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Full Length Research Paper

Potential of farm-produced crop residues as protein sources for small-medium yielding dairy cows

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The nutritive value of fifteen crops and by-products were investigated in terms of the protein and energy value for rumen microbial protein synthesis using *in-situ* and mobile bag techniques. The sunflower feedstuffs and the cotton seed cake have low digested carbohydrates, which may limit optimum microbial protein synthesis, while forage legumes and cereals have higher digested carbo-hydrates (P< 0.05). Thus, one way of improving protein digestibility protein rich crops is to feed them with cereal crops. The cereal grains (maize, sorghum and pearl millet) and the forage legumes (groundnut and cowpea tops) showed a negative protein balance value, suggesting that nitrogen limited optimum microbial protein synthesis in relation to the available carbohydrates (P< 0.05). The nitrogen (N) content of the ram press sunflower cake (43 g/kg DM) was within the range of the N content found in the commercial dairy concentrates (32 - 57 g/kg DM). However, the N in the sunflower was more degradable in the rumen (92%) than that in the commercial dairy concentrate (P < 0.05). It can therefore, be concluded that the ram press sunflower cake is potential source of N for small-medium yielding dairy cows.

Key words: Crop residues, energy, digestible, microbial protein, sunflower.

INTRODUCTION

Grazing systems on the smallholder farms offer limited potential for dairy production in Zimbabwe. The animals suffer severe nutritional stresses in the dry-season when the rangelands are of low nutritional value and usually in short supply (Manyuchi and Ngongoni, 1993). As a result of these dry-season adverse conditions, animals lose weight, body condition and have low milk yields, low con-ception rates and increased calf mortalities, all of which culminate into heavy economic loses to the smallholder farmers (Ngongoni et al., 2006). In addition, high prices and unavailability of protein-rich commercial concentrates in the smallholder areas exacerbate this problem, and justify the investigation of alternative sources of protein for smallholder dairy animals.

For the majority of smallholder farmers, crop residues from dual-purpose crops constitute 50 - 70 % of total dry matter intake, especially during the dry season (Ngongoni et al., 2006). The main dominant crop is maize, while sor-ghum, cotton and sunflower are grown in low rainfall are-as. Although most dairy farmers in Zimbabwe produce crop yields with surplus, crop residues and crop by-pro-ducts (cereal milling by- products and oilseed cakes) are rarely used to formulate dairy rations on the farm (Ngon-goni et al., 2006) . The potential of homegrown crops and crop by-products as a source of protein for moderate milk production has not been evaluated in Zimbabwe. To imp-rove efficiency of utilization of the crop residues and crop by-products, it is essential to have a good knowledge of their nutritive value, production and availability (FAO, 1990). This can potentially lead to improvements in the productivity of smallholder dairy production systems.

The objectives of this experiment were to evaluate the nutritive value of homegrown crops and crop by-products as potential sources of protein for the rumen microorga-nisms and for the host animal, and to determine the pro-tein value of the feedstuffs in terms of Amino Acid Truly

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(AAT) absorbed and Protein Balance Value (PBV). The AAT- PBV protein evaluation system (Hvelplund, 1987) is used to estimate the amount of N supply for microbial synthesis in the rumen and the amino acids truly absorbed in the small intestine. It is important to assess protein digestibility in the different feedstuffs because the mobile bag technique has revealed differences in the digestibility of undegraded dietary protein among different feeds and within the same protein sources (Hvelplund et al., 1992).

MATERIALS AND METHODS

Feed samples

Fifteen samples of crop residues and crop by-products mainly used by smallholder dairy farmers in Zimbabwe were randomly collected for nutritive evaluation. The samples included three varieties of sunflower (*Helianthus annus*) (Panar, Masasa and Perodovik), ram press sunflower cake, sunflower heads, groundnuts tops (*Arachis hypogea*), cow pea tops (*Vigna unguiculata*), cottonseed cake (a commercial high protein concentrate), milk flow (a conventional commercial dairy meal), maize grain (*Zea mays*) (white, R215 and yellow, ZS206), corn and cob, snap corn, sorghum (*Sorghum bicolor*) (mapfunde) and pearl millet (mhunga). Samples were dried to a constant weight at 40ºC, ground to pass through 4 mm screen, packed and air-freighted to the Research Centre Foulum, Denmark, where the experiment was conducted.

Animals and feeding

Three multi-parous dry Holstein cows, surgically fitted with a rumen cannula were used. The cows weighed 681 ± 19.8 kg at the beginning of the experiment. The ruminal cannulae were made of soft silicone and measured 10.2 cm in diameter. The cows were kept in individual stalls with rubber mat bedding and were tethered by chain to prevent turning. They received slightly above maintenance diet (5.4 kg DM) of 70% hay and 30% concentrate in two equal parts twice per day. Water was available *ad libitum* from the drinking nipple.

Rumen degradability

Rumen degradability of DM and N in the feedstuffs was determined using the *in situ* (nylon bag) technique (Mehrez and Ørskov, 1977) described by Kristensen et al. (1982) and modified by Madsen and Hvelplund (1984). The bag residues from high fibre feeds (groundnut tops, cowpea tops, sunflower heads, snap corn and corn and cob) were treated in the stomacher for 5 min to remove microbial contamination of the bag residues (Sharpe and Jackson, 1972; Michalet-Doreau and Ould-Bah, 1992). Effective degradability was calculated according to McDonald (1981) with a particle passage rate of 5%/h which seems justified at the feeding level likely to be used with these feeds (Ganev et al., 1979).

Estimation of particle loss

Particle loss was measured according to the method of Weisbjerg et al. (1990). For some feeds, especially compounded and starch rich feedstuffs including whole crop cereals, part of the non water soluble particles may leave the nylon bag through the pores and thus are estimated as being degraded (Hvelplund et al., 1995).

AAT-PBV system

The AAT-PBV protein evaluation system of Hvelplund and Madsen (1995) was used to estimate the amount of N supply for microbial synthesis in the rumen (PBV) and the amino acids truly absorbed in the small intestine. The AAT-PBV protein evaluation system is based on formulae expressed by factors (Hvelplund and Madsen, 1985), which are either constants or variables and are related to analysis of the feeds.

AAT g/kg DM
= g crude protein/kg DM
x (1-degradability in the rumen)
x proportion of amino acids in undegraded feed protein (0.85)
x digestibility in the small intestine of undegraded amino acids
+ g microbial protein produced per kg DM
x proportion of AA in microbial protein (0.70)
x digestibility in the small intestine of microbial amino acids (0.85)

PBV g/kg DM
= g crude protein per kg DM
x degradability in the rumen
- microbial protein produced per kg DM

Microbial amino acid nitrogen (g/kg DM) is obtained from digested carbohydrates (NFE + crude fibre) * 0.02 (Hvelplund and Madsen, 1985). Digested carbohydrates can be calculated as digested organic matter–(digested crude protein + digested crude fat) (Hvelplund and Madsen, 1985). The digestibility of amino acids in undegarded feed protein has been found to be a variable, measured using the mobile bag technique (Hvelplund et al., 1992)

Chemical analysis

Feed samples were analyzed for dry matter (DM), nitrogen (N), fat (ether extract), calcium (Ca) and phosphorus (P) according to conventional procedures (AOAC, 1990). Neutral Detergent Fibre (NDF) was determined according to Van Soest et al., *(*1991), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL) was determined according to Goering et al. (1972). The water insoluble ash in all samples was determined by soaking the test feed in 50 ml of distilled water (20ºC) for 1 h in glass fibre crucibles of known weight. The porous base was rubber stopped to prevent water loss. The samples were washed in distilled water through a vacuum pump. The residue was air dried and ashed in a muffle furnace for 3 h at 600ºC. Cell wall and ADF were estimated by reflux according to Faichney and White (1983). Hemi-cellulose was estimated as the difference between NDF and ADF while cellulose was estimated as the difference in weight between ADF and the residue after digestion in 72% sulphuric acid (H_2SO_4). Lignin was estimated as the DM disappearance from the residue left form the 72% H_2SO_4 digestion after ashing at 600ºC for 3 h.

Statistical analysis

The data were analyzed using the NLIN Procedure (SAS, 2000) for estimation of degradation constants. Means were compared using Fischer's least significant differences when the F-test was significant at $P < 0.05$.

RESULTS

The chemical composition of the feedstuffs is shown in Table 1. The N content varied with the highest values ob-

Table 1. Chemical composition of farm-produced crop and crop residue feed ingredients available in the smallholder sector.

Feedstuff type	Chemical composition (g/kg DM)					
	OM	N	EE	Ash	Ca	P
Sunflower based feed stuffs						
Panar seed	968	32^{b}	467^{a}	32^{d}	2^{c}	5^{ab}
Masasa seed	977	21^{c}	302^{b}	23^{d}	1^{c}	3^{c}
Perodovik seed	974	25^{c}	323^{b}	26^{d}	2^{c}	4^{ab}
Ram press sunflower cake	957	43^{a}	315^{b}	43^{c}	2^{c}	6^{a}
Sunflower heads	933	12^{e}	148^{c}	67^{b}	10^{a}	2^{c}
Cotton based feed stuffs						
Cottonseed cake	939	57^{a}	19^{f}	61^{c}	2^{c}	10^{a}
Dairy concentrate	943	32^{b}	22^{f}	57^{c}	4^{b}	7^{a}
Forage feedstuffs						
Groundnut tops	943	14^{e}	15^{f}	107^{a}	11^{a}	2^{c}
Cowpea tops	930	16^{d}	13^{f}	70^{b}	8^{a}	1^{c}
Cereal based feed stuffs						
Yellow maize	988	19^{d}	41^{e}	12^{d}	0.06^{d}	2^{c}
White maize	986	18^{d}	48^{d}	14^{d}	0.08^{d}	2^{c}
Pearl millet (mhunga)	937	23^{c}	51^{d}	27^{c}	2^{c}	3^{c}
Sorghum (pfunde)	984	19^{d}	35^{e}	16^{d}	0.09^{d}	2^{c}
Corn and cob	988	16^{c}	36^{e}	12^{d}	0.08^{d}	2^{c}
Snapcorn	987	16^{c}	40^{e}	13^{d}	0.01^{d}	2^{c}

[a,b,c,d,e,f] Means in the same column with different superscripts differ significantly $P< 0.05$.

served in cotton seed cake (57 g/kg DM) and the ram press sunflower cake (43 g/kg DM) compared with the other feedstuffs (12 - 32) g/kg DM) ($P< 0.05$). The N content also varied according to the sunflower variety (21-32 g/kg DM) with Panar having more N (32 g/kg DM) than Perodovik (25 g/kg DM) and Masasa (21 g/kg DM) ($P< 0.05$). The conventional dairy concentrate had a similar N content to that of Panar seed. The N content in cereal grains (maize grain, pearl millet and sorghum) ranged from 19 - 23 g/kg DM with pearl millet having the highest N (23 g/kg DM) ($P< 0.05$). The N content in the sunflower head (12 g/kg DM) was comparable to that of the groundnut tops (14 g/kg DM) while the groundnut tops, cowpea, corn and cob and snapcorn had a similar N content (16 g/kg DM).

The oil content as ether extract (EE) was highest in the sunflower feedstuffs (315-467 g/kg DM) compared to that of the other feedstuffs (13 - 51 g/kg DM) ($P< 0.05$). The sunflower heads had significantly more oil than the forage legumes and the cereal-based feedstuffs. The oil content varied with sunflower variety, Panar (467 g/kg DM) yielding significantly more than Perodovik and Masasa (323 and 302 g/kg DM), respectively. The ram press sunflower cake and the empty sunflower head contained a substantial amount of residual oil (315 and 148 g/kg DM), respectively. White maize and pearl millet (48 - 51, corn and cob, snapcorn and yellow maize (35-41 g/kg DM) ($P< 0.05$). However, the forage legumes (cowpea and groundnut tops) showed the least oil content (13 - 15 g/kg DM) compared with the other feedstuffs ($P< 0.05$). The forages (groundnut tops, cowpea and sunflower heads) and sunflower feedstuffs, respectively contained more ash with a higher calcium content in forages and more phosphorus in the sunflower feedstuffs, cottonseed cake and the conventional concentrate than in the cereals (cereal grains and their by-products) ($P< 0.05$).

Table 2 shows the fibre content of the feedstuffs. The NDF of most of the feedstuffs was above 200 g/kg DM with a wide variation (225 - 462 g/kg) ($P< 0.05$). Exceptions to this were the cereal grains, which had lower cell wall content (136-141 g/kg DM) ($P< 0.05$) . The ADF followed a similar pattern to the NDF content in which significantly lower values were observed in cereal grains (30 - 33 g/kg DM), than in the other feedstuffs (85 - 338 g/kg DM). Generally, cereals showed a higher hemi-cellulose (103 - 172 g/kg DM) and lower lignin content (7 - 13 g/kg DM) than the sunflower feedstuffs ($P< 0.05$). Generally, a high level of lignin was observed in sunflower, forage and cottonseed cake with highest values in sunflower heads and Masasa ($P< 0.05$). Forage feedstuffs had highest cellulose levels (257 - 262 g/k DM) ($P< 0.05$).

Table 3 shows effective degradability (ED) of dry matter g/kg DM), respectively contained more oil than sorghum, (DM) and nitrogen (N), calculated using an assumed rumen fractional outflow rate of 5%/h, both uncorrected and corrected for particle loss, filter paper water solubility, tot-

Table 2. Proportion of fibre fractions in the homegrown feedstuffs.

Feedstuff type	Fibre proportions (g/kg DM)				
	NDF	ADF	Hemicellulose	Cellulose	Lignin
Sunflower based feed stuffs					
Panar seed	225^{c}	177^{b}	48^{d}	75^{c}	102^{a}
Masasa seed	421^{a}	338^{a}	83^{c}	205^{a}	133^{a}
Perodovik seed	363^{B}	284^{a}	79^{c}	174$^{\mathbf{a}}$	110^{a}
Ram press sunflower cake	253^{c}	176^{b}	77^{c}	89^{c}	87^{b}
Sunflower heads	339^{B}	257^{a}	82^{c}	135^{a}	122^{a}
Cotton based feed stuffs					
Cottonseed cake	352^{B}	251^{a}	111^{a}	156^{a}	95^{b}
Dairy concentrate	395^{a}	138^{b}	117^{a}	87^{c}	45^{c}
Forage feedstuffs					
Groundnut tops	402^{a}	324^{a}	78^{c}	257^{a}	67^{b}
Cowpea tops	462^{a}	346^{a}	116^{b}	262^{a}	84^{b}
Cereal based feed stuffs					
Maize (yellow)	138^{d}	30^{c}	108^{b}	23^{d}	7^{d}
Maize (white)	140^{d}	31^{c}	109^{b}	23^{d}	8^{d}
Pearl millet (mhunga)	136^{d}	33^{c}	103^{b}	23^{d}	10^{d}
Sorghum (mapfunde)	141^{d}	33^{c}	108^{b}	25^{d}	8^{d}
Corn and cob	227^{c}	85^{b}	142^{a}	72^{c}	13^{d}
Snapcorn	272^{c}	100^{b}	172^{a}	88^{c}	12^{d}

[a,b,c,d] Means in the same column with different superscripts differ significantly P< 0.05.

al tract and the true intestinal digestibility of the undegraded dietary protein. The N in sunflower is significantly more degraded (89.6 - 93.4 %) than that in the other feedstuffs (45.3 -78.7%) (P < 0.05). Cowpea and cereals (except pearl millet, 69.0%) had the lowest N degradabilities (38.0 - 54.9%) (P < 0.05). The degradability of N and DM in the sunflower head (73.4 and 74.8%, respecttively) was comparable to that in the groundnut tops (78.7 and 65.7% respectively). The effective degradabilities corrected for particle loss were lower than those that were not corrected.

The total true tract digestibilities of N measured using the mobile bag technique after 16 h of rumen pre- incubation and the true small intestinal digestibilities of the undegraded dietary protein (UDN) calculated according to Hvelplund et al. (1992) are presented in Table 3. The mobile bag intestinal digestibilities of N in the sunflower and cotton based feedstuffs were significantly higher (84.2 - 94.2%) than those of the forage legumes (74.7 - 77.9%) and the cereals (57.8 - 61.3%) (P < 0.05). The true digestibility of the UDN was significantly higher in the ram press sunflower cake and cottonseed cake (70.8 and 72.9%, respectively) than in the other feedstuffs (20.3 – 66.2%).

The *in sacco* degradation constants for DM and N of the feedstuffs are shown in Tables 4 and 5. The water-soluble fraction 'a' for both DM and N in the sunflower 0.05). On the contrary, the potentially degradable fraction feedstuffs was higher than in the other feedstuffs (P < 'b' for DM was significantly lower in the sunflower seeds than that in the other feedstuffs. The degradation rate constant 'c' for N in the cereals was lower than that for DM. In the oil-rich and protein-rich feedstuffs, the 'c' rate for N was higher than that for DM (P < 0.05). Generally, the cereals had lower degradation rates than the oil- rich and protein-rich feedstuffs with yellow maize having the lowest values for 'a', 'b' and the 'c' rate constants for N (P < 0.05).

Compared with other feeds, the cottonseed cake and the ram press sunflower cake had more RDP, UDP-AA, UDP-AAT, AAT and PBV (P < 0.05) (Table 6). The DCHO was higher in the cereals (716 - 778 g/kg DM) than in the forages (412 - 586 g/kg DM), conventional dairy concentrate (566 g/kg DM), sunflower feedstuffs (136 - 287 g/kg DM) and cottonseed cake (264 g/kg DM) (P < 0.05) (Table 6). Based on the content of DCHO, microbial AA was significantly higher from the cereals (90-97 g/kg DM) than from the sunflower and forage feedstuffs (17 - 73 g/kg DM). The conventional concentrate gave a significantly higher amount of microbial AA (71 g/kg DM) than the cottonseed cake (33 g/kg DM) and the ram press sunflower (36 g/kg DM). Cereals and forage legumes showed negative PBV values, while positive values were observed in the sunflower, cottonseed cake and the conventional feedstuffs (P < 0.05).

Table 3. Effective degradability (ED) (%) of N and DM at 5% passage rate, mobile bag digestibility and true digestibility of UDN, water-soluble and particle loss (%) of feeds in the smallholder sector.

Feedstuff type	Water soluble	Particle loss	DM ED	N ED	*ED	Mobile bag digestibility[1]	TDN of UDN
Panar seed	13.0[c]	47.8[b]	75.0	93.4[a]	85.3	93.5[a]	55.4[b]
Masasa seed	33.2[a]	48.5[b]	59.7	91.5[a]	68.9	92.8[a]	66.8[b]
Perodovik seed	19.3[c]	66.9[a]	60.4	91.2[a]	48.3	91.9[a]	61.8[b]
Ram press sunflower cake	28.5[b]	42.9[b]	68.3	92.0[a]	80.1	94.2[a]	70.8[a]
Cottonseed cake	10.6[c]	9.6[d]	61.2	70.3[b]	66.7	90.3[a]	72.9[a]
Dairy concentrate	34.3[a]	9.2[d]	64.4	74.7[b]	70.6	84.2[a]	46.4[b]
Sunflower heads	2.4[d]	43.8[b]	74.8	73.4[b]	56.4	63.2[c]	38.7[c]
Groundnut tops	37.5[a]	15.0[d]	65.7	78.7[b]	72.0	77.9[b]	30.9[d]
Cowpea tops	37.5[a]	12.3[d]	55.4	46.1[c]	60.5	74.7[b]	66.2[b]
Yellow maize	15.6[c]	4.8[d]	55.8	38.0[c]	34.2	59.7[c]	39.0[d]
White maize	13.6[c]	7.9[d]	66.1	49.6[c]	44.5	57.8[c]	42.6[d]
Pearl millet (mhunga)	3.1[d]	27.1[c]	74.3	69.0[b]	56.9	58.5[c]	36.0[d]
Sorghum (mapfunde)	12.6[c]	12.0 [d]	6904	54.9[c]	47.8	58.4[c]	20.3[e]
Corn and cob	9.6[c]	19.2[d]	59.9	45.3[c]	30.6	60.7[c]	46.7[b]
Snap corn	6.3[d]	26.9[c]	55.9	45.9[c]	24.1	61.3[c]	24.0[e]

[a,b,c,d] Means in the same column with different superscripts differ significantly P< 0.05 ED= p=a + (b*c)/(c+k) Øskorv and McDonaldI (1979). Water soluble=water soluble through filter paper (%). Particle loss= difference between water soluble and zero hour incubation (%). Corrected *ED= according to equation of (Weinsbjerg et al., 1990) True intestinal digestibility of rumen undegraded protein: TD= (Digestibility-ED corrected= (UDN-TU)/UDN (Hvelplund et al*.,* 1992) (UDN= fraction of undegraded dietary protein; TU= fraction of true indigestible protein in the feed).

Table 4. *In sacco* degradation constants and standard deviations for N of sunflower, cottonseed, cereal and forage based feedstuffs.

Feedstuff Type	Degradation constants			
	a	b	a + b	c
Panar seed	60.9±1.39[1]	34.9±1.51[2]	95.8±1.10[2]	0.821±0.108[1]
Masasa seed	81.9±0.3[1]	11.6±0.33[3]	93.5±0.13[2]	0.267±0.019[1]
Perodovik seed	85.8±0.43[1]	7.9±0.48[3]	93.7±0.07[2]	0.152±0.024[1]
Ram press sunflower cake	72.1±1.7[1]	23.3±1.86[2]	95.4±0.51[2]	0.335±0.061[1]
Cottonseed cake	21.3±0.83[3]	74.3±1.00[1]	93.2±2.90[2]	0.098±0.005[2]
Dairy concentrate	45.3±2.11[2]	48.1±2.66[2]	95.8±2.50[2]	0.079±0.012[2]
Sunflower heads	42.0±3.12[2]	46.8±3.68[2]	88.8±2.39[2]	0.103±0.022[1]
Groundnut tops	51.2±1.55[2]	37.8±1.75[2]	89.0±1.50[2]	0.136±0.017[1]
Cowpea tops	32.5±1.68[2]	24.7±2.42[3]	69.7±1.40[3]	0.058±0.009[2]
Yellow maize	17.4±4.25[3]	21.9±4.65[3]	39.3±2.10[4]	0.005±0.013[2]
White maize	25.8±4.60[3]	92.6±2.23[1]	118.4±6.80[1]	0.01±0.009[2]
Pearl millet (mhunga)	21.7±2.17[3]	80.4±4.05[1]	102.1±6.22[1]	0.035±0.005[2]
Sorghum (pfunde)	30.1±0.69[3]	67.1±0.90[1]	97.2±7.80[2]	0.07±0.003[2]
Corn and cob	26.0±2.77[3]	91.0±2.08[1]	116.0±4.00[1]	0.014±0.006[2]
Snapcorn	32.9±1.68[3]	88.2±3.05[1]	121.1±2.22[1]	0.009±0.005[2]

[1,2,3] Means in the same column with different superscripts differ significantly P< 0.05; a= water soluble fraction; b= potentially degradable not soluble fraction (%); c= degradation rate constant (h^{-1})

Table 5. *In sacco* degradation constants for DM of sunflower, cottonseed, cereal and forage based feedstuffs.

Feedstuff Type	Degradation constants			
	a	b	a + b	c
Panar seed	67.5±0.97^{1}	10.4±1.11^{4}	78.2±0.10^{2}	0.121±0.035^{1}
Masasa seed	54.3±0.0^{1}	10.0±1.23^{4}	64.3±0.10^{2}	0.079±0.029^{2}
Perodovik seed	53.8±1.80^{1}	10.0±2.05^{4}	63.8±0.10^{2}	0.128±0.075^{1}
Ram press sunflower cake	51.0±1.89^{1}	26.6±2.28^{3}	77.5±0.80^{2}	0.094±0.022^{2}
Cottonseed cake	30.1±1.00^{2}	53.5±1.28^{2}	83.7±3.00^{2}	0.071±0.005^{2}
Dairy concentrate	31.8±1.18^{2}	58.4±1.59^{2}	90.2±3.50^{2}	0.064±0.005^{2}
Sunflower heads	49.0±2.49^{1}	36.9±2.87^{3}	85.9±1.50^{2}	0.116±0.024^{1}
Groundnut tops	37.4±2.05^{2}	39.7±2.34^{3}	77.1±1.70^{2}	0.125±0.019^{1}
Cowpea tops	31.9±1.84^{2}	43.8±2.56^{3}	75.7±2.00^{2}	0.060±0.009
Yellow maize	18.0±2.70^{2}	85.7±4.58^{1}	103.6*±6.90^{1}	0.040±0.006^{2}
White maize	25.9±2.85^{2}	74.6±4.00^{1}	100.5*±6.80^{1}	0.06±0.01^{2}
Pearl millet (mhunga)	30.0±2.69^{2}	71.7±3.69^{1}	101.7*±6.40^{1}	0.06±0.009^{2}
Sorghum (mapfunde)	29.6±2.07^{2}	68.4±2.48^{1}	98.0±0.50^{1}	0.09±0.009^{2}
Corn and cob	22.7±2.68^{2}	76.3±4.08^{1}	116.0*±4.00^{1}	0.05±0.007^{2}
Snapcorn	22.5±2.90^{2}	76.6±4.43^{1}	121.1*±2.22^{1}	0.05±0.008^{2}

^{1,2,3,4} Means in the same column with different superscripts differ significantly $P < 0.05$; a= water soluble fraction; b= potentially degradable not soluble fraction (%);c= degradation rate constant (h^{-1}).

Table 6. Rumen degradable protein (RDP), undegradable dietary protein (UDP), digested carbohydrates (DCHO), microbial amino acids (MAA), undegraded protein amino acids (UDP-AA), truly absorbed amino acids (AAT) and Protein balance (PBV) (g/kg) in protein and starch rich farm feedstuffs.

Feedstuffs	RDP	UDP	DCHO	MAA	UDP-AA	MAAT	UDP-AAT	AAT	PBV
Panar seed	149.8^{b}	50.2^{b}	136 ^{c}	17.0^{e}	42.7^{c}	14.4^{e}	39.9^{c}	54.4^{d}	125.5^{a}
Masasa seed	78.4^{c}	52.9^{b}	153 ^{c}	19.1^{e}	45.0^{c}	16.3^{e}	41.7^{c}	58.0^{d}	51.0^{b}
Perodovik seed	94.6^{c}	61.7^{b}	199 ^{c}	24.8^{d}	52.5^{c}	21.1^{d}	48.2^{c}	69.3^{c}	59.1^{b}
Ram press sunflower cake	192.1^{a}	89.2 ^{a}	287 ^{c}	35.9^{d}	75.8^{b}	30.5^{d}	714.4^{b}	101.9^{a}	140.8^{a}
Cotton seed cake	218.1^{a}	138.2^{a}	264 ^{c}	33.0^{d}	117.5^{a}	28.1^{d}	106.1^{a}	134.2^{a}	170.8^{a}
Dairy concentrate	128.8^{b}	71.2 ^{b}	566 ^{b}	70.7^{b}	60.5^{b}	60.1^{b}	51.0^{c}	111.0^{b}	27.8 ^{b}
Sunflower heads	59.9^{d}	20.1^{c}	452 ^{b}	56.5^{c}	17.1^{e}	48.0^{c}	10.8^{d}	58.8^{d}	-20.8 ^{c}
Groundnut tops	57.8^{d}	30.2^{c}	586 ^{b}	73.2^{b}	25.7^{d}	62.2^{b}	20.0^{d}	82.2^{c}	-46.7 ^{c}
Cowpea tops	55.4^{d}	44.6^{c}	422 ^{b}	52.8^{c}	37.9^{c}	44.9^{c}	28.3^{d}	73.2 ^{c}	-20.0 ^{c}
Yellow maize	66.4^{c}	52.6^{b}	778 ^{a}	97.2^{a}	44.7^{c}	82.6^{a}	26.7^{d}	109.3^{b}	-72.4^{d}
White maize	76.0^{c}	39.0^{c}	769 ^{a}	96.2^{a}	33.1	81.7^{a}	19.2^{d}	100.9^{b}	-61.4^{b}
Pearl millet	106.6^{b}	37.4^{c}	732 ^{a}	91.5^{a}	31.8^{d}	77.8 ^{a}	18.6^{d}	96.4^{b}	-24.2 ^{c}
Sorghum	80.5^{c}	35.5^{c}	771 ^{a}	96.4^{a}	30.2^{d}	82.0 ^{a}	17.6^{d}	99.6^{b}	-57.2^{d}
Corn and cob	59.9^{d}	40.1^{c}	745 ^{a}	93.1^{a}	34.1^{d}	79.2 ^{a}	20.7^{d}	99.9^{b}	-73.2^{d}
Snapcorn	59.9^{d}	44.1^{c}	716 ^{a}	89.5^{a}	37.5^{d}	76.0	23.0^{d}	99.0^{b}	-71.9^{d}

^{a,b,c,d} Means in the same column with different superscripts differ significantly $P < 0.05$ MAA= 0.02 x DCHO X 0.625 (Madsen and Hvelplund, 1984); MAAT= MAA x 0.85; UDP-AA= CP X (1- degradability) x 0.85; UDP-AAT =UDP-AA X digestibility of undegraded dietary protein; AAT= CP X (1 - degradability) x 0.85 x intestinal digestibility + 0.02 x DCHOX 0.85 X 6.25 (Madsen, 1982); PBV= CP x degradability – (0.02x DCHO)/ 0/7 x 0.625.

DISCUSSION

Sunflower is grown for oil in many parts of the world including 15 countries in Africa, 12 in Asia, 13 in Europe, 7 in Latin America, Russia, USA and Mexico (FAO, 1990). The oil content of sunflower (30-47 %) in this study is consistent with the levels (30 - 45 %) reported by McGuffey and Schingoethe (1982). Although, sunflower is becoming important as a source of animal feed (FAO, 1990) the high oil interferes with normal rumen function and limit rumen degradability of forage resulting in low intake of feed (Van Kempen and Jansman, 1994). The maxi-mum recommended level of oil inclusion in ruminant diets is 5% (Palmquist and Jenkins, 1980).

Higher N content was found in the cottonseed cake (57 g/kg DM) and the ram press sunflower cake (43 g/kg DM) than in the forages (12 g/kg DM) and cereals (16 - 19 g/kg DM). Feeds with low N content restrict rumen microbial growth; reduce the rate of fermentation and passage of digesta through the digestive tract, and Voluntary Feed Intake (VFI) (Ngongoni and Manyuchi, 1993). The intake of low protein diets (6-16 g/kg N) is related to N content of the feed than to digestibility (Topps and Elliot, 1963). Protein Balance Values were negative for cereals (- 24 to -72 g/kg DM) and forage legumes (-2.6 to -48g/kg DM). The negative PBV for forage legumes can be attributed to the presence of anti-nutritional factors and this warrants further investigation. However, the PBVs were positive for sunflower feedstuffs (13 - 159 g/kg DM), cottonseed cake (171 g/kg DM) and the conventional dairy meal (28 g/kg DM). This indicates a deficiency of N for microbial growth in cereals and legumes, and excess in sunflower, cottonseed cake and the conventional dairy meal. However, the DCHO was higher in cereals (716 - 778 g/kg DM) and forage legumes (412 - 586 g/kg DM) than in sunflower feedstuffs (136 - 377 g/kg DM).

The basis of formulating least cost rations for moderate milk yield is to combine the homegrown cereal feedstuffs with a high N content and those with a high DCHO in order to synchronize optimum microbial growth. The AAT-PBV system suggests that microbial growth in the rumen is related to the amount of digested carbohydrates (Hvelplund et al., 1992) and that the contribution of fat and protein to the ATP pool in the rumen is negligible (Hvelplund and Madsen, 1985). This is consistent with the current study in which oil-rich and protein-rich feedstuffs have lower microbial-AAT (14.4 - 30.5 g/kg DM) than found in carbohydrate-rich cereals (79.2 - 82.6 g/kg DM).

Effective degradability of N and the water -soluble fraction (‘a’) was consistent in all the feedstuffs. It was higher in sunflower-based feedstuffs (70 - 85 %) than for other feedstuffs (17-48%), suggesting the solubility of the protein as a predisposing factor for the degradation by the rumen microbes. If the protein goes into solution quickly, the rate of enzymatic degradation is often increased. The high degradability of N in sunflower represents a readily available source of nitrogen for rumen microbial protein synthesis and requires a readily available energy source for coupled fermentation. However, a higher particle loss was observed in the sunflower feedstuffs (48%) than the cottonseed cake (10%), conventional dairy meal (9%), forage legumes (26%) and cereals (16%). For some feedstuffs, especially those rich in starch and whole crop cereals part of the non- water soluble particles may leave the nylon bag through the pores and are estimated as being degraded (Hvelplund et al., 1995). Some of the material lost from the nylon bag is neither degraded in the rumen nor absorbed in the small intestine (Hvelplund et al., 1992). The lost water-soluble portion is assumed to be readily degradable while the lost particles may have degradability similar to that of the fraction, which is not lost from the bags.

The degradability of the undegraded dietary protein of the sunflower cake (0.71) was higher than that of the full fat sunflower seed varieties (0.55 - 0.67). The reasons for this difference are not clear, but it may be due to a higher proportion of nitrogen in the full fat sunflower seed being bound to the cell wall (Palmquist and Jenkins, 1980). It is important to assess the digestibility of undegraded dietary protein in the different feedstuffs because the mobile bag technique has revealed differences in the digestibility of undegraded dietary protein among different feeds and within the same protein sources (Hvelplund et al., 1992). The prediction of the flow of amino acids to the small intestine from undergraduate dietary protein is commonly based on the degradability of crude protein obtained by the nylon bag method. The undegraded dietary protein is then converted to amino acids by factor (0.65 and 0.85 for roughage and concentrates, respectively). This was considered to represent the proportion of amino acids in the undegraded dietary protein (Madsen and Hvelplund, 1984).

A higher true intestinal digestibility was observed in the sunflower feedstuffs (88 - 94%), cottonseed cake (90%) and conventional dairy meal (84%) than for the forage legumes (67%, range 52 - 79%) and cereals (59%, range 58 - 61%). The low true digestibility of nitrogen from the forage legumes was probably a reflection of a high proportion of cell wall bound nitrogen in the forages (Martens, 1985). Hvelplund (1985) reported digestibility coefficients of 0.86 and 0.89 for the sunflower cakes and cottonseed cake respectively. The digestibility of sunflower feedstuffs, cotton seed cake and conventional dairy meal in this study were higher than the fixed digestibility factor (0.82) proposed by Madsen and Hvelplund (1984) for concentrates when the AAT-PBV system was being introduced. The current study supports the suggestion that the true digestibility of different feedstuffs is variable. The digestibility of the undegraded dietary protein was low and varied between and within feedstuffs than the true intestinal digestibility. This was attributed to possible digestion of nitrogen in the hindgut, which had been observed in other experiments (Møller et al., 1984). The digestion in the hindgut may be affected by the amount of energy available for hind gut fermentation. The lower digestibility of the undegraded dietary protein in the sunflower seeds and the sunflower heads (38.7 - 66.8%) than found in the ram press sunflower cake (70.8%) might be attributed partially to the higher lignin in these feedstuffs.

Lignin content is high and variable in sunflower, cotton seed cake and forages than in cereals. Lignin exerts a negative effect on digestion and is generally regarded as the main factor affecting digestibility of the cell wall in ruminant feeds, probably by shielding the polysaccharides from enzymatic hydrolysis (Jung and Allen, 1995). Fibre is essential in ruminants for rumination, saliva flow, rumen buffering, health of the rumen wall and high butterfat in milk (Martens, 1985). The fibrous cell wall consists of hemicelluloses, cellulose and lignin, some of which may be digested by the rumen microbes (Van Soest et al., 1991). High cell wall content increases rumination time and is associated with a decreased efficiency of conversion of metabolizable energy to net energy (Van Soest, 1991).

Conclusion

The study has shown that the ram press sunflower cake has high N content which is comparable with that in commercial dairy concentrates, but the N in sunflower is more degradable than in commercial concentrates, suggesting a source of readily available N for rumen microbial protein synthesis needing ready energy too. The full fat sunflower seed contains excessive oil, which may interfere with optimum rumen microbial activities and roughage degradation. The sunflower feedstuffs and the cotton seed cake have low digested carbohydrates, which may limit optimum microbial protein synthesis, while forage legumes and cereals have higher digested carbohydrates. Thus, one way of improving protein digestibility protein rich crops is to feed them with cereal crops. The conventional dairy concentrate showed higher absorbed amino acids (AAT) than single ingredients of sunflower feedstuffs and the cereals. Consequently, the study identified the ram press sunflower cake as a potential source of N in home mixed dairy rations.

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