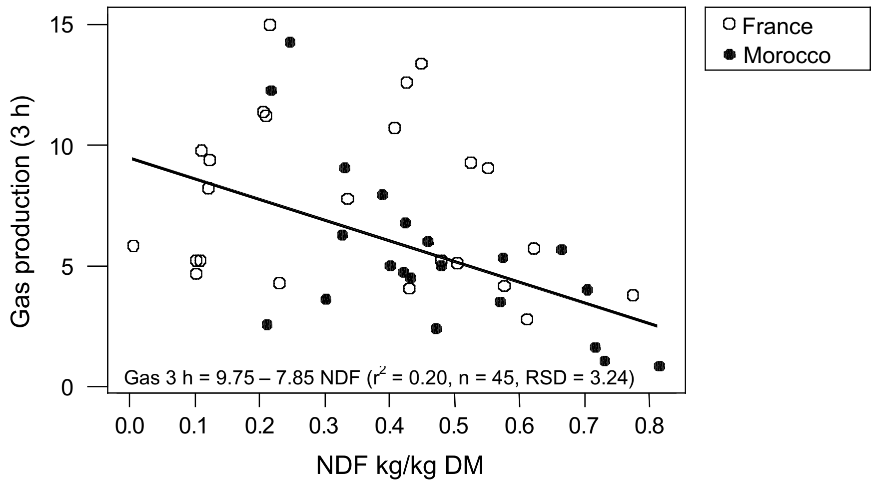

Fig. 4. Relationship between 3 hours gas production and NDF content.

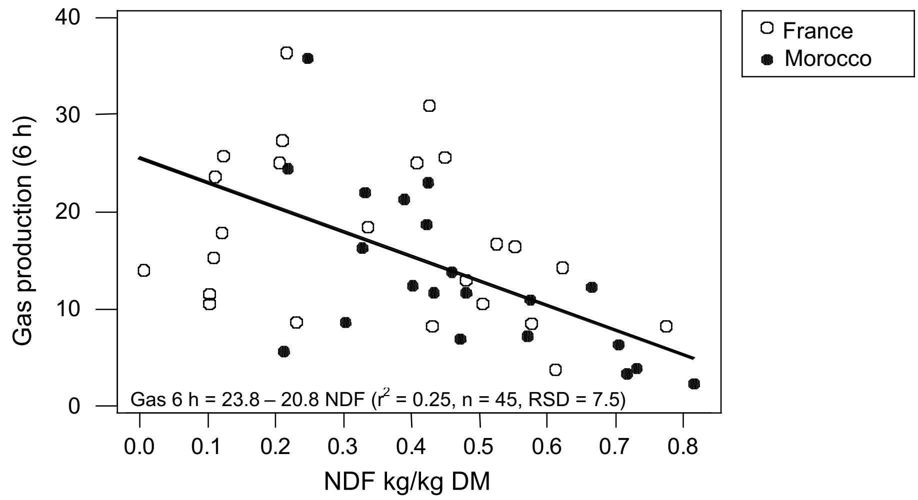

Fig. 5. Relationship between 6 hours gas production and NDF content.

In both cases, the CP content of the feedstuffs improved the relationship:

Gas 3 h = 12.1 – 10.2 NDF – 8.56 CP [4]
(r^2 = 0.28, n = 45, RSD = 3.11)

Gas 6 h = 31.1 – 27.9 NDF – 26.3 CP [5]
(r^2 = 0.38, n = 45, RSD = 6.93)

Gas productions provide good estimates of the acidogenic potential of feedstuffs, since they are well correlated with the *in vitro* pH decrease (Giger-Reverdin *et al.*, 1999). Nevertheless, they are not correlated with either intrinsic initial pH or buffering capacity of feedstuffs, as mentioned before.

Even if the feeds were quite different, the country effect was not significant when considering the residuals of the equations [1] to [5]. The equations obtained for the 45 feedstuffs were similar to those previously proposed using 24 conventional feedstuffs (Giger-Reverdin, 2000; Giger-Reverdin *et al.*, 2002) and to those reported by Baraka (2000) for Moroccan feeds with both conventional and unconventional ones.

Conclusion

This work involved very different kinds of feedstuffs, and in particular, conventional and non-conventional feedstuffs. Nevertheless, these non-conventional feedstuffs did not differ from the others in the observed relationships that could be applied to both kinds of samples. The residual standard deviation of the equations relating physical or *in vitro* parameters (expressed as gas production) to chemical measurements remained high, implying that the former two sets of methods did not give similar information as the chemical methods. The methods for measuring physical parameters, which are quite easy to perform, may be useful in providing a more thorough feed characterisation, especially when considering a wide range of feedstuffs of highly variable nature and origin, such as non-conventional by-products. They should be tested for their ability to predict the fill value or the potential acidogenicity of feedstuffs.

References

AFNOR (1977). *Aliments des animaux. Dosage des cendres brutes*. NF V18-101, 2 pp.

AFNOR (1982). *Aliments des animaux. Détermination de la teneur en eau*. NF V18-109, 5 pp.

AFNOR (1997). *Aliments des animaux. Détermination séquentielle des constituants pariétaux. Méthode par traitement aux détergents neutre et acide et à l'acide sulfurique*. NF V18-122, 11 pp.

Baraka, A. (2000). *Détermination de quelques paramètres physiques des aliments pour ruminants et utilisation dans la prévision de leur qualité nutritive*. Mémoire de Troisième Cycle en Agronomie, Option Productions Animales, IAV Hassan II, Rabat, Morocco, 94 pp.

Ehle, F.R. (1984). Influence of feed particle density on particulate passage from rumen of Holstein cows. *J. Dairy Sci.*, 67: 693-697.

Giger, S., Thivend, P., Sauvant, D., Dorléans, M. and Journaix, P. (1987). Etude de l'influence préalable de différentes enzymes amylolytiques sur la teneur en résidu NDF d'aliments du bétail. *Ann. Zootech.*, 36: 39-48.

Giger-Reverdin, S. (2000). Characterisation of feedstuffs for ruminants using some physical parameters. *Anim. Feed Sci. Tech.*, 86: 53-69.

Giger-Reverdin, S., Duvaux Ponter, C., Sauvant, D., Maaroufi, C. and Meschy, F. (1999). Variabilité des pouvoirs tampon et acidogène de 24 matières premières destinées aux ruminants. Liaison avec la composition chimique. In: *6èmes Rencontres autour des Recherches sur les Ruminants*, 1-2 December 1999. INRA-Institut de l'Elevage, Paris, France, pp. 95-98.

Giger-Reverdin, S., Duvaux-Ponter, C., Sauvant, D., Martin, O., Nunes do Prado, I. and Müller, R. (2002). Intrinsic buffering capacity of feeds. *Anim. Feed Sci. Tech.*, 96: 83-102.

ISO (1997). *Aliments des animaux. Détermination de la teneur en azote et calcul de la teneur en protéines brutes. Méthode Kjeldahl*. ISO5983, 9 pp.

Maaroufi, C., Le Pierres, J.L., Giger-Reverdin, S., Chapoutot, P., Crispin, A., Poissonnet, P., Quintard, M., Ragot, V. and Sauvant, D. (1999). Adaptation de la méthode HFT à des mesures en cinétique de la dégradation des aliments. *Cahier des Techniques de l'INRA*, 42: 19-28.

McConnell, A.A., Eastwood, M.A. and Mitchell, W.D. (1974). Physical characteristics of vegetable foodstuffs that could influence bowel function. *J. Sci. Food Agr.*, 25: 1457-1464.

Menke, K.H. and Steingass, H. (1988). Estimation of the energetic feed value obtained from chemical analysis and *in vitro* gas production using rumen fluid. *Anim. Res. Develop.*, 28: 7-55.

Montgomery, M.J. and Baumgardt, B.R. (1965). Regulation of food intake in ruminants. 2. Rations varying in energy concentration and physical form. *J. Dairy Sci.*, 48: 1623-1628.

Robertson, J.A. and Eastwood, M.A. (1981). An investigation of the experimental conditions which could affect water-holding capacity of dietary fibre. *J. Sci. Food Agr.*, 32: 819-825.

Seoane, J.R., Côtè, M., Gervais, P. and Laforest, J.P. (1981). Prediction of the nutritive value of alfalfa (Saranac), bromegrass (Saratoga), and timothy (Champ, Climax, Bounty) fed as hay to growing sheep. *Can. J. Anim. Sci.*, 61: 403-413.

Singh, B. and Narang, M.P. (1991). Some physico-chemical characteristics of forages and their relationships to digestibility. *Indian J. Anim. Nutr.*, 8: 179-186.
van Soest, P.J. and Wine, R.H. (1967). Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. *J. Assoc. Off. Anal. Chem.*, 50: 50-55.
Wattiaux, M.A. (1990). *A mechanism influencing passage of forage particles through the reticulo-rumen: Change in specific gravity during hydration and digestion*. PhD Thesis, The University of Wisconsin, Madison, USA, 253 pp.