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Green fodder from energy forest farming

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Abstract. The study examined the yield, chemical composition and nutritive value of energy tree leaves under one year rotation, and considered the methods and results in the entire tree utilization. The proportion of leaves was 31 % for *Salix cv. Aquatica* and 16 % for *S. viminalis* of the total biomass yield. The dry matter yield of leaves amounted to 3—5 tn DM/ha. The average chemical composition of willow leaves was as follows: dry matter 27 %, ash 7.7 %, crude protein 19.5 %, ether extract 4.9 %, and crude fibre 14.1 %. The content of tannins was 4.1 % in willow leaves and 3.4 % in alder leaves. Fertilization had a significant effect on the ash and protein contents of willow leaves. Crude fibre content of alder leaves was higher compared to willow leaves. *In vitro* digestibility of willow leaves was 64 % for organic matter and pepsine-HCl soluble protein was 65 % on average. Fertilization improved the digestibility 6—8 %-units. Calcium content of willow leaves was 10 g/kg DM, phosphorus 3g/kg DM and magnesium 2.8 g/kg DM. The amount of trace elements was considerably high. On account of the high content of protein and minerals willow leaves are a considerable source of feed for domestic animals or wild ruminants. The harvesting and conservation of leaves is still a technical question that has to be resolved.

Introduction

Energy forest farming is a discipline of cultivated trees and husban dry in which the solar radiation is collected and converted into biotic energy of the phytomass in the growing trees. The aim is to produce high annual energy yields by selecting, breeding and raising fast-growing deciduous tree crops.

The energy tree crop may be, in Finnish conditions, willow, poplar, alder, aspen and birch. The essential common feature for them is the coppicing ability and fast growth after the harvest.

Promising results in northern energy forest farming have been achieved with the use of selected willow clones (POHJONEN et al. 1980). The first willow experiments were established in 1973. A Danish willow clone, *Salix cv. "Aquatica"* produced in the latitude of the arctic circle a dry matter yield of about 10 tons/ha already during the first summer (POHJONEN 1974). More willow species have been screened in subsequent experiments. The annual yields have been maintained at their high level, between 10 and 20 tons/ha, in gross energy equivalents between about 160 and 320 gigajoules per hectare. The largest dry matter yield so far reported in the Nordic countries has been 32 tons/ha (SIREN and SIVERTSSON 1976), which includes the harvested stemwood only.

The fastest growing clones do not drop their leaves before the autumn frosts and the stems can thus be harvested with green leaves.

With suitable methods in the autumn harvest the leaves could be separated from the stem yield and could be used for instance as a green fodder for animals. In earlier times it was common to utilize forest tree leaves as forage for sheep and cattle. The concept could be developed by using high-yielding varieties and modern animal husbanrdy methods.

The purpose of this study is to find out the amount, chemical composition and nutritive value of energy tree crop leaves, and to consider the methods and results in the whole tree utilization.

Materials and methods

The study consisted of 36 samples of tree leaves from nine clones of willow (*Salix* sp.), two samples from the clones of poplar (*Populus* sp.) and four samples from alder (*Alnus incana*). The samples were collected on October 10—12, 1979 in the experimental areas of Kannus, Suonenjoki and Suomusjärvi of the Finnish Forest Research Institute. The fertilization in Kannus was per ha N 150 kg, P 60 kg and K 255 kg. In Suonenjoki the experimental plots were fertilized with N 250 kg and from woodash with P 20 kg anf K 76 kg. In Suomusjärvi there were five different fertilization treatments, 1) without fertilization; 2) woodash 10 tn dry matter, supplied per ha, P 92 kg and K 382 kg; 3) P + Mo, Superphosphate, P 92.4 kg and Na_2MoO_4 x $2H_2O$ 6.9 kg; 4) NPK I, N 150 kg, P 92.4 kg and K 382 kg, 5) NPK II, N 150 kg from urea, P 92.4 kg and K382 kg.

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 (PALOHEIMO 1969). *In vitro* digestbility determinations were made by the method of TILLEY and TERRY (1963). Mineral composition of the leaves was determined by atomic absorption spectrophotometer (Varian Techtron AA 1000) and phosphorus by the method of TAYSSKY and SHORR (1953). Tannin determinations were made by Official methods of analysis (1970).

Results and discussion

The accurate percentages for leaves were determined in Kannus during the autumn harvest, October 23—25. The proportion of leaves of the total, above ground biomass, was 31 % for *S.cv. Aquatica* and 16 % for *S. viminalis* as calculated on a dry matter basis.

In Suonenjoki the yield determinations were made per square meter basis due to the small area of the experimental plots. They included figures (stems only) from 1.4 to 3 kg/m^2 for *Salix Pa 75, 2.6 kg/m$_2$ for S. dasyclados* and 1.5 kg/m^2 for *S. phylicifolia.*

A separate measurement for the percentage of leaves was made in Suonenjoki for *Salix* PA 77. It resembles *Salix viminalis* and is 19.4 %.

More detailed determinations on the accumulation of the biomass, both stems and leaves, were made with *Salix* cv. Aquatica in Kannus. The leaves consisted of about one third of the total yield of dry matter (4000 kg/ha vs. 12000 kg/ha).

The chemical composition of willow and poplar leaves are presented in Tables 1 and 2. The average dry matter content of leaves was 27 %. The ash content in DM was on average 7.7 %, and there was relatively wide variation in the ash content of different clones. The crude protein content varied between 12 and 25 % in DM averaging 19.5 %. The proportion of true protein from crude protein was on average 4.9 % in DM. Probably this also includes other substances than fat e.q. waxes, resin and green colour. Crude fibre varied between 12 and 19 % and the average was 14.1 %. This value is quite low compared to grass species also in an early cut. The protein content of the leaves is considerably higher and the crude fibre content only less than half compared to that of hay.

Table 1. Chemical composition and *in vitro*-digestibility of different clones of willow and poplar (% in dry matter).

Clone		Dry matter	Ash	Crude protein	True protein	Ether extract	Crude fibre	Sugars	NFE	In vitro dig. org. matter.	Pepsine HCl soluble protein %
Salix cv. Aquatica	1)	26.8	8.6	20.5	16.5	4.5	16.4	8.5	49.9	58.6	58.3
S. viminalis	1)	30.7	7.7	18.0	14.2	4.1	15.6	7.0	54.7	75.2	51.3
S. triandra	1)	23.9	8.0	12.4	8.9	3.2	19.3	7.6	57.1	52.7	37.6
S. cv. Aquatica	2)	24.9	7.5	23.1	20.7	5.5	13.4	10.4	50.6	67.4	71.8
S. viminalis	2)	27.3	8.4	23.1	19.7	5.3	13.8	8.1	49.4	63.4	70.5
S. smithiana	2)	27.6	8.2	22.7	20.9	4.9	17.3	8.1	47.0	62.4	71.6
S. schwerinii	2)	30.1	6.4	20.0	17.1	4.8	14.1	11.0	54.8	62.4	66.3
S. dasyclados	2)	28.3	7.7	20.7	18.2	5.5	13.6	11.1	52.6	68.0	69.0
S. superlauriana	2)	25.7	7.5	21.5	19.7	5.4	13.7	10.8	51.9	52.4	61.6
S. fragilis	2)	25.0	9.9	21.6	18.8	6.5	12.9	10.1	49.2	70.6	74.8
S. phylicifolia	2)	25.2	7.7	20.7	16.7	5.7	13.8	5.9	52.1	50.3	59.9
Populus laurifolia	1)	34.4	9.9	21.0	16.3	4.9	14.0	15.1	50.2	75.4	76.6
P. rasymowskyana	1)	28.4	9.8	20.2	15.4	4.8	14.1	13.4	51.1	73.0	74.6
x̄		27.6	8.3	20.4	17.2	5.0	14.8	9.8	51.6	64.0	64.9
s.d.		2.9	1.1	2.8	3.2	0.8	1.9	2.6	2.7	8.6	11.1

1) Samples fram Experiment Station in Kannus
2) Samples fram Experiment Station in Suonenjoki

Table 2. The effect of fertilization on the composition and *in vitro*-digestibilitv of leaves of *Salix cv. Aquatica.*

Fertilization	n	Dry matter	Ash	Crude protein	True protein	Ether extract	Crude fibre	Sugars	NFE	Tannins	In vitro dig. org. matter	Pepsine HCl soluble protein %
Control	3	27.8	5.6	16.2	14.3	4.4	13.7	17.5	60.1	5.4	59.0	57.4
Ash	3	27.5	6.7	17.2	14.8	4.8	14.0	19.1	57.3	4.4	64.9	61.8
P + Mo	3	26.9	6.6	17.5	15.2	4.6	13.8	18.7	57.5	4.4	64.8	62.2
NPK I	3	26.4	7.5	18.9	16.3	4.7	14.0	18.1	55.0	3.6	66.9	63.3
NPK II	3	26.4	7.6	18.3	16.3	4.5	13.2	18.0	56.4	3.7	66.0	63.3
x̄	15	26.9	6.8	17.6	15.4	4.6	13.7	18.3	57.2	4.1	64.3	61.6
s.d.		1.4	0.8	1.4	1.1	0.3	0.5	1.4	2.0	0.7	4.0	4.1

content of the leaves is considerably higher and the crude fibre content only less than half compared to that of hay.

Samples of poplar clones had a slightly higher protein content than the willow leaves, but the overall composition was quite similar. The crude fibre content of alder leaves was higher compared to that of the willow leaves.

The review of BECKER and NEHRING (1965) has dealt in detail with the composition of leaves of different natural forest species. The composition of cultivated willow leaves differs in many cases. The willows and poplar had been fertilized and this incresed e.g. the protein content. The protein content of the natural leaves earlier in summer can be quite high, over 20 % in DM, which is the case with nitrogen fixing trees.

Fertilization had a significant effect on the chemical composition of willow leaves (Table 2). The ash content increased with wood ash or phosphorus fertilizer over one percentage unit and with NPK-fertilizer over two percentage units. There was no effect on the ether extract or crude fibre content of willow leaves. The fertilizer markedly reduced the crude fibre content of alder leaves.

In vitro digestibility coefficients are presented in Tables 1, 2 and 3 and also the percentages of pepsine HCl soluble protein of crude protein, which indicate the value of leaves as a feed for animals. There was relatively wide variation in the digestibvility among samples from different clones. The average digestibility was 64 % for organic matter. These correspond with values of good quality hay, but as regards a suitable chemical composition it would be 70—80 %. Pepsine HCl soluble protein was on an average 65 % and this is also low for such a high protein content. Poplar leaves were higher in digestibility and pepsine HCl soluble protein. Some clones of willow *S. viminalis* and *S. fragilis* had *in vitro* digestibility over 70 %. The alder leaves were poorly digested *in vitro,* 45 %, and the pepsine HCl soluble protein was only 40 %. The values were 20—25 % units lower than in willow leaves. Fertilization improved the digestibility 6—8 % units and the pepsine HCl soluble protein 4—6 % units.

The tree leaves contain tannins which reduce the digestibility and protein utilization. The content of tannins in willow leaves was on average 4.1 %. In alder leaves the value was 3.4 %. BECKER andNEHRING (1965) present 2.8 % for alder. The content of tannins in willow leaves was negatively correlated to the pepsine-HCl soluble protein (—0.67xx) and to organic matter *in vitro* digestibility (—0.68xx). The tannin content in leaves increases during the growth period, and the

Table 3. Chemical composition and *in vitro*-digestibility of alder leaves, *Alnus incana.*

Fertili-zation	Dry matter	Ash	Crude protein	True protein	Ether extract	Crude fibre	Sugars	NFE	Tannis	In vitro dig. org. matter.	Pepsine HCl soluble protein, %
Control	32.8	5.4	17.6	16.2	3.7	23.7	11.4	49.7	3.2	36.7	30.9
Ash	29.9	5.7	17.8	16.3	5.2	17.7	15.1	53.6	4.1	42.7	43.9
NPK I	30.2	7.3	17.6	16.6	3.8	19.9	13.1	51.4	2.6	44.7	35.3
NPK II	29.0	6.5	17.8	16.3	4.7	17.3	15.8	53.8	3.8	46.7	48.0
$\bar{x}$	30.5	6.2	17.7	16.4	4.3	19.6	13.8	52.1	3.4	42.7	39.5
s.d.	1.6	0.9	0.1	0.2	0.8	2.9	2.0	1.9	0.7	4.4	7.8

values in the autumn are twice as high as in the spring (BECKER and NEHRING 1965).

The digestibility of different species varies widely, while also the age of the leaves has a considerable influence (BECKER and NEHRING 1965). The digestibility of Canadian poplar (*Populus canadiensis*) can be as high as 86 % in the early growth stage while it decreases to 50 % in autumn. *In vivo*-digestibilities of pressed pulp of willow leaves with leaf protein production measured with rams were 60 %, 61 % and 52 % for dry matter, organic matter and crude protein, respectively (NÄSI to be published). *In vitro*-digestibilities were in good accordance with *in vivo*-results. The digestibility of willow leaves for growing pigs was 41 % for organic matter (NÄSI to be published).

The mineral composition of willow and poplar leaves is presented in Table 4, the effect of fertilization on the mineral composition of willow leaves, *S. cv. Aquatica* in Table 5, and the values of alder leaves *A. incana* in Table 6. The calcium content of willow leaves is high, 10 g per kg DM, which exceeds the value of grass species. The phosphorus content is 3 g per kg DM, which corresponds to the value of grass species. Magnesium content was on an average 2.8 g per kg DM.

Table 4. Mineral composition of leaves of different willow and poplar leaves.

Clone	P	Ca	Mg	K	Na	Fe	Cu	Zn	Mn
		g/kgDM					mg/kg DM		
Salix cv. Aquatica	3.60	10.47	2.27	22.29	78	98	8	418	425
S. viminalis	4.07	8.18	4.60	19.60	192	93	8	165	393
S. triandra	1.67	10.37	5.37	11.16	157	156	9	685	537
S. cv. Aquatica	3.25	8.13	3.13	29.59	134	48	8	252	249
S. viminalis	4.26	10.06	3.25	26.83	166	59	9	304	189
S. smithiana	3.85	12.43	3.13	25.50	128	59	9	202	201
S. schwerinii	4.38	11.52	2.93	14.00	110	57	4	269	337
S. dasyclados	2.52	9.21	3.36	26.69	187	46	4	204	118
S. superlauriana	2.84	9.21	1.84	27.76	55	47	3	217	208
S. fragilis	4.26	11.43	2.98	33.38	61	62	11	429	174
S. phylicifolia	2.48	7.68	1.26	32.26	54	69	8	529	205
Populus laurifolia	4.13	7.55	2.45	31.79	99	109	10	124	252
P. rasymowskyana	4.06	8.78	3.21	28.24	102	116	16	183	188
x̄	3.49	9.62	3.06	25.31	117	78	8	306	267
s.d.	0.86	1.57	1.07	6.85	48	34	3	164	120

Table 5. Effect of fertilization on the mineral composition of willow leaves *Salix cv. Aquatica*.

Fertilization	n	P	Ca	Mg	K	Na	Fe	Cu	Zn	Mn
			g/kg DM				mg/kg	DM		
Control	3	1.54	10.31	2.99	12.12	103	78	12	497	410
Ash	3	2.04	10.89	2.19	19.08	132	84	10	448	365
P + Mo	3	2.54	11.29	3.52	14.24	135	83	8	336	451
NPK I	3	2.38	8.94	1.57	26.35	134	83	9	289	467
NPK II	3	2.43	8.84	1.51	28.57	136	87	11	342	479
x̄	15	2.19	10.06	2.36	20.07	128	83	10	382	434
s.d.		0.43	1.22	0.94	6.92	18	5	4	97	50

Table 6. Mineral composition of alder leaves, *Alnus incana*.

Fertili-zation		P	Ca	Mg	K	Na	Fe	Cu	Zn	Mn
			g/kg	DM				g/kg DM		
Control		1.06	1.37	3.82	2.67	66	80	7	61	530
Ash		1.28	13.69	1.87	8.39	67	99	8	65	495
NPK I		1.75	13.41	1.64	14.98	102	96	5	72	511
NPK II		1.68	12.41	1.65	14.33	79	88	8	67	528
	$\bar{x}$	1.44	13.47	2.25	10.09	78	91	7	66	516
	s.d.	0.33	0.81	1.06	5.77	17	9	1	5	16

The mineral composition varied somewhat within the clones. The fertilizer had a significant effect on the mineral composition of willow leaves. The calcium content decreased 2 g per kg DM and the magnesium like wise to half of the control, but phosphorus increased 1 g per kg DM and potassium over 10 g per kg DM or twice to that of the control.

Nowadays leaves are of small importance as feed for domestic animals. For wild ruminants leaves are important as a feed source. Previously, leaves were collected in bundles for ruminants, mainly for sheep. Leaves are considered a suitable supplement to a ration predisposing to deficiencies in protein, minerals and vitamins and may accordingly serve as a protective feed. When feed resources were scarce, leaves were used as emergency feeds (POIJÄRVI 1940, NEHRING and SCHÜTTE 1951, BREIREM and HOMB 1970, MASSON and DECAEN 1980).

Energy forestry produces considerable amounts of green biomass of good nutritive value (SIREN et. al. 1970). This by-product from energy production should be made use of as a protein source for animals. Some tehcnical problems arise in the collecting and conservation of leaves. Besides the conventional drying, silage making and leaf protein production should be investigated.

Conclusion

As a by-product of biotic energy production using fast-growing energy crops, a green fodder yield corresponding to a moderate yield of normal pasture in Finnish conditions could be harvested. This fodder reserve must be considered on a national scale a considerable source of food for domestic animals or wild ruminants. The possible methods in harvesting and conservation of leaves would be silage making for ruminants or leaf protein extraction for non-ruminants using the pulp for ruminants as a roughage.

On the global scale energy farming cannot compete on land area with food crops. Therefore the suitable areas for the purpose have been sought outside the areal crop growing zones, for instance in northern peatland forests (POHJONEN 1980). The other possibility is a combined energy and green fodder production which opens new alternatives in the management of land area resources.

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Tutkimuksessa selvitettiin energiametsän lehtimassan satoa, kemiallista koostumusta ja *in vitro* sulavuutta pyrkimyksenä lyhytkiertopuiden kokonaiskäyttö. Lehtien osuus oli 31 % vesipajulla (*Salix cv. Aquatica*) ja 16 % koripajulla (*S. viminalis*) koko biomassan tuotannosta. Lehtien kuiva-ainetuotos oli 3—5 tn/ha. Pajunlehtien kemiallinen koostumus oli seuraava: kuiva-aine 27 %, tuhka 7.7 %, raakaproteiini 19.5 %, raakarasva 4.9 % ja raakakuitu 14.1 %. Pajunlehtien tanniinipitoisuus oli 4.1 % ja lepänlehtien 3.4 %. Lannoituksella oli vaikutusta pajunlehtien raakaproteiinin ja tuhkan pitoisuuksiin. Lepänlehtien kuitupitoisuus oli korkeampi kuin pajunlehdissä. Pajunlehtien orgaanisen aineen *in vitro*-sulavuus oli 64 % ja pepsiini-HCl-liukoinen valkuainen 65 %. Lannoitus paransi sulavuutta 6—8 %-yksikköä. Pajunlehdet sisälsivät kalsiumia 10 g/kg ka, fosforia 3 g/kg ka ja magnesiumia 2.8 g/kg ka. Hivenainepitoisuudet olivat myös korkeita. Korkean raakavalkuais- ja kivennäispitoisuuden takia energiametsän lehtimassa edustaa suhteellisen hyvää rehulähdettä sekä kotieläimille että riistaeläimille. Lehtien korjuu ja säilöntä on teknisesti ratkaisematta.