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Correlation Between the Physical and Chemical Properties of Some Forages and Non-Forage Fiber Sources

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Abstract: Physical and chemical properties of 11 feeds including 3 forages; Alfalfa Hay (AH), Corn Silage (CS), Barley Silage (BS) and 8 Non-Forage Fiber Sources (NFFS); Soy Hull with Low (LSH) and High Seed (HSH), Cotton Seed Hull (CSH), Pistachio Hull (PH), Ground Peanut Hull (GPH), Sunflower Hull (SFH), Wheat Bran (WB) and Sugar Beet Pulp (SBP) were investigated. NFFS had a high bulk density (BD, 0.578-0.243; g mL^{-1}) and ADL content and low water holding capacity (WHC, g/insoluble DM). Soluble DM (SDM) and soluble OM (SOM, g L^{-1}) was low for SFH (0.7 and 0.62) and high for pH (6.25 and 4.19). Among all feed WHC had highest correlation with ADF and ash, while for NFFS, correlation was noted between WHC with BD and BC. Among all feeds BD had highest correlation with the NDF and NFC. For NFFS, BD had the highest correlation with ADF and SOM. Among all feeds BC had significant correlation with ash and Sash and pH had significant correlation with soluble fractions. In NFFS, significant correlation was noted between BC with ash, cell wall constituents, soluble fractions and pH. When NFFS were used for providing best predictive models, the r^2-values were increased for most of presented models compare with all feeds. The best models were that predicted SOM and BC in NFFS (r^2 = 0.995). Based on the results it appears that the type of feeds is critical factor influencing the relationship between physical and chemical parameters.

Key words: Forages, non-forage fibers, chemical properties, physical properties, correlation, predictive models

INTRODUCTION

Agricultural and agro-industrial byproducts can be economical feed sources for ruminants in many countries. There are big differences between byproducts in their physical and chemical characteristics. Although in most agricultural by-products high fiber and phyto-chemical (as tannin in pistachio hull) contents limit their digestibility and utilization by animals, but some by-products such as soy hull, pistachio hull and cotton seed hull provide valuable Non-Forage Fiber Sources (NFFS) in ruminants mainly high-producing dairy cows. Studying the physical properties of feeds and ratio has drawn a great attention by Giger-Reverdin (2000) and Serena and Knudsen (2007). Also physical characteristics of feeds such as bulk density, particle size, peNDF and functional specific gravity have been studied by Yansari (2004) and Bhatti and Firkins (1995). Although, many models presented to estimation physical parameters of feed, there is inconsistency among the reported studies for practical models to predicting physical parameter (Giger-Reverdin, 2000; Chaji *et al.*, 2008).

The objective of this study was establishing predictive models based on chemical and/or physical properties of feeds for estimation of physical parameters.

MATERIALS AND METHODS

Eleven feeds including 3 forages; Alfalfa Hay (AH), Corn Silage (CS), Barley Silage (BS) and 8 Non-Forage Fiber Sources (NFFS); Soy Hull with Low Seed (LSH), Soy Hull with High Seed (HSH), Cotton Seed Hull (CSH), Pistachio Hull (PH), Ground Peanut Hull (GPH), Sunflower Hull (SFH), Wheat Bran (WB) and Sugar Beet Pulp (SBP) were studied. All feeds were ground to pass through 2 and 1 mm screen for analytical and physical measurements. Bulk Density (BD), Water Holding Capacity (WHC), Soluble DM (SDM), Soluble OM (SOM) and Soluble ash (Sash) were determined according to the methods of Giger-Reverdin (2000).

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For measuring the initial pH (ipH) of feeds 0.5 g dry sample were added to 30 mL deionized water. To avoid VFA losses during drying, pH and Buffering Capacity (BC) of silages were measured on fresh samples. Samples were stirred for 3 min on a magnetic stir plat, leaved for 2 min and then the pH of mixture was measured immediately by Metrohm 691 pH m. BC was determined by titrating the 30 mL of solution from it's initial pH to pH of 5 with HCl (1.0 N) and by titrating similar prepared solution from it's initial pH to pH of 7 with NaOH (1.0 N) according to Le Ruyet *et al.* (1992).

Dry Matter (DM), ash, Ether Extract (EE) and Crude Protein (CP) contents of samples were determined by the standard methods of AOAC (1998). Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) were determined according to Vansoest *et al.* (1991). Calcium (Ca), potassium (K) and Phosphorus (P) were determined following to dry ashing and digestion of sample by HCl 3 N (AOAC, 1998). Ca and K were determined by atomic emission spectrophotometer (Flame Photometer 410, Wagtech) and P by molybdate-vanadate method using a spectrophotometer (Cecil, CE 1021) at 350 nm according to the recommended method of AOAC (1998). Cellulose (Cell) determined as ADF minus ADL, Hemi Cellulose (HeCell) as NDF minus ADF and Holo Cellulose (HoCell) as NDF minus ADL.

Means comparison of physical characteristics were conducted by GLM procedure of SAS (2002) (Var. 9.0). Relationships between chemical and physical parameters were investigated using the CORR procedures of SAS. Determination of the best model between dependent with independents variables in physicals parameters were performed by REG procedures of SAS by using stepwise option. The predictive models were separately obtained for all feeds and for NFFS. The significance of models was firstly examined at level of 0.01. When there wasn't any relationship at this level the 0.05 level was considered.

RESULTS AND DISCUSSION

Chemical compositions: Chemical compositions of feeds are shown in Table 1. There was a wide difference between feeds in chemical compositions. With the exception of SHM (CP 204.9 g kg^{-1} DM and EE 69 g kg^{-1} DM) other feeds had low contents of CP and EE. High levels of CP and EE concentration in SHM was preliminary because of high seed contamination in product provided from factory. NDF and ADF contents of GPH (891.5 and 767.5 g kg^{-1} DM, respectively) were high, while SFH and BS had the highest level of Cell (484.5 g kg^{-1} DM) and HeCell (322.5 g kg^{-1} DM). WB had the high level of P (11.8 g kg^{-1} DM), while level of Ca was quit high in SBP and SH (6.3 g kg^{-1} DM). The high level of Ca in SH and SBP might be because of high level of calcium pectinate (the insoluble salt of pectin). High level of P in WB might be because of high level of phytase complexes. As expected the pH of fermented feeds (i.e., CS and BS) was markedly lower from other feeds with the exception of PH (4.91). PH had highest levels of ash (120.9 g kg^{-1} DM) and K (36.8 g kg^{-1} DM). Interestingly PH had high content of NFC (401.7 g kg^{-1}) compare with other feeds because of low cell wall constituents. The ADL contents of some NFFS were considerably high (GPH, CSH and SFH; 355.5 209.5 and 200.5 g kg^{-1} DM, respectively). These high levels of ADL can be resulted in low DM and NDF degradability of these sources in animals or in *in vitro* trails (Jung *et al.*, 1997).

Physical parameters: Physical parameters of feeds are shown in Table 2. SBP had the highest and BS lowest BD (0.578 and 0.176 kg L^{-1}, respectively). WHC values reported here was slightly higher than reported by Giger-Reverdin (2002). WHC was highest in CS (8.95) and lowest in GPH and SFH (3.71 and 3.80, respectively). The SDM (g L^{-1}) varied greatly between feeds. It was quit low for SFH and GPH (0.7 and 0.77) and very high for PH (6.25). The soluble OM content (SOM, g L^{-1}) was very low for SFH and GPH (0.62 and 0.65, respectively) and very high for PH (4.19). The ash content (g L^{-1}), which was solubilised varied between 1.06 for PH and 0.08 for CSH. Sash and SOM contents of feeds followed the same trend as SDM and nearly all feeds showed the same trends in soluble fraction. In the case of PH, high level of SOM might be in part due to high soluble phenolic compound (soluble tannin). Bohluli and Naserian (2007) reported 9.6% total phenolic and 4.5% tannin in pistachio hulls based on dry matter. High level of Sash in PH could be due to high K content, which is soluble in water.

Correlations: The correlation coefficients between chemicals and physicals parameters are shown in Table 3 and 4. Table 3 contains the simple correlation among all feeds and Table 4 contains only the correlation among NFFS. Among all feeds (Table 3) BD had highest correlation with NDF (r = -0.60) and NFC (r = 0.82). For NFFS (i.e., AH, BS and CS were omitted; using only NFFS, n = 8) BD had the highest negative correlation with ADF (r = -0.75) and there was positive correlation between BD with SOM (r = 0.84).

Yansari (2004) in his study shown same correlation between BD with cell wall constitutes and NFC among all feeds. Also, same correlation between BD with cell wall constitutes were reported by Chaji (2008) and

Table 1: Chemical composition of the studied feeds ($g\ kg^{-1}$DM)

Variables	DM	CP	EE	NDF	ADF	Cell[1]	HeCell[2]	ADL	Ash	Ca	P	K	NFC[3]
SHM	938.0	204.9	69.0	496.5	390.5	367.5	106.0	23.0	62.0	2.6	1.6	15.3	167.7
SH	924.4	93.6	10.0	694.5	513.5	506.0	183.0	7.5	52.0	6.3	0.5	16.2	147.9
CSH	933.0	55.0	30.0	811.0	690.2	482.5	119.0	209.5	28.0	2.1	0.7	12.8	84.8
PH	944.6	158.2	69.5	250.0	207.5	122.0	42.5	85.5	120.9	5.6	2.4	36.8	401.7
GPH	943.9	47.9	13.0	891.5	767.5	412.0	124.0	355.5	40.3	2.7	0.4	5.6	6.6
SFH	952.4	35.1	15.0	881.5	685.0	484.5	196.5	200.5	15.5	1.3	0.2	6.4	52.9
CS	202.5	85.2	17.0	670.5	348.0	322.0	322.5	46.0	79.0	2.1	2.7	14.2	148.3
BS	256.4	107.2	32.0	609.5	413.5	302.0	196.0	64.5	113.0	3.7	4.2	20.3	138.3
AH	935.8	186.0	11.0	495.0	400.0	333.5	95.0	66.5	108.0	14.0	2.0	18.3	292.0
WB	925.2	183.4	42.0	375.0	121.0	76.5	254.0	44.5	54.0	1.9	11.8	15.5	345.7
SBP	932.4	99.6	1.5	486.5	259.5	244.5	227.0	15.0	48.0	6.3	0.3	11.0	346.6

Cellulose = ADF-ADL; HemiCellulose = NDF-ADF; Non-Fiber carbohydrate = 100 - (NDF + Ash + CP + EE)

Table 2: Physical properties of the studied feeds

Variables	BD	WHC ($l\ kg^{-1}$ DM of sample)	WHC ($l\ kg^{-1}$ InsDM of sample)	SDM (% per DM)	SDM ($g\ L^{-1}$)	Sash (% per ash)	Sash ($g\ L^{-1}$)	ipH	BC
SHM	0.388^{d}	3.32^{e}	4.84^{f}	31.50^{c}	3.15^{c}	55.65^{bdc}	0.345^{d}	6.78	2.07^{ed}
SH	0.418^{c}	4.80^{d}	5.87^{e}	18.25^{f}	1.83^{f}	51.92^{dc}	0.270^{e}	6.81	2.88^{cd}
CSH	0.243^{h}	3.26^{e}	3.68^{g}	11.25^{g}	1.13^{g}	28.57^{e}	0.080^{g}	6.82	1.08^{ef}
PH	0.557^{b}	4.53^{d}	9.53^{a}	52.50^{a}	5.25^{a}	87.59^{a}	1.060^{a}	4.91	7.07^{b}
GPH	0.278^{g}	3.43^{e}	3.71^{g}	7.750^{h}	0.78^{h}	31.68^{e}	0.125^{g}	8.28	1.46^{ef}
SFH	0.298^{f}	3.54^{e}	3.80^{g}	7.000^{h}	0.70^{h}	51.61^{dc}	0.085^{g}	6.68	0.76^{f}
CS	0.237^{i}	6.69^{a}	8.95^{b}	25.25^{e}	2.53^{e}	55.7^{bdc}	0.440^{c}	3.86	9.17^{a}
BS	0.176^{k}	6.00^{b}	8.05^{c}	25.50^{e}	2.55^{e}	62.39^{bc}	0.705^{b}	4.51	9.17^{a}
AH	0.273^{j}	5.27^{c}	8.33^{c}	36.75^{b}	3.68^{b}	69.91^{bac}	0.755^{b}	6.23	3.35^{c}
WB	0.357^{e}	3.57^{e}	5.00^{f}	28.75^{d}	2.88^{d}	72.22^{ba}	0.390^{dc}	6.54	1.86^{ef}
SBP	0.578^{a}	5.35^{c}	7.52^{d}	29.00^{d}	2.90^{d}	72.71^{ed}	0.205^{f}	6.12	0.95^{def}

Values with different superscript letters are significantly different

Table 3: Correlation coefficients and significance levels between the factors among all feeds (n = 11)

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
NDF		0.92	0.67	-0.93	-0.84	-0.64	0.85	0.18	0.86	-0.74	-0.95	-0.96	-0.60	-0.62	-0.31	0.51
ADF	***		0.78	-0.89	-0.74	-0.53	0.87	-0.22	0.68	-0.60	-0.82	-0.84	-0.51	-0.64	-0.37	0.34
ADL	**	**		-0.63	-0.62	-0.41	0.37	-0.30	0.17	-0.40	-0.60	-0.64	-0.36	-0.56	-0.32	0.27
NFC	***	***	*		0.68	0.52	-0.83	-0.06	-0.78	0.62	0.85	0.88	0.67	0.62	0.14	-0.54
CP	***	***	*	*		0.58	-0.61	-0.25	-0.69	0.63	0.80	0.81	0.32	0.40	0.20	-0.33
Ash	*	NS	NS	NS	NS		-0.47	-0.25	-0.56	0.96	0.80	0.72	0.03	0.87	0.78	-0.56
Cell	***	***	NS	***	*	NS		-0.08	0.86	-0.58	-0.74	-0.75	-0.46	-0.51	-0.30	0.30
HeCell	NS	NS	NS	NS	NS	NS	NS		0.44	-0.34	-0.30	-0.28	-0.23	0.07	0.17	0.41
HoCell	***	*	NS	**	*	NS	***	NS		-0.70	-0.83	-0.83	-0.53	-0.42	-0.19	0.48
Sash	**	*	NS	*	*	***	NS	NS	**		0.87	0.79	0.16	0.82	0.70	-0.62
SDM	***	**	*	***	**	**	**	NS	*	***		0.99	0.53	0.77	0.47	-0.64
SOM	***	***	*	***	**	**	**	NS	***	**	***		0.61	0.72	0.38	-0.62
BD	*	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	*		0.22	-0.24	-0.20
WHC	*	*	NS	*	NS	***	NS	NS	NS	**	**	**	NS		0.76	-0.56
BC	NS	NS	NS	NS	NS	**	NS	NS	NS	*	NS	NS	NS	**		-0.28
pH	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*	*	NS	NS	NS	

Table 4: Correlation coefficients and significance levels between the factors among NFFS (n = 8)

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
NDF		0.96	0.70	-0.93	-0.86	-0.81	0.87	0.11	0.87	-0.82	-0.95	-0.97	-0.70	-0.79	0.70	0.69
ADF	***		0.78	-0.95	-0.82	-0.62	0.88	-0.19	0.76	-0.65	-0.84	-0.87	-0.75	-0.70	-0.48	0.36
ADL	*	*		-0.69	-0.68	-0.36	0.38	-0.29	0.26	-0.36	-0.61	-0.66	-0.66	-0.54	-0.24	0.26
NFC	***	***	NS		0.66	0.70	-0.87	0.11	-0.78	0.71	0.86	0.88	0.82	0.84	0.55	-0.51
CP	***	**	NS	NS		0.62	-0.69	-0.11	-0.71	0.63	0.79	0.82	0.52	0.45	0.56	-0.19
Ash	**	NS	NS	NS	*		-0.64	-0.59	-0.84	0.97	0.93	0.89	0.70	0.86	0.97	-0.59
Cell	**	**	NS	**	NS	NS		-0.06	0.92	-0.68	-0.77	-0.78	-0.56	-0.62	-0.52	0.33
HeCell	NS	NS	NS	NS	NS	NS	NS		0.34	-0.54	-0.35	-0.29	-0.05	-0.29	-0.71	0.46
HoCell	**	*	NS	*	*	**	***	NS		-0.86	-0.88	-0.86	-0.59	-0.69	-0.77	0.50
Sash	**	NS	NS	*	NS	***	NS	NS	**		0.91	0.87	0.63	0.83	0.97	-0.63
SDM	***	**	NS	**	NS	***	*	NS	**	**		0.99	0.81	0.87	0.84	-0.60
SOM	***	**	NS	**	**	**	*	NS	**	**	***		0.84	0.86	0.79	-0.58
BD	*	*	NS	**	NS	*	NS	NS	NS	NS	**	**		0.91	0.54	-0.38
WHC	*	*	NS	**	NS	**	NS	NS	NS	**	**	**	**		0.75	-0.61
BC	*	NS	NS	NS	NS	***	NS	*	*	***	**	*	NS	*		-0.62
pH	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

*p<0.05; **p<0.01; ***p<0.001, NS: Not Significant

Giger-Reverdin (2002). As mentioned by Giger-Reverdin (2002) feedstuffs with low BD and high level of NDF can affects rumen fill and results in decrease in dry matter intake by ruminants. The correlation of SDM with BD in present study was positive and was in contrast to previous study of Yansari *et al.* (2004), who found negative correlation between these parameters (r = -0.34).

Among all feed WHC had highest correlation with ADF (r = -0.64) and ash (r = 0.87). When the NFFS were considered, WHC was significantly correlated with BD and BC (r = 0.75) and correlation coefficient value (r) of WHC with all parameters with the exception of ash and BC were increased. WHC had negative correlation with cell wall constitute (NDF and ADF) and had high positive correlation with NFC.This finding is in contrast with those of Giger-Reverdin (2000), who found high positive correlation (r^2 = 0.46) between WHC and NDF. One of the reasons for this discrepancy could be the wide range of feedstuffs studied in his study and differences in WHC expression in the study compare with his study. Because in present study WHC was reported based on insoluble dry matter, while in the study of Giger-Reverdin (2000) WHC expressed based on dry matter. WHC expression as L/kg of sample DM could not increase the r values in none of the cases. Serena and Knudsen (2007) found that in most of agricultural co-products soluble non cellulosic polysaccharides was positively correlated to water binding capacity.

Also WHC was correlated with BC and ash among all feed (0.76 and 0.87, respectively) and NFFS (r = 0.75 and 0.86, respectively). Van Soest and Robertson (1976) reported high correlation between cation exchange and hydration (r = 0.76). According to Van Soest (1994), the carboxyl groups in hemi cellulose and the phenol groups in lignin contribute most to hydration and ion exchange capacity. Results from the present study could not shown positive relationship between WHC with ADL and HeCell.

The soluble values based on g/L were correlated with other parameters rather than percent of initial values. SDM (g/L) was significantly correlated with all parameters with the exception for HeCell, BD and BC. For NFFS, SDM was significantly correlated with all parameter with the exception of ADL, CP, HeCell, BD and BC was appeared. SOM (g/L) was significantly correlated with all parameters apart from HeCell and BC. When the NFFS were considered SOM was significantly correlated with all parameters apart from ADL, HeCell and pH. Positive correlation of SDM and SOM with Sash in present study was similar to the results of Chaji (2008) and Giger-Reverdin (2000), respectively. The highest significant correlation was noted between Sash (g/L) with ash (r = 0.96) and NDF (r = -0.74).

For NFFS a highest negative correlation was noted between Sash with HoCell (r = -0.86), while highest positive correlation was noted between Sash with BC (r = 0.97). In contrast to Sash as g/L, there was lower correlation between Sash as DM (%) of initial ash with ash content (g/kg DM) among all feed (r^2 = 0.54) and among NFFS (r^2 = 0.59).

Among all feeds (Table 3, n = 11) BC had significant correlation with ash and Sash content of feeds and pH had significant correlation with soluble fractions of feeds. When the NFFS were considered in correlation analysis (Table 4, n = 8), significant correlation was noted between BC with NDF, Cell, ash, HeCell, HoCell, SDM, SOM, Sash and pH. Generally, mineral content of the feeds (Jasaitis *et al.*, 1987) and the amount of fiber and the cation exchange capacity of the fiber matrix (McBurney *et al.*, 1983) are important factors influencing BC.

In present study, significant correlation was evident between BC with ash across all feeds (Table 3, n = 11) and with cell wall constituents (NDF, Cell, HeCell and HoCell), soluble fractions (SDM, SOM and Sash), ash, WHC and pH among NFFS (Table 4, n = 8). However, among all feeds BC had significant correlation only with ash and Solash. Same results shown by Jasaitis *et al.* (1987). In their study, when all types of feeds were considered, acid BC was correlated with cation-anion differences ((Ca + Mg + K + Na) - (Cl + N + P + Si + S) and (Ca +Mg + K + Na) - (Cl +P +S)), total cations (Ca + Mg + K + Na) and total ash. Also, Fadel (1992) shown high correlation between BC and ash.

In present study, when NFFS was considered a high correlation evident between BC with NDF, cell, HeCell, HoCell, WHC and pH. Significant correlations of cell wall constitute especially HeCell and NDF with BC might be because of partial solubilization of hemi cellulose and releasing bounded-minerals under acid or base treatment in the method of BC determination. In an *in vitro* fermentation system, Crawford *et al.* (1983) found that the BC of feeds was correlated to soluble CP, CP, NDF, ADF, total NSF and total ash. Generally a higher content of CP increased pH and BC of feeds due to buffering ability of amine groups (Jasaitis *et al.*, 1987). But we didn't find any relationship of BC and pH with CP. This discrepancy might be because of deferent experimental procedures of measuring BC.

Table 5: The best predictive models

All feeds	p-value	r^2	NFFS	p-value	r^2
BD = 0.22 + 0.66 NFC	<0.05	0.450	BD = 0.26 + 0.66 NFC	<0.05	0.670
WHC = -0.55 + 15.5 BD	<0.01	0.840	WHC = 2.75 + 54.21 ash	<0.01	0.740
BC = -1.2102 + 73.766 ash	<0.01	0.610	BC = -1.72 + 5.36 Sash -7.54 HeCell	<0.01	0.995
Sash = -0.17 + 8.77 ash	<0.01	0.920	Sash = -0.22 + 10.39 ash	<0.01	0.950
SOM = 0.006 + 0.998 SDM -0.994 Sash	<0.01	0.995	SOM = 0.004 + SDM -1.001 Sash	<0.01	0.995

Predictive models: The models for prediction of physical parameters are shown in Table 5. The best models are presented either for all feeds or NFFS. Probably value (p-value) and r^2 are shown for each model. Jasaitis *et al.* (1987) shown that simple linear regression was not sufficient to predict accurately acid buffering capacity from total ash value. According to this assumption and in contrast (Giger-Reverdin, 2000; Chaji, 2008) a stepwise regression analysis of the data instead of simple linear regression was used to develop predictive equations among parameters, which were significantly correlated.

Thus in the present study, presented models are more complex. For example Giger-Reverdin (2000) reported an equation for estimation of SOM including only Sash as an independent variable (r^2 = 0.54). But in the present study SOM predicted by the model SOM = 0.006 + 0.998S DM-0.994 Sash (r^2 = 0.995) included two independents variables.

In present study, whenever only NFFS were used for providing best predictive models, the r^2-value increased compare with all feeds especially for the models, which predict BD, WHC and BC (Table 5). Fadel (1992) shown high correlation between BC and ash in sugar beet pulp, but not for alfalfa. Also, he found that the correlation coefficients between BC with NDF, ADF and ADL were higher for individual feeds than among all feeds.

In the study of Jasaitis *et al.* (1987), when the significant correlations were examined by feed type, significant relationships were evident between acid BC and total cations or acid BC and total ash except for fermented feeds and mineral additives. In their study, base BC was correlated with (K + Na) - C1, C1 + P + S, Ca + Mg + K + Na and total ash. However, only in low protein and fermented feeds were significant correlations found with base BC.

CONCLUSION

The chemical composition and physical properties of NFFS are wide different. Some of NFFS are contained high level of ADL and some have high BD resulting in limiting digestion and intake, respectively. Based on the results and previous researches, it appears that the type of feeds is critical factor influencing the relationship between physical or chemical parameters. Thus, it can be concluded that same group of feeds (i.e., forages, NFFS or etc.) must be taken in to account separately for developing predictive models. When NFFS were used for providing best predictive models, the r^2-values were increased for most of presented models compare with all feeds. The predictive model in Table 5 should be interpreted with caution because the number of observation was limited.

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