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Nutrient intake and digestibility by west african dwarf (wad) sheep fed graded levels of boiled pigeon pea concentrate diets

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A study was carried out to evaluate the nutrient intake and digestibility by West African Dwarf (WAD) sheep fed graded levels of dietary pigeon pea seed meal (PSM). Four diets designated A, B, C and D were formulated to contain 0, 10, 20, and 30% levels of PSM respectively. Four WAD rams aged between 15 and 17 months and weighing between 16 and 19kg were used to conduct digestibility study in a 4 x 4 Latin square design experiment. Data were collected on dry matter intake (DMI), nutrient intake and digestibility. Simple linear regression and correlation were used to assess the degree of relationships between some of the digestion components. There were no significant ($P>0.05$) differences in DMI among the treatment means. The nitrogen intake (g/d) was significantly ($P<0.05$) higher in the animal group fed PSM based diets than in the control group. Faecal nitrogen though higher in the animals fed diets C and D, did not differ significantly ($P>0.05$). Urinary nitrogen was significantly ($P<0.05$) higher in the group fed PSM diets than in the control group. Apparent-nitrogen digestibility was also significantly ($P<0.05$) higher in the treatment groups fed PSM diets than in the control group. The metabolic faecal nitrogen (MFN) and the endogenous urinary nitrogen (EUN) increased with increasing levels of PSM. The biological value (BV) and digestible crude protein (DCP) also increased significantly ($P<0.05$) with increasing dietary levels of PSM. The results of this study indicated that the inclusion of boiled pigeon pea seed meal at 30% level enhanced digestibility and nutrient utilization by West African Dwarf sheep.

Key words: Nutrient intake, digestibility, rams, pigeon pea, meal, diets

Introduction

The increase in world population especially in developing countries like Nigeria calls for urgent improvement in livestock production. It is believed that deficiency of animal proteins is one serious nutritional problem that needs urgent intervention in Nigeria and other African countries. Small size, slow rate of growth and poor productive and reproductive performance of livestock in

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Nigeria are accounted for the poor consumption of protein of animal origin. Animal proteins content in diets of most Nigerians are very low and have reached a crisis level. Average consumption of animal protein in this country is estimated at 4.5g/head/day as against the minimum requirement of 35g/head/day recommended by the Food and Agricultural Organization of the United Nation (Atsu, 2002).

Sheep are among the most important livestock species in Nigeria with an estimated population of approximately 22.09million heads (Okali and Lipton, 1984). There is large market for sheep and goats in the Southern Nigeria; hence there is mass importation/movement of these small ruminants from the North of the country due to inadequate number of the animal produced in the south (Okali and Lipton, 1984). It is interesting to note that the total world consumption of sheep's milk (8.2×10^6 tonnes per year) is slightly higher than that of goats milk (7.7×10^6 tonnes per year) (Okali and Lipton, 1984).

On the average, less than 2% of all the milk consumed by humans is from sheep. However, in developing and indeed most tropical countries sheep produce about 4% of all milk consumed by humans. In Syria 46% of milk is produced by sheep, and in four countries in the Near East the proportion is over 20% (FAO, 1083).

Conventional protein and energy feedstuffs are expensive and their use in ruminant nutrition competes with monogastric animals and human nutrition. There is need to address this problem of scarce feed resources in ruminant animal nutrition especially the protein concentrates. This can be achieved by searching for alternative protein feedstuff that attracts less competition from monogastric animals and humans. Nature has endowed Many varieties of legumes synthesize a wide variety of chemical substances known to exert deleterious effect when ingested by animals. Pigeon pea seeds contain such anti-nutritional factors like trypsin, chymotrypsin, polyphenolic compounds and amylase inhibitors which tend to inhibit the activity of digestive enzymes thereby causing digestive losses (Ani and Okeke, 2003). The use of these legumes is encumbered by the presence of these proteolytic inhibitors and other anti-nutritional factors, many of which are heat-labile and others heat-stable. Pigeon pea seed is reported to contain hemagglutinin (Amaefule, 2002) which is known to affect the blood formation in animals by reduction of PCV (Akinmutimi, 2004). Ene-Obong (1985) has also reported the presence of tannins in pigeon pea seed. Raw pigeon pea seed are rich in protein (18.5 - 31.1%) and carbohydrate (36.0 – 66.0%) depending on the variety (Kay, 1979).

It has a biological value of 60% (Oyenuga, 1968). The high protein genotypes contain significantly higher (about 25%) sulphur – containing amino acids, namely methionine and cystine (Singh *et al.* 1990). Pigeon pea is a good

source of dietary minerals such as calcium, phosphorus, magnesium, iron, sulphur and potassium. It is a good source of water-soluble vitamin, especially thiamine, riboflavin, niacin and cholines.

When alternative feedstuffs which attract little or no competition between human and livestock are used as feed resources for animals, cost of production is generally reduced. Although pigeon pea seed meal, as an alternative feedstuff has been used in monogastric animals feeding trials, there is still paucity of information on its use for sheep nutrition. This study was therefore designed to evaluate the yield and composition of milk of West African Dwarf sheep fed graded levels of dietary pigeon pea seed meal.

Materials and methods

Location

This study was carried out in the Sheep/Goat unit of the Teaching and Research farm of Michael Okpara University of Agriculture, Umudike. Umudike is in Abia State of Nigeria, located on latitude 05^{o} 28´ North and longitude 07^{o}31´ East and lies at an altitude of 122 meters above sea level. It lies within the tropical rainforest zone characterized by average annual rainfall of 2,177mm in 148-155 rain days. Average ambient temperature was 25.5 ^{o}C with minimum and maximum temperatures of 22^{o}C and 29^{o}C respectively. Relative humidity ranged from 76-87% (NRCRI, 2004).

Procurement and Processing of experimental material

The pigeon pea seeds used in this study were purchased from open markets in Enugu, the Capital of Enugu State. The pigeon pea seeds were cleaned up by winnowing, and the clean seeds boiled for 30 minutes at about 100^{o}C as earlier reported by Kaankula *et al.* (2000). The seeds were then dried on a concrete floor for 3 days before milling in a grinding machine to cracked sizes of 2-4 parts/seed.

Experimental diets

The processed pigeon pea seeds were used to formulate four diets, at 0, 10, 20 and 30% levels designated A, B, C and D respectively. The ingredients and composition of the experimental diets are shown in Table 1.

Table 1. The Composition and proximate constituents of experimental diets and pigeon pea seed meal

Ingredients(%)	Diets				
	A	**B**	**C**	**D**	**PSM**
Cassava peel	52.50	52.50	52.00	45.50	
Pigeon pea	0.00	10.00	20.00	30.00	
Maize offal	35.50	25.50	16.00	12.50	
Palm kernel cake	10.50	10.50	10.50	10.50	
Bone meal	1.00	1.00	1.00	1.00	
Common salt	0.50	0.50	0.50	0.50	
Total	100.00	100.00	100.00	100.00	
Chemical Composition (% DM)					
Dry matter (%)	87.00	87.10	86.70	86.60	93.16
Crude protein	6.80	7.20	8.37	9.54	20.50
Crude fibre	9.27	9.93	11.96	10.13	6.52
Ether extract	1.31	2.18	1.30	2.17	2.42
Ash	6.53	7.40	5.64	6.50	4.24
N-free extract	63.09	60.39	59.43	58.26	59.48
*ME (MJ/kgDM)	1.50	1.51	1.52	1.53	1.74

*Calculated
PSM = Pigeon pea Seed Meal

Experimental animals, design and management

Four mature WAD rams weighing between 16.0kg and 19.0kg were used in the study. The rams were selected from the Teaching and Research farm of Michael Okpara University of Agriculture, Umudike. The animals were first dewormed and also bathed with acaricide against external parasites, using Ferbendazole and Pfizona respectively. They were subsequently housed in previously disinfected metabolism cages. Each animal was fed one of the four experimental diets (Table 3.1) in a 4 x 4 Latin square design. During phase 1 which lasted 21 days each animal received 1kg of one of the 4 experimental diets. Potable water was offered *ad libitum* to each animal daily. Daily voluntary feed intake was determined by weighing the quantity offered and the refusal. Total faeces and urine voided by the experimental animals were collected during the last 7 days (21^{st} – 28^{th}). In phases 2-4 each animal was offered each of the remaining 3 experimental diets in rotational periods of 28 days each. The last 7 days in each of the feeding period, was also used for total urine and faecal collection. Samples of each diet was collected and used for dry matter (DM) determination and chemical composition analysis. Total faeces were collected in the mornings before feeding and watering during days 21 – 28 of each period. The faeces were weighed fresh, dried and bulked for each animal. A sub-sample from each animal was dried in forced draft oven at

100-105^{o}C for 48 hours for DM determination. Another sample was dried at 60^{o}C for 48-72 hours for determination of proximate composition. Total urine for each animal was collected daily as in the faeses. The urine was trapped in a graduated transparent plastic container placed under each cage and to which 15ml of 25% H_2S0_4 had been added daily to reduce volatilization of ammonia from the urine. The total volume of urine output per animal was measured and about 10% of the daily outputs were saved in plastic bottles labeled and stored in deep freezer at -5^{o}C. At the end of each 7-day collection period, the sample collections were bulked for each animal and sub-samples taken for analysis.

Analytical procedure

All feed and faecal samples were analysed for proximate composition using the official analytical methods (AOAC, 2000). Nitrogen in urine samples was also determined according to AOAC (2000).

Statistical analysis

The data obtained from this study were subjected to analysis of variance (ANOVA) applicable to a 4 x 4 Latin square experiment (Steel and Torrie, 1980). Differences between treatment means were determined by Duncan's multiple range test (SAS, 1999).

Results

The nutrient composition of the experimental diets is presented in Table 1. The dry matter intake (DMI), nutrient intake and digestibility by WAD sheep fed graded levels of dietary pigeon pea seed meal are presented in Table 2.

Table 2. Feed intakes and digestibility in WAD sheep fed graded levels of dietary pigeon pea seed meal

Parameters	Diets				
	A	B	C	D	SEM
Mean wt.(kg)	17.75	17.63	18.00	17.88	0.18
Mean wt. ($Wkg^{0.75}$)	8.65	8.60	8.74	8.69	0.06
DMI(g/day)	532.88	553.45	574.39	557.49	23.61
DMI ($Wkg^{0.75}$)	61.73	64.64	65.93	64.23	2.47
DMI as % BW	3.01	3.16	3.21	3.13	0.12
CP intake (g/day)	36.24^{b}	39.85^{b}	48.12^{a}	53.19^{a}	1.74
Total N-intake (g/day)	5.80^{b}	6.38^{b}	7.70^{a}	8.51^{a}	0.28
Faecal-N (g/day)	2.51	2.15	2.62	2.74	0.23
Urinary-N (g/day)	0.69^{c}	1.14^{bc}	1.41^{b}	2.48^{a}	0.14
N-balance (g/day)	2.60	3.09	3.67	3.29	0.34
N-balance ($g/dWkg^{0.75}$)	0.31	0.36	0.42	0.38	0.04
Absorbed-N (g/day)	3.29^{c}	4.23^{b}	5.08^{ab}	5.77^{a}	0.26
Absorbed-N ($g/dWkg^{0.75}$)	0.38^{c}	0.49^{b}	0.58^{ab}	0.66^{a}	0.03
N-intake ($g/d/Wkg^{0.75}$)	0.67^{c}	0.74^{c}	0.89^{b}	0.98^{a}	0.03
Apparent-N digestibility (%)	56.20^{b}	65.82^{a}	66.42^{a}	68.06^{a}	2.61

[a, b, c] Means on the same row with different superscripts differ significantly($P<0.05$)

The values of DMI expressed as percentage of body weight were 3.01, 3.16, 3.21 and 3.13% for sheep fed diets A, B, C and D, respectively. Nitrogen intake values (g/d) were higher for the PSM diets than the control diet.

Nitrogen output (faeces and urine) increased with increase in N-intake except for diet B which recorded lower faecal nitrogen value than diet A. The faecal-N values were 2.51, 2.15, 2.62 and 2.74 for diets A, B, C and D, respectively. The urinary nitrogen values were significantly influenced by dietary pigeon pea seed meal.The N-balance (g/d) values were similar ($P>0.05$) for all the treatments. The values were 2.60, 3.09, 3.69 and 3.29 for diets A, B, C and D, respectively.

Nitrogen absorbed (g/d) by the animals increased in the same pattern as the N-intake from diets A to D. All the PSM diets recorded significantly ($P<0.05$) higher absorbed – N than the control. The values (g/d) obtained were 3.29, 4.23, 5.08 and 5.77 for diets A, B, C and D, respectively.

Apparent-N digestibility followed the same pattern as absorbed-N and increased with increased CP in diets. Faecal-nitrogen (g/kg DM) was positively correlated with N-intake (g/d) (Table 3).

Table 3. Regression analysis and correlation coefficient between faecal-N (g/kg/DM) (Y) and N-intake (g/day) (X) in WAD sheep fed graded levels of dietary pigeon pea seed meal

Diets	Regression Equation	Correlation Coefficient(r)	Std. Error	Intercept on Y-axis	MFN g/100g
A	Y=0.713+0.084X	0.588ns	0.081	0.713	0.071
B	Y=0.793+0.067X	0.329ns	0.390	0.793	0.079
C	Y=0.930+0.052X	0.323ns	0.277	0.930	0.093
D	Y=0.950+0.043X	0.190ns	0.296	0.950	0.095

ns = not significant

The coefficients of correlation (r) between faecal-N and N-intake were 0.588; 0.329; 0.323 and 0.190 for diets A, B, C and D respectively. The intercept on the ordinate axis gave the nitrogen excreted in faeces for each diet, when the nitrogen intake was hypothetically zero, which is the metabolic faecal-nitrogen (MFN). The values of MFN ranged from 0.071 to 0.095g/100g DM, with the values increasing as nitrogen intake increased progressively from diet A to D.

The relationship between urinary-nitrogen (g/day/Wkg$^{0.75}$) and absorbed nitrogen (g/day/Wkg $^{0.75}$) in this study is presented in Table 4.

Table 4. Regression analysis and correlation coefficient between urinary-N (g/d/Wkg$^{0.75}$) (Y) and absorbed-N (g/d/Wkg$^{0.75}$) (X) in WAD sheep fed graded levels of dietary pigeon pea seed meal

Diets	Regression Equation	Correlation Coefficient(r)	Std. Error	Intercept on Y-axis	EUN/day/Wkg$^{0.75}$ g/100g
A	Y=0.028+0.155X	0.865**	0.070	0.028	0.028
B	Y=0.061+0.247X	0.951***	0.058	0.061	0.061
C	Y =0.095 + 0.541X	0.726**	0.011	0.095	0.095
D	Y =0.175+0.582X	0.984***	0.042	0.175	0.175

** (P<0.01); *** (P<0.001)

These parameters indicated positive correlation for all the diets, A to D, and were significantly different at different levels of probability. The coefficient of correlation and their significant levels were A (r = 0.865; P<0.01); B (r = 0.951; P<0.001); C (r = 0.726; P<0.01) and D (r = 0.984; P<0.001). Diets C and D which indicated highest absorbed nitrogen (Table 2) were also highly correlated (P<0.001) with the urinary nitrogen. The intercept on the Y axis gave the urinary nitrogen value at zero nitrogen absorption, which is the endogenous urinary nitrogen (EUN) in g/day/Wkg$^{0.75}$). The values obtained in this study were 0.028, 0.061, 0.095 and 0.175 for diets A, B, C and

D, respectively. The mean EUN value of 0.09±0.06 obtained in this study was close to the 0.06 g/day/WKg$^{0.75}$ reported by Akinsoyinu (1974) for WAD goats. The EUN values increased as nitrogen intake increased progressively from animals fed diet A to those fed diet D.

Nitrogen balance (g/day/WK$^{0.75}$) was linearly and positively correlated with absorbed nitrogen (g/day/Wkg$^{0.75}$) as shown in Table 5.

Table 5. Regression analysis and correlation coeficients between N-balance (g/day/WKg $^{0.75}$) (Y) and absorbed-N (g/day/Wkg $^{0.75}$) (X) in WAD sheep fed graded levels of of dietary pigeon pea seed meal

	Regression Equation	Correlation Coefficient(r)	Std. Error	N-absorbed at zero N-balance	Biological Value	DCP for maintenance g/d/Wkg$^{0.75}$
A	Y=0.081+0.540X	0.957***	0.065	0.081	54	0.51
B	Y=0.092+0.581X	0.986***	0.058	0.092	58	0.58
C	Y=0.129+0.727X	0.875**	0.011	0.129	73	0.81
D	Y=0.134+0.758X	0.994***	0.041	0.134	76	0.84

** (P <0.01); *** (P<0.001)

The correlation coefficient and the significant levels for each of the diets were A (r=0.957; P<0.001); B(r=0.986; P<0.001); C(r=0.875; P<0.01) and D (r=0.994; P<0.001). The gradients of lines relating N-balance to absorbed-N were the indices of biological value (BV) while the absorbed – N at zero N-balance when multiplied by 6.25 gave the digestible crude protein (DCP) requirement for maintenance (Mba *et al.,* 1975). The BV obtained for WAD sheep in this study ranged from 54 -76. The DCP (g/d/WKg$^{0.75}$) obtained in this study were 0.51, 0.58, 0.81 and 0.84% for diets A, B, C and D, respectively, with a mean of 0.69±0.17. Dry matter and nutrient digestibility coefficients are presented in Table 6.

Table 6. Apparent digestibility coefficients (%) of WAD sheep fed graded levels of dietary pigeon pea seed meal

Constituents	Diets				
	A	B	C	D	SEM
Dry matter	60.40	68.73	65.13	70.94	3.61
Crude protein	56.27	65.83	66.41	68.05	2.66
Crude fibre	57.33[d]	62.01[c]	67.05[b]	70.11[a]	0.70
Ether extract	66.99[c]	69.00[bc]	74.86[ab]	76.12[a]	2.32
N-free Extract	65.64	72.19	69.91	76.31	4.10
Energy	63.98[b]	72.14[ab]	69.23[ab]	74.74[a]	2.86

[a, b, c,d] Means on the same row with different superscript differ significantly ($p<0.05$)
These values did not differ significantly ($P>0.05$).

Crude protein followed a progressive pattern in digestibility. The values, however, did not indicate any significant difference ($P>0.05$). The crude fibre digestibility showed significant differences among the treatment groups ($P<0.05$). The values were 57.33, 62.01, 67.05 and 70.11 percent for diets A, B, C and D, respectively. The ether extract digestibility values also increased progressively from diet A to D. The values were 66.99, 69.00, 74.86 and 76.12 percent for diets A, B, C and D, respectively, and indicated significant difference ($P<0.05$) among the treatment groups. However, the values for A and B, B and C, and C and D were similar ($P>0.05$).

Nitrogen-free extract and energy digestibility followed the trend observed in DMD. The values, however, did not differ statistically ($P>0.05$). The energy digestibility values (%) were A (63.98); B (72.14); C (69.23) and D (74.74) and these differed significantly ($P<0.05$). Values for A, B and C were similar ($P>0.05$) as well as the values for B, C and D. DMD was positively correlated with N-free extract and energy digestibility from the observations in this study.

Discussion

There were no significant differences in DMI among the treatment groups ($P>0.05$); however, diet C recorded highest DMI (574.93g/d) followed by diet D (557.498g/d) and B (553.46g/d), while diet A (532.88g/d) was lowest. This observation is contrary to the inverse relationship between DMI and fibre content of feed established by Reid and Kloptenstein (1983). However, it agrees with the observation of Ahamefule (2005) who reported a higher DMI for diets with high fibre content than those with low fibre content. Meanwhile, the comparatively low DMI recorded by animals fed diet A might be in response to the nitrogen content of the diet. DMI is positively correlated with

dietary nitrogen (Rajpool *et al*. 1981) and according to Malacheck and Provenza (1981), low nitrogen contents of feed significantly reduce the DMI of feeds. The nitrogen contents of the experimental diets in this study could not be adjudged too low as the crude protein level of the lowest (6.80%) was close to the 7.00% which is the minimum requirement for small ruminants reared in the tropics (Devendra and Mcleroy, 1987). The DMI, though higher for the PSM diets, did not indicate significant differences ($P > 0.05$). The results of the present study however, indicated that nitrogen intake is positively correlated with DMI as earlier reported by Rajpool *et al.* (1981) and Ahamefule (2005).

The increasing levels of PSM in the diets might probably have promoted nutrient harmony in diets, with the best synchronization of available nutrients at the 20% PSM diet. Dry matter intake expressed as percentage of body weight did not differ among the treatment groups ($P>0.05$). The values suggest that animals fed various diets showed positive DMI status by consuming within 3% of their body weight which is the recommended daily DMI for small ruminants reared for meat in the tropics (Devendra and Mcleroy, 1987). The N-intake values were significantly ($P<0.05$) higher for diets C (7.70g/d) and D (8.51g/d) compared with diets A (5.80 g/d) and B (6.38g/d). The N-intake values increased progressively as the level of PSM increased in the diet. This agrees with values reported elsewhere (Rajpool *et al*., 1981; Preston and Leng, 1986).

Faecal nitrogen values were not influenced by diets ($P>0.05$). Black *et al.* (1978) and Ahamefule (2005) had also earlier observed that faecal – nitrogen was not significantly affected by nitrogen intake. This might suggests that one single factor like nitrogen intake; protein quality or nutrient relationship could not adequately serve as an index for faecal-N, but the interactions of these factors. The significant ($P<0.05$) urinary-N values observed among animals on different treatment diets might be due to variation in nitrogen metabolism and/or nitrogen intake. Animals on diet A consumed less DM, less nitrogen and should excrete less nitrogen in urine. This had earlier been reported by Ibeawuchi *et al*. (1993). The concentration of ammonia in the rumen fluid would depend on the quantity and solubility of protein fed to animals (Ranjah, 1981). It is therefore possible that the PSM protein was very soluble, thereby releasing more rumen ammonia as the level of PSM increased in the diets from B to D. This might probably explain the higher urinary-N values obtained in the animals fed the PSM diets than the control. Animals on diets C and D recorded significantly ($P<0.05$) higher urinary-N than those on diet A. It could also be adduced that urinary-N is more positively correlated with N-intake than is faecal-N. The positive N-balance (g/d) values obtained for all the treatment diets indicated that the maintenance requirements of the experimental animals were adequately met by the rations they consumed. This is explained by the

fact that none of the experimental animals lost weight during the study. The increasing values of absorbed N- as level of PSM increased in the diet might again indicate high protein quality of PSM. The increasing apparent-N digestibility with increased CP in the diets agrees with the reports elsewhere (Ikhatua and Adu, 1981; Olaleru and Adegbola, 2001). The values of coefficients of correlation (r) between faecal-N and N-intake did not differ significantly ($P>0.05$). The MFN values obtained in this study were lower than the 0.24g/100g DM reported by Ellis (1956) for ruminants. However, this variation might be due to differences in breeds and even within breed, and also nutrition, environmental conditions and seasons when studies were conducted might lead to variations. The higher EUN values might be due to increased N-intake, as earlier reported by Ibeawuchi *et al.* (1993) that animals which consumed less nitrogen excreted less urinary nitrogen. Endogenous urinary nitrogen is the differential between protein catabolism and re-synthesis, which is wasted as urine (Akinsoyinu, 1974). The mean BV (65.25 ± 10.87) obtained in this study agrees with the 65 often quoted for ruminants, but lower than the 98 obtained for Red Sokoto goats (Mba *et al.* 1975). The mean DCP ($g/d/WKg^{0.75}$) value, 0.69±0.17 compared favourably with the range of 0.63 – 0.68$g/d/WKg^{0.75}$ DCP reported by Akinsoyinu (1974) for goats for maintenance. Variability in DCP arises from the experimental technique, particularly if a variety of nitrogen free, low-nitrogen or nitrogen-rich diet is given (Devendra and Mcleroy, 1987). Whatever diet is used, it is important that adequate energy is provided. Devendra and Burns (1983) had earlier reported that DMI is an important factor in the utilization of feed by ruminant livestock.

The results of crude fibre digestibility in this study showed that crude protein content of diets was positively correlated with the CPD and crude fibre digestibility (CFD). This agrees with reports elsewhere (Owen, 1983; Ash, 1990; Olaleru and Adegbola, 2001; Fasae *et al*., 2005) that CFD and CPD decrease with decreasing level of CP in diets. A very important consideration in the utilization of nutrients by animals may be the synchronization of nutrients especially protein and energy. This had earlier been observed by French *et al.* (2001).

Conclusion and recommendation

The quality of livestock feed can be assessed in three major ways, viz; laboratory analysis, digestibility study and feeding trail. Digestibility study gives an insight as to what is available to the animal after digestion for its physiological functions. This of course varies depending on the feed and animal (species and individual). In this study therefore, is slightly decreased in nitrogen balance from 3.67g/d to 3.29g/d at 20% and 30%PSM levels

respectively. It is therefore recommended that boiled PSM should not be included at levels beyond 30% in WAD sheep diets.

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