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Evaluation of various types of forest biomass and wood processing residues as feed for ruminants

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Abstract. Eight digestibility trials were performed with rams to evaluate the nutritive values of energy willow leaves (*Salix Aquatica*), whole short rotation trees (*S. Aquatica, S. dasyclados*), forest biomass, consisting of branches, foliage and browses, entire hardwood, hydrolysed birch tree pulp and dissolving pulp. The chemical composition of the materials varied according to the leaf-to-wood ratio and the degree of hydrolysis of the pulp. The leaves had high protein contents and low crude fibre contents but remarkably high contents of acid detergent fibre (ADF). The materials containing wood had a high crude fibre content, 41—54 %, as had also both pulps, 44—75 %, but the ADF content was on average 17.4 %-units higher than the content of crude fibre. The lignin content was high in the wood-containing materials (29—34 %) and also high in one of the leaf pulps. The digestibilities of the leaf pulps varied considerably, from 42 to 61 % for DM. The forest biomass had organic matter OM digestibility varying from 20 to 39 %. The digestibility was affected by the ratio of foliage to wood in the material. Hydrolysed wood pulp had poor digestibility, 38 % for OM, but the digestibility of dissolving pulp was comparable to that of good quality roughage, 75 %. The leaf pulps and dissolving pulp had FU values of 0.48—0.69/kg DM. Forest biomass and hydrolysed birch pulp had low values, 0.22—0.34 FU/kg DM. Various energy evaluation systems were compared in the feed value calculations. The fibre correction system gave very low values. Tree foliage and cellulosic wastes with a low lignin content can be utilized as ruminant feed but the possibilities of disposing in this way of cellulosic wastes with high lignocellulosic contents are very limited.

Introduction

Considerable research has recently been devoted to the use of alternative, non-conventional feed sources for animal production. Wastes from the forest industry and the processing of short-rotation or noncommercial trees, and tree residues have received considerable attention as potential feed sources for ruminants (Baker et al. 1975, Kommeri 1981, Pohjonen and Näsi 1983).

Browse and foliage are normal food for wild ruminants and also serve to supplement the diets of livestock on pasture. The *in vitro*

Index words: Forestry by-products, forest biomass, wood residues, tree leaves, ruminant nutrition

digestibility of some tree leaves has been found to be moderate and their protein content high (Näsi and Pohjonen 1981, Ciszuk and Murphy 1982). Tree foliage and the unlignified sprout biomass of some short rotation energy woods have proved to have considerable nutritional value (Baertsche 1980) and ensiled green biomass is being investigated as a possible forage crop for cattle feeding (Hooper and Winch 1979). Energy wood production and the utilization of whole trees provide large amounts of surplus material of potential value as animal feed.

The high cost of pollution control has stimulated active research to evaluate the utilization of waste fibre from the pulping industry as energy feed for ruminants. Cellufibre, with a low lignin content, has high digestibility (Saarinen et al. 1959), but waste fibre has usually rather low digestibility and is less palatable to ruminants (Millett et al. 1973, Van Soest and Robertson 1976).

The object of the present study was to estimate the feed value of some products from short rotation energy willow stands, forest biomass material and wood-processing residues in the diets of ruminants.

Materials and methods

Eight digestibility trials were conducted with 3—4 rams to evaluate the feeding values of various forest biomass products and wood processing by-products. The total collection method was used to study the digestibilities of various nutrients. A preliminary acceptability period of 10—15 days and a 10-day standardization period were followed by a seven-day collection. In the test period the food intake was reduced to 90 % of average *ad libitum* intake.

The experimental diets and the inclusion of forest biomass materials and wood-processing by-products were as follows:

1. Leaf pulp from *Salix Aquatica* foliage, collected in the period 25 Sept. — 5 Oct. 1980. Pressed for leaf juice as described by Näsi (1983). The diet consisted of 2500 g leaf pulp and 100 g wheat straw. Intake 46 g DM/kg $W^{0.75}$.

2. Leaf pulp from Aquatica foliage, collected between 7 and 17 Sept. 1981 (Näsi 1983). The diet consisted of 2100 g leaf pulp and 100 g oat straw. Intake 44 g DM/kg $W^{0.75}$.

3. Foliage and shoots of *S. dasyclados*. Collected between 10 and 20 Oct. 1981 and stored in bundles when semidried. Chopped before feeding. The diet consisted of 1650 g crushed energy willow and 100 g oat straw. Intake 31 g DM/kg $W^{0.75}$.

4. Chopped whole small birches and willows, stored in plastic-covered haulms with addition of 1.8 % urea-ureaphosphate in June 1981 (Ettala et al. 1983). The diet consisted of 1495 g forest biomass and 100 g oat straw. Intake 35 g DM/kg $W^{0.75}$.

5. Chopped whole plants of *S. Aquatica* collected between 13 and 24 Sept. 1982, stored in large plastic sacks with addition of 2 % urea-ureaphosphate (Ettala 1983 b). The diet consisted of 1055 g of crushed energy willow, 150 g rolled barley and 150 g rape seed meal. Intake 36 g DM/kg $W^{0.75}$.

6. Chopped shoots and foliage of birches and willows collected between 21 June and 20 July 1982. Stored in plastic covered halms with addition of 2.0 % urea-ureaphosphate. The diet consisted of 1115 g forest biomass and 150 g rolled barley and 150 g rape-seed meal. Intake 37 g DM/kg $W^{0.75}$.

7. Birch tree pulp hydrolysed with acetic acid. The diet consisted of 410 g pelleted fibre, 875 g hay and 100 g soy bean meal. Intake 50 g DM/kg $W^{0.75}$.

8. Dissolving pulp, dehydrated screen rejected. The diet consisted of 420 g pulp, 845 g hay and 100 g soy bean meal. Intake 45 g DM/kg $W^{0.75}$.

The 7-day faecal collections were weighed daily, mixed thoroughly and subsampled for later analysis. Urine was collected in pails containing 30 ml of 10 N H_2SO_4 and a 5 % aliquot sample of daily urine was saved for nitrogen analysis. Feed samples were also collected daily during each collection period and pooled for chemical analysis.

Dry matter contents were determined by oven heating at 103 °C and samples for feed analyses were dried in a vacuum oven at 50 °C. The feed analyses were made on the dried samples by standard methods. Acid detergent fibre (ADF), neutral detergent fibre (NDF) and lignin (ADL) were determined according to Coering and Van Soest (1970). Crude lignin and water-soluble carbohydrates were determined as described by Salo (1965). Analyses for tannin were made by the Official method of analysis (Anon 1970). *In vitro* digestibilities were determined by the method of Tilley and Terry (1963).

The digestibility coefficients were calculated from the difference in the digestibility of the total diet, on the basis of the measured or table values of the basic feed. Net energy values were calculated according to Breirem (1969), Van Es (1978), Salo et al. (1982) and Møller et al. (1983) and values for metabolizable energy according to Maff (Anon 1975).

Results and discussion

The chemical composition of the various forestry and wood-processing by-products is presented in Table 1. The two first materials are pulped willow leaves, the four following are chopped foliage with wood material and the two last processed wood fibre, so that the composition of the materials thus varies a good deal. The crude protein varied according to the amount of foliage in the material and to the urea-ureaphosphate used as preservative. The willow leaf pulp had a high value for true protein, on average 18.2 %, while the wood pulp materials had a very low value. The products containing wood material (nos. 3—6) had high crude fibre contents (41.0—54.2 %) and the dissolving material,

Table 1. Chemical composition of different forestry by-products (% of dry matter).

	S. Aquatica leaf pulp 1980	*S. Aquatica* leaf pulp 1981	*S. dasyclados* chopped whole plant 1981	Forest biomass chopped whole trees 1981	*S. Aquatica* chopped whole plant 1982	Forest biomass chopped shoots and foliage 1982	Hydrolysed wood pulp	Dissolving pulp
Dry matter	32.6	36.6	31.9	49.7	32.0	43.6	89.2	9.6
Ash	6.7	5.6	5.0	2.6	5.5	3.6	5.1	1.4
Crude protein	20.6	18.5	14.6	10.1	31.2	26.7	7.9	0.8
True protein	19.4	16.9	12.8	7.5	13.8	15.0	—	—
Ether extract	5.7	4.6	1.3	1.3	1.2	3.4	1.9	4.5
Crude fibre	15.2	18.5	40.7	54.2	41.6	41.0	43.9	74.9
N.F.E.	51.8	52.9	38.4	31.9	20.5	36.2	41.1	18.5
Acid detergent fibre	29.3	45.9	64.5	71.6	62.8	60.1	50.2	84.5
Neutral detergent fibre	30.3	46.2	70.1	85.6	77.1	72.1	69.1	89.1
Acid detergent lignin	12.9	26.3	28.6	30.7	35.8	25.5	9.3	0.7
Crude lignin	17.9	29.9	29.2	29.6	34.2	25.5	11.1	1.8
Water-soluble carbohydr.	11.2	0.9	0.7	0.6	1.4	0.9	3.9	0.3
Tannins	2.3	2.6	1.5	0.9	0.9	0.9	1.1	—

which is almost pure cellulose, had 75 %. Crude fibre is not a good indicator of the feed value of a material, owing to its high content of lignocellulose components. The analytical technique worked out by Coering and Van Soest (1970) enables more detailed studies and evaluation of different complex carbohydrate fractions and lignin. On average the ADF contents exceeded the crude fibre contents by 17.4 %-units. The lignin content was high in the wood-containing materials (29—34 %), but also high in the leaf pulp of the later year. The lignin values are somewhat higher that those presented by Van Soest and Robertson (1976).

The tannin content of the leaf pulp averaged 2.5 % which exceeds the value for the other materials. Tannin compounds can apparently reduce protein digestibility and impair the voluntary intake (Mc Leod 1974, Van Soest and Robertson 1976). Tannin can also influence cellulose digestion through inhibition of microbes and formation of a tannin-cellulose complex (Mc Leod 1974). Here, the intakes of diets containing leaf pulp averaged 45 g DM/kg $W^{0.75}$; the value with forest biomass averaged 35 g DM and for those with cellufiber 47 g DM. The intakes were low but comparable to the results of experiments made by Nastis and Malechek (1981) and Wilson (1977). Two sheep on diet no 4 refused to eat forest biomass and one on diet no. 7 refused to eat hydrolysed wood pulp and had to be removed from the experiment. All animals on diets nos. 3—7 lost weight during the collection period. This can also be seen from the results for the nitrogen balance, which were negative (Table 2).

The digestibility coefficients (Table 2) are calculated from the difference in the total diet digestibilities. The digestibilities of the two willow leaf pulps differed considerably (61—42 % for OM). The pulp of the later year was contamined by rust and the lignin content was twice as high as in the first leaf pulp. The digestibilities correspond to the results presented for various energy tree leaves (Näsi and Pohjonen 1981) and to the values for various tree leaves of natural stands (Nehring 1965, Ciszuk and Murphy 1982). The suitable chemical composition, especially the low crude fibre content, suggests a higher digestibility for leaves, but the rather high lignin content (18—30 %) and the contents of tannins reduce digestibility.

The digestibility of forest biomass depends on the ratio of foliage to wood in the material. The separation of wood material from foliage was very difficult and thus digestibilities were low, 20—39 % for OM. Unmodified mature hardwood sawdust is totally indigestible because of the association of cellulose and hemicellulose with lignin (Van Soest and Robertson 1976, Nehring 1965 a) Young hardwood and browse are digestible to some extent, because the bark and cambial layers contain soluble carbohydrates, and unlignified twigs are also digested (Hooper and Winch 1979, Baertsche 1980, Singh and Kamstra 1981). In mature wood, 70—80 % of DM consists of carbohydrates: cellulose, hemicellulose and a small amount of sugars, but without pretreatment only a small proportion of these carbohydrates is available for digestion by the rumen microbes (Scott et al. 1969, Millett et al. 1970). Baertsche (1980) presents quite a high digestibility value for short-rotation poplar biomass, 54 % for OM, 52 % for CP and 35 % for ADF, but Hooper and Winch (1979) found lower values for bark and wood, 28—42 % for DM, and 67 % for the DM of leaves. Wylie (1981), however, obtained the very low value of 13 % for DM digestibility of energy willow biomass.

In this study hydrolysed wood pulp had rather a low digestibility. The lignin content was 11.1 %, which indicated that acetic acid hydrolysis had been ineffective. The digestibility of dissolving pulp was comparable to that of good quality roughage. Baker et al. (1975) reported that the digestibility in vitro of many pulp and paper-making residues

Table 2. Digestibility coefficients of different forestry by products, and nitrogen balance and biological values of diets.

		S. Aquatica leaf pulp 1980 n = 3	*S. Aquatica* leaf pulp 1981 n = 3	*S. dasyclados* chopped whole plant n = 3	Forest biomass chopped whole trees 1981 n = 1	*S. Aquatica* chopped whole plant n = 3	Forest biomass chopped shoots and foliage 1982 n = 4	Hydrolyzed wood pulp n = 3	Dissolving pulp n = 4
Dry matter	$\bar{x}$	56.7	42.0	25.1	35.0	38.2	17.2	38.2	77.3
	s.d.	1.0	0.3	7.2		5.0	9.2	2.8	8.7
Organic matter	$\bar{x}$	61.3	42.2	26.2	37.6	38.7	19.5	37.9	75.0
	s.d.	0.6	1.0	7.9		4.2	8.9	4.1	6.7
Crude protein	$\bar{x}$	51.9	36.3	37.2	27.0	64.6	38.5	65.7	0
	s.d.	1.3	3.5	7.6		0.6	8.9	11.6	—
Ether extract	$\bar{x}$	74.0	62.1	22.4	38.1	54.9	30.9	61.2	6.7
	s.d.	0.7	4.0	14.5		7.2	11.4	4.5	6.3
Crude fibre	$\bar{x}$	49.3	39.0	27.2	43.7	28.8	19.3	20.7	67.3
	s.d.	1.4	1.1	7.9		3.5	10.7	2.4	6.3
N.F.E.	$\bar{x}$	66.3	43.1	19.9	27.2	21.3	33.5	42.0	26.5
	s.d.	1.2	2.0	8.3		13.7	9.3	5.1	12.8
Nitrogen balance	$\bar{x}$	0.2	2.6	−2.9	−8.2	−9.5	−8.0	3.20	−0.51
	s.d.	0.7	2.8	0.3		0.2	2.8	0.90	0.65
Biological value	$\bar{x}$	41.7	66.4	37.8	−11.8	−13.5	−6.9	55.8	65.9
	s.d.	4.8	17.5	4.0		1.2	15.4	2.6	3.6
In vitro digestibility									
Dry matter		69.2	42.3	28.6	18.6	42.9	28.7	47.1	35.0
Organic matter		57.3	39.7	25.6	16.7	39.9	26.4	46.4	34.6

Table 3. Calculated feed values of different forestry by-products.

	S. Aquatica leaf pulp 1980	*S. Aquatica* leaf pulp 1981	*S. dasyclados* chopped whole plant 1981	Forest biomass chopped whole trees 1981	*S. Aquatica* chopped whole plant 1982	Forest biomass chopped shoots and foliage 1982	Hydrolysed wood pulp	Dissolving pulp
Value number-syst.								
FU/kg DM	0.687	0.479	0.227	0.334	0.342	0.296	0.322	0.643
kg/FU	4.47	5.71	13.81	6.03	9.15	7.76	3.49	16.18
DCP in feed	3.49	2.46	1.73	1.36	6.45	4.48	4.64	0
g DCP/FU	156	140	239	82	590	348	162	0
Fiber correction-syst.								
FU/kg DM	0.720	0.429	0.023	0.017	0.145	0.080	0.077	0.118
kg/FU	4.26	6.37	135.3	116.2	21.6	28.8	14.5	88.0
Danish-system								
FE_K	0.672	0.326	—0.001	0.131	0.326	0.177	0.163	0.364
van Es-system								
NEW MJ/kg DM	4.68	2.61	1.23	2.17	2.93	1.97	1.91	4.47
NEL MJ/kg DM	4.88	3.18	1.89	2.79	3.45	2.61	2.55	4.72
MAFF-system								
MJ ME/kg DM	8.54	5.64	3.08	4.96	5.24	4.25	4.48	8.40

ranged from 45 of 65 % but some attained levels as high as 90 %.

The feed values calculated for the different forestry by-products and pulps are presented in Table 3. For comparison, the net energy values are calculated by four different methods. The number values were calculated from equations presented by VAN ES (1978) as the ratio of GE to ME for production and maintenance in relation to barley. The number value for leaf pulps averaged 0.80, for forest biomass and hydrolysed pulp 0.65 and for dissolving pulp 0.80. The FU k values were calculated from values for digestible energy corrected for digestible fibre (MØLLER et al. 1983). Leaf pulp and dissolving pulp had FU values of 0.48—0.69/kg DM, corresponding to hay. Whole chopped energy willows and hydrolysed wood pulp had low values, 0.22—0.34 FU/kg DM. The fibre correction system gave very low energy values, 0.02—0.15 FU.

The possibilities of disposing of cellulosic wastes from forestry by feeding them to ruminants are limited at present. Materials with low digestibility, such as lignocellulose wastes, must be made more digestibile by chemical or biological techniques before they can be utilized by ruminants, and in practice processing costs may be prohibitive. High quality cellulosic wastes with a low lignin content can be removed from the environment by ruminant feeding. Browses and foliage can be eaten by animals put out to pasture.

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SELOSTUS

Erilaisten metsätalouden ja puunjalostusteollisuuden sivutuotteiden arvo märehtijäin rehuna

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Tutkimuksessa selvitettiin energiapajun lehtien (*Salix Aquatica*), koko energiapuun (*S. Aquatica, S. dasyclados*), metsäbiomassan, joka koostui varvuista, lehdistä ja puuaineksesta, hydrolysoidun puukuidun ja viskoosikuidun koostumusta, sulavuutta ja rehuarvoa. Pajunlehtien valkuaispitoisuus oli korkea (18.5—20.6 %) kun taas puukuitujen valkuaispitoisuus oli alhainen. Puuainesta sisältävien tuotteiden kuitupitoisuus oli korkea (41.0—54.2 %) ja viskoosikuitu, joka on lähes puhdasta selluloosaa, sisälsi raakakuitua 74.9 %. Ligniinipitoisuus oli puuainesta sisältävissä tuotteissa niinikään korkea (29—34 %), mutta myös pajunlehdissä oli paljon ligniiniä (18—30 %). Tuotteista määritettiin myös happo- ja neutraalidetergenttikuitu.

Eri tuotteiden sulavuus määritettiin kahdeksana sulavuuskokeena 3—4 pässillä. Pajunlehtiä sisältävillä ruokinnoilla pässit söivät keskimäärin 45 g kuiva-ainetta metabolista elopainokiloa kohti, ja vastaavasti puuainesta sisältäviä eri metsäbiomassoja 35 g sekä puukuituja sisältävää diettiä 47 g. Pajunlehtien orgaanisen aineen sulavuus vaihteli 42—61 % ja eri metsäbiomassoilla 20—39 %. Sulavuuteen vaikutti lehtien ja puuaineksen suhde eri metsäbiomassoissa. Etikkahapolla hydrolysoitu puukuitu suli huonosti (38 %), mutta viskoosikuitu huomattavasti paremmin (75 %). Pajunlehtien ja viskoosikuidun rehuyksikköarvoksi saatiin 0.48—0.69/kg ka. Metsäbiomassojen ja hydrolysoidun kuidun ry-arvoksi saatiin 0.22—0.34/kg ka. Eri energia-arvon laskutapoja verrattiin keskenään, ja laskutavasta riippuen saatiin erilaisia tuloksia.

Puunlehtiä ja vähän ligniiniä sisältävää selluloosakuitua voidaan käyttää märehtijöiden rehuna. Sitävastoin puuainesta tai lievästi hydrolysoitua puukuitua ei voida käyttää rehuna alhaisen sulavuuden takia.