ZEMĚDĚLSKÁ TECHNIKA

Agricultural Engineering

ČESKÁ AKADEMIE ZEMĚDĚLSKÝCH VĚD

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ZEMĚDĚLSKÁ TECHNIKA

AGRICULTURAL ENGINEERING

International Workshop
AGROMATERIALS FOR INDUSTRIAL USE
Prague, August 25–26, 1994

This Workshop was organized by the International Society for Agromaterials Science and Engineering (ISASE) in Prague. The main task of this Workshop, sponsored by Agrobanka Praha, a. s., and by the Czech University of Agriculture in Prague, was taking an inventory of and evaluating various activities in and options recently have become available to vegetable production designed for non-foodstuff purposes. The significance of these activities is now namely in the possibility of decreasing the output of foodstuffs, a part of which form unmarketable surplus, and using the soil fund for other marketing purposes, especially for the production of raw materials for manufacturing fuels of various forms (organic waste, wood, liquid fuels, biogas, etc.), as well as for manufacturing various materials which can then be used in the engineering, building and textile industries, in packing products, etc. (fibres, oils, starch and other components).

Of the twenty-four participants in the Workshop, 14 of them were from abroad, most devoted themselves to two groups of problems: to the production of biomass, designed primarily for power engineering purposes, and comprehensive problems of production and processing vegetable fibres. The theoretical scope of the first group of problems was provided by L. N á t r ' s paper, supplemented by papers by S. N o n h e b e l and K. G a r t l a n d who deal with their specific domestic problems (the Netherlands and Great Britain). The paper of Z. P a s t o r e k and J. W o l f was devoted to the technical problems of manufacturing biogas in the Czech Republic. J. K á r a dealt with the exploitation of biomass for power engineering purposes. A slight departure from the principal topic of the problem was R. C a r l s s o n ' s paper on the fractionation of *Chenopodiaceae species* and the papers of G. S k u b i s z and A. K u c z y n s k i devoted to the properties of some plant products (rape stalk and apple). This series of papers was completed by the paper of absent authors: J. I l a v s k ý, E. M a j e r and M. M o r a v e c, which analyzes the exploitation of lumber waste in the Slovak Republic. This part of the Workshop was added by a round-table discussion on „Biological resources – present and future", chaired by L. N á t r and S. N o n h e b e l.

The second group of problems was represented namely by the papers of the staff of the Institute of Natural Fibres from Poznan (Poland), headed by the the Director of the Institute, R. K o z l o w s k i. These papers deal with nearly all the aspects of growing and processing flax and hemp under Central European conditions. An important presentation of the German programme of growing and processing flax was the paper by K.-H. K r o m e r. This was supplemented by information on the established database on flax data (P. P ü t z and A. B e c k m a n n), and on methods of determining the quality of flax fibre (A. B e c k m a n n and K.-H. K r o m e r). Information on the present state of the Czech flax industry was presented by L. R o s e n b e r g, P. Š m i r o u s and S. K r m e l a. Problems of biologically degradable materials on the basis of starch were discussed in J. D r o b n í k ' s paper. The paper by J. B l a h o v e c was devoted to the economic aspects of processing agricultural materials. This group of problems was finished by a round-table discussion of „Processing agricultural materials" (J. D r o b n í k).

The papers presented at the Workshop and submitted in written form in these special issues of the journal Zemědělská Technika (Agricultural Engineering). Depending on their extent and manner of presentation, they are published either as an original paper, or as a current topic. It should be pointed out that dividing the papers into the two above groups has nothing to do with their quality. All papers of discussion or information nature, and papers which were not sufficiently supported by references, had to be included among the current topics in line with the journal's tradition.

In conclusion of this brief introduction, I would like to thank all the participants in the Workshop for the very active parts they took in all sessions. I would like to assure them that I very much appreciate their enthusiasm and erudition. I also wish to thank all the members of the Organizing Committee and assistants for their help in preparing and organizing the Workshop. Last, but not least, my thanks are due to the sponsors to whom I am indebted for providing the possibility of organizing the Workshop.

<div style="display:flex; justify-content:space-between;">
Prague, October 29, 1994
Jiří Blahovec
</div>

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International workshop
AGROMATERIALS FOR INDUSTRIAL USE
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Pracovní setkání pojmenované Agromaterials for Industrial Use organizovala mezinárodní společnost pro nauku o zemědělských materiálech ISASE (International Society of Agromaterials Science and Engineering) se sídlem v Praze. Hlavní úkol tohoto setkání, které bylo sponzorováno Agrobankou Praha, a. s., a Českou zemědělskou univerzitou v Praze, spočíval v inventuře a zhodnocení různých aktivit a možností nově se nabízejících pro rostlinnou produkci určenou k nepotravinářským účelům. Význam zmíněných aktivit spočívá v současné době zejména v možnosti snížit produkci potravin, z nichž část tvoří neprodejné přebytky, při tržním využití půdního fondu k jiným účelům, zejména k produkci surovin pro výrobu paliv v různých formách (organické zbytky, dřevo, tekutá paliva, bioplyn apod.) a pro výrobu různých materiálů s dalším využitím ve strojírenství, stavebnictví, v textilním průmyslu, při balení produktů apod. (vlákna, oleje, škrob a další komponenty).

Z dvaceti čtyř účastníků setkání, z nichž čtrnáct bylo ze zahraničí, se převážná část zabývala dvěma okruhy problémů: produkcí biomasy určené převážně k energetickým účelům a komplexními problémy s produkcí a zpracováním rostlinných vláken. Teoretický rámec prvé skupině problémů dala přednáška L. Nátra, doplněná přednáškami S. Nonheblové a K. Gartlanda, které se zabývaly specifickými problémy v domácích podmínkách (Nizozemí a Velká Británie). Technickým problémům při výrobě bioplynu v českých podmínkách byl věnován příspěvek Z. Pastorka a J. Wolfa. Využitím biomasy k energetickým účelům v České republice se zabýval J. Kára. Trochu stranou od hlavního těžiště problému byla přednáška R. Carlssona, věnovaná frakcionaci merlíkovitých, a příspěvky K. Skubiszové a A. Kuczynského, věnované vlastnostem některých rostlinných produktů (lodyha řepky a jablko). Tuto řadu prací uzavírá příspěvek nepřítomných autorů J. Ilavského, E. Majera a M. Moravce, který rozebírá využití dřevního odpadu ve Slovenské republice. Prvou část setkání uzavírala diskuse u kulatého stolu, kterou pod názvem Biologické zdroje – současný stav a výhled vedli L. Nátr a S. Nonheblová.

Druhý okruh problémů je reprezentován zejména příspěvky skupiny pracovníků Ústavu přírodních vláken z Poznaně (Polsko), vedených ředitelem ústavu R. Kozlowskim. V těchto příspěvcích se objevují téměř všechny aspekty pěstování a zpracování lnu a konopí ve středoevropských podmínkách. Významnou prezentací německého programu pěstování a zpracování lnu je přednáška K.-H. Kromera. Doplňují ji informace o vytvořené databázi poznatků o lnu (P. Pütz a A. Beckmann) a metodách určování kvality lněného vlákna (A. Beckmann a K.-H. Kromer). Informaci o současném stavu českého lnářství podal L. Rosenberg, P. Šmirous a S. Krmela. Problematice biologicky rozložitelných materiálů na bázi škrobu je věnován příspěvek J. Drobníka. Ekonomickými aspekty zpracování zemědělských materiálů se zabývá příspěvek J. Blahovce. Celý tento okruh otázek uzavírá diskuse u kulatého stolu na téma Zpracování zemědělských materiálů (J. Drobník).

Příspěvky prezentované na pracovním setkání, které byly předloženy písemně, jsou uvedeny ve dvou speciálních číslech časopisu Zemědělská technika. Podle rozsahu a způsobu zpracování je uvádíme buď jako původní práce, nebo jako aktuality. Zde je třeba se zmínit, že zařazení příspěvků do obou zmíněných skupin nemá nic společného s jejich vyšší či nižší kvalitou. Mezi aktuality musely být podle tradice časopisu zařazeny všechny práce diskusního a informačního charakteru, popř. práce, které nebyly dostatečně doloženy literárními prameny.

Na závěr stručného úvodu bych rád poděkoval všem účastníkům pracovního setkání za jejich velmi aktivní přístup ke všem jednáním. Chtěl bych je ujistit, že si velice vážím jejich enthusiasmu a erudice. Chtěl bych také poděkovat všem členům organizačního výboru a pomocníkům za pomoc při přípravě a organizaci pracovního setkání. Můj dík patří v neposlední řadě i sponzorujícím organizacím, jejichž pomoci vděčíme za možnost realizovat zmíněnou akci.

Praha, 29. 10. 1994   Jiří Blahovec

CHENOPODIACEAE SPECIES FOR GREEN BIOMASS AND GRAIN PRODUCTS FOR INDUSTRY

MERLÍKOVITÉ DRUHY JAKO ZDROJ ZELENÉ BIOMASY A ZRNA PRO PRŮMYSL

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ABSTRACT: The paper deals with the plants of the goosefoot family, particularly with fat hen, goosefoot, kochia and spear thistle which can be cultivated on dry soil with high content of salt and they have high yields of dry matter (14 to 16 t.ha^{-1}) under these conditions at high protein content (in Chilean goosefoot the protein yield per 1 hectare is higher than 1,200 kg). Proteins obtained from various parts of goosefoot family plants are very rich in valuable amino acids, such as lysine, methionine and cysteine. Green biomass can be used rationally as a source of food, feeds and valuable substances for pharmaceutical industry by fractionation method which is technically provided. Different possibilities of green biomass processed by fractionation are charted in Fig. 1. Similarly, it is possible to use seeds of some other goosefoot species. This information is confirmed by experimental values acquired during cultivation of goosefoot family plants in various parts of the world (Tabs. I to IV).

Chenopodiaceae species; leaf proteins; amino acids; foods; feeds; pharmaceutical industry

ABSTRAKT: Práce se zabývá merlíkovitými rostlinami, zejména lebedou, merlíkem, bytelem a slanobýlem, které se mohou pěstovat na suché půdě s vysokým obsahem soli a v těchto podmínkách mají vysoké výnosy sušiny (14 až 16 t.ha^{-1} za rok) při vysokém obsahu bílkovin (u merlíku chilského je výnos bílkovin z hektaru vyšší než 1 200 kg). Bílkoviny získané z různých částí merlíkovitých jsou velmi bohaté na cenné aminokyseliny, jako je lysin, methionin a cystein. Zelenou biomasu lze racionálně využít jako zdroj potravin, krmiv a cenných látek pro farmaceutický průmysl metodou frakcionace, která je technicky zvládnuta. Různé možnosti zpracování zelené biomasy metodou frakcionace jsou graficky znázorněny v obr. 1. Obdobně je možné využít semen některých dalších druhů merlíkovitých. Tyto informace jsou potvrzeny experimentálními hodnotami získaných při pěstování merlíkovitých v různých částech světa (tab. I až IV).

Chenopodiaceae species; listové proteiny; aminokyseliny; potraviny; krmiva; farmaceutický průmysl

INTRODUCTION

The biological diversity of plants offers a wide range of underutilized and potential plants for production of more food and raw materials for industrial uses (National Research Council, 1990; W i c k e n s et al., 1989).

Several *Chenopodiaceae* plants are adapted to or grow fairly well on dry saline soils (C a r l s s o n , 1993a, b). This extends the potential areas for new agricultural crops. *Chenopodiaceae* species from the genera *Atriplex, Chenopodium, Kochia, Salicornia, Sansola* and *Suaeda* seem possible to grow on mentioned types of marginal lands. Such lands cover up to 25% of available arable lands (N a b o r s , 1985).

The mentioned *Chenopodiaceae* plants have been used as forage and fodder crops, "spinach" vegetables, and as pseudocereals.

For the former two utilizations the green plant biomass can be wet-fractionated to produce a fibrous, pressed crop (PC) for bioenergy, paper pulp, and ruminant fodder, a leaf nutrient concentrates (LNC) for human food supplements, non-ruminant feed, and lipophilic phytochemicals, and a de-proteinized brown juice (DPJ) for industrial fermentations, including ethanol and biogas production (C a r l s s o n , 1993a; Fig. 1).

The grains are a potential, good source for food proteins, starch, oils and other constituents for industry (C a r l s s o n , 1993a).

Also, the occurrence of gluten-allergy by consumption of temperate cereal grains makes grains from pseudocereals interesting for medical diets as well as for health food industry, as the latest types of grains do not cause gluten intolerance.

GREEN BIOMASS

The dry matter production of native stands of forage species of *Chenopodiaceae* has been recorded to be-

1. Wet-fractionation of green biomass
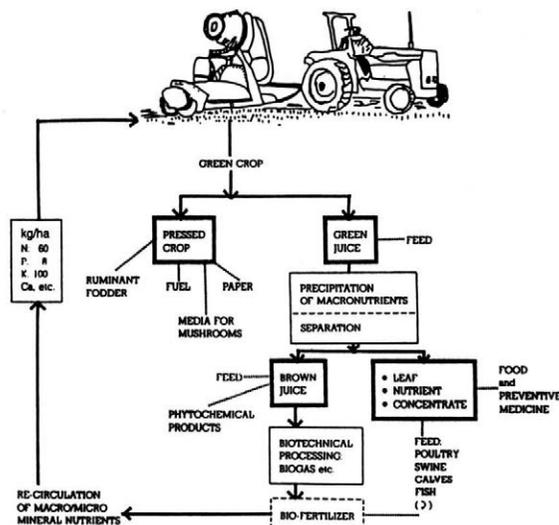
tween 14 to 18 tonnes per ha. Under controlled cultivation in agriculture, species of *Atriplex, Chenopodium, Kochia* and *Salicornia* are most productive (C a r l s s o n , 1993a). For example, the true protein yield per ha of green biomass of *Chenopodium quinoa* and *Atriplex hortensis* was more than 1 200 kg (C a r l s s o n , 1980).

Wet-fractionation of the green biomass of *Atriplex, Chenopodium* and *Kochia* species produces LNC with a protein content of 50 to 60% of the DM. The well--balanced protein amino acid composition of LNC has in *in vivo* feed experiments with rats given high nutritive values, similar to the ones of milk protein (C a r - l s s o n , 1980, 1984). The lysine values of LNC range from 5.7 to 7.0% of the protein, the methionine values from 1.8 to 2.3%, and the cystein values from 1.5 to 1.7% (C a r l s s o n , 1993a).

When necessary, the leaf proteins for LNC can be further fractionated into a green, chloroplastic-enriched

I. Proximate composition of grains of species of *Chenopodiaceae* (% of DM)

Latin name (Reference)	Starch	Protein	Lipids	Fibre	Ash
Atriplex:					
A. hortensis	–	30.5	7.4	2.8	3.7
	50	20.9	6.4	–	–
A. canescens	–	5.4	1.0	–	6.5
A. triangularis	–	16.4	9.4	–	3.5
Chenopodium:					
C. album	65.8	16.0	7.0	–	3.0
	–	18.2	–	–	–
C. amaranticolor	–	16.4	–	–	–
C. giganteum	–	19.0	–	–	–
C. pallidicaule	58.6	15.2	8.0	3.9	3.4
C. quinoa	58	16	4.5	–	–
	59.7	13.8	5.0	4.1	3.4
	60	17.3	6.3	2.0	3.6
	61.6	14.3	2.6	2.8	3.1
Kochia:					
K. scoparia	–	29.0	13.6	6.1	4.8
Salsola:					
S. kali	–	49.9	–	10.4	7.4

II. Amino acid composition of extracted protein fractions of *Atriplex hortensis* L. cv BP 150 (mg amino acid per 100 mg amino acids)

Amino acid	Protein fraction			
	Albumin	Globulin	Prolamin	Glutelin
Cysteine	1.6	1.7	5.3	1.9
Methionine	3.1	2.2	1.4	2.5
Aspartic acid	10.1	11.4	7.6	10.3
Threonine	5.9	5.3	3.7	3.4
Serine	5.4	5.8	4.3	6.0
Glutamic acid	14.6	15.2	13.4	20.0
Proline	3.0	2.1	15.5	4.4
Glycine	5.8	5.8	8.6	4.5
Alanine	5.1	5.1	5.6	3.6
Valine	6.0	6.3	3.7	5.0
Isoleucine	5.0	4.8	3.6	4.8
Leucine	7.6	7.9	5.2	5.8
Tyrosine	3.8	4.1	5.2	3.6
Phenylalanine	5.2	5.5	3.6	4.4
Lysine	7.3	7.0	3.1	4.2
Hystidine	2.7	2.4	2.6	3.5
Arginine	8.1	7.4	4.4	12.6

Source: (Author)

III. Amino acid composition of extracted protein fractions of *Chenopodium album* L. cv C 4-India (mg amino acid per 100 mg amino acids)

Amino acid	Protein fraction			
	Albumin	Globulin	Prolamin	Glutelin
Cysteine	2.0	1.1	6.0	1.6
Methionine	3.3	3.3	2.2	3.3
Aspartic acid	10.8	9.9	7.9	9.6
Threonine	5.9	4.1	4.7	3.7
Serine	5.7	5.6	4.9	5.2
Glutamic acid	15.9	17.0	17.4	18.5
Proline	2.5	3.7	6.0	4.7
Glycine	6.1	5.5	9.4	5.6
Alanine	5.6	4.3	6.8	4.0
Valine	5.8	5.6	4.4	5.0
Isoleucine	4.8	5.5	3.4	5.1
Leucine	7.6	7.3	6.2	6.4
Tyrosine	3.8	4.2	5.8	4.0
Phenylalanine	4.9	4.8	4.6	4.8
Lysine	6.6	5.6	3.4	4.5
Hystidine	2.2	3.1	1.3	3.6
Arginine	6.3	9.2	5.6	10.6

Source: (Author)

LNC and soluble proteins such as Rubisco protein (F I-protein) and F II-proteins for food industry. The amino acid composition of soluble leaf proteins is even better than the one for LNC. F I and II proteins have good functional properties (Carlsson, 1985). The white F I + F II protein isolates of *C. quinoa* and *A. hortensis* have a high nutritive value *in vivo* (Ostrowski-Meissner et al., 1984).

The LNC in general is a good food supplement source, not only for its high-quality proteins, but also for its high contents of beta-carotene, and minerals, such as iron and calcium (Carlsson, 1983).

The LNC has been incorporated into flour-based products (pasta and bread), ice cream, and meat products. The use as food supplement is utilized in tropical countries, such as Bolivia, Mexico, Nicaragua, Bangladesh, India, Pakistan, and Sri Lanka (Find Your Feet, 1991).

GRAINS

Pseudocereals especially of *Chenopodium quinoa* and related species, such as *C. nuttalie* and *C. pallidicaule* were used for long times in South America as food (Carlsson, 1993a; Tab. I; Tapia, 1979; Risi and Galwey, 1984). Grains of other species, e. g. *Atriplex* species were used as a source of edible oil.

The grain yield has been quoted to be from 2 to 10 tonnes per ha, and the grain protein yield up to 970 kg per ha for different *Chenopodiaceae* species (Carlsson, 1993a; the same reference valid for the text below, too).

The grain protein content for different *Chenopodiaceae* species varies from 15 to 30% protein of the DM. The content of fat/oil varies from 5 to 9%, and the starch content from 50 to 60%.

The whole grain protein is rich in lysine (up to 7.0%), methionine (up to 2.3%), and cysteine (up to 2.0%), which makes it one of the best composed food grain proteins. The grain proteins have been fractionated into albumin, globulin, prolamin, and glutelin. It was found out that albumin had the highest lysine content (6.6–7.3%) as well as the highest methionine content (3.1–4.4%), while the highest cysteine content was recorded for prolamin (3.9–6.0%) (Tabs. II–IV). As the contents of each protein fraction vary between cultivars and provenances, it is possible to make a simple genetic selection for even better composed whole grain protein.

CONCLUSIONS

Several *Chenopodiaceae* species contain high quality proteins, both in their green biomass and in their grains. The species are promising raw material sources for industrial use of protein, starch, fat, fibres and phytochemicals from plants grown at marginal lands that are dry or saline (Carlsson, 1993a).

IV. Amino acid composition of extracted protein fractions of *Chenopodium quinoa* Willd. cv Sajama-Bolivia (mg amino acid per 100 mg amino acids)

Amino acid	Protein fraction			
	Albumin	Globulin	Prolamin	Glutelin
Cysteine	1.4	1.3	3.9	0.9
Methionine	4.4	1.7	1.7	2.2
Aspartic acid	9.9	10.8	7.7	11.0
Threonine	5.2	4.0	4.5	4.5
Serine	5.5	6.3	5.0	5.0
Glutamic acid	16.1	18.8	14.0	18.0
Proline	2.2	3.0	10.1	5.3
Glycine	5.5	5.5	9.4	5.8
Alanine	5.3	5.4	4.6	5.6
Valine	5.8	5.0	3.8	6.4
Isoleucine	4.2	4.8	2.6	5.9
Leucine	8.0	8.0	6.4	8.3
Tyrosine	3.8	3.8	5.8	4.1
Phenylalanine	4.8	5.2	3.5	5.8
Lysine	6.9	4.4	6.0	3.7
Hystidine	2.9	3.4	3.6	2.5
Arginine	8.1	9.6	7.3	8.2

Source: (Author)

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BIOMASS POTENTIAL AS A SOURCE OF ENERGY IN THE CZECH REPUBLIC

BIOMASA JAKO ZDROJ ENERGIE V ČESKÉ REPUBLICE

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ABSTRACT: Inspection of available sources of biomass in the Czech Republic shows that about 7 million tons of these materials should be used annually for energy purposes directly in the countryside. This regards to about 1 million tons of wood waste, 2.5 million tons straw agricultural waste (maize and rape), 1 million tons of fast-growing tree species, 1.5 million tons of municipal waste and 1 million tons industrial waste. A great amount of radiation is produced during combustion of waste wood of various heat output from small boilers for heating of households to the output of 3 MW (Sigma Brno, ČKD Praha – Fig. 1). Equipment for combustion of straw is missing at the moment. The researchers of the Research Institute of Agricultural Engineering in Prague deal with its development in cooperation with Austria and Denmark. Rural regions have not prepared the energy conception till now. Market prices of fuels will create prerequisites for higher utilization of biomass as a source of heat, the district heating of regions or cities by heat acquired from combustion of biomass seems to be prospective. Central heating of villages may be based upon present heating plants of enterprises by adjustment to biomass combustion (output of 1 to 10 MW is predicted). The whole spectrum of smaller facilities intended for biomass combustion is required for households (up to 30 kW), enterprises, halls, etc. (20 to 500 kW). Respective devices should be tested and approved as soon as possible, the machines and equipment (chip machines, presses, transport vehicles, and so on). These demands are associated with necessity to amend the present standard being in effort in this sphere.

wood waste; straw agricultural wastes; fast-growing tree species; municipal wastes; industrial wastes; biomass combustion

ABSTRAKT: Inventura dostupných zdrojů biomasy v České republice ukazuje, že cca 7 milionů tun těchto materiálů by mohlo být ročně použito k energetickým účelům přímo na venkově. Jde o cca 1 mil. tun dřevního odpadu, 2,5 mil. tun slamnatých zemědělských odpadů (kukuřice a řepka), 1 mil. tun rychle rostoucích dřevin, 1,5 mil. tun komunálních odpadů a 1 mil. tun průmyslových odpadů. Vyrábí se velké množství zařízení pro spalování odpadového dřeva s různým tepelným výkonem od malých kotlů pro vytápění domácností až po výkon 3 MW (Sigma Brno, ČKD Praha – obr. 1). Zatím chybí zařízení na spalování slámy. Jeho vývojem se zabývají pracovníci Výzkumného ústavu zemědělské techniky v Praze v ko-operaci s Rakouskem a Dánskem. Ve venkovských regionech však není zpracována energetická koncepce. Tržní ceny paliv vytvoří předpoklady pro vyšší využití biomasy jako zdroje tepla, perspektivní se zdá dálkové vytápění regionů či měst teplem získaným spalováním biomasy. Centrální vytápění vesnic může vycházet z dosavadních výtopen podniků úpravou na spalo-vání biomasy (lze předpokládat výkon 1 až 10 MW). Celé spektrum menších zařízení určených ke spalování biomasy je potřebné pro vytápění domácností (do 30 kW), podniků, hal apod. (20 až 500 kW). Příslušná zařízení by měla být urychleně zkoušena a schvalována, měly by být vyvíjeny potřebné stroje a zařízení (štěpkovače, lisy, přepravní zařízení apod.). Tyto potřeby souvisí s nutností úprav současných norem v této oblasti.

dřevní odpad; slamnaté zemědělské odpady; rychle rostoucí dřeviny; komunální odpady; průmyslové odpady; spalování biomasy

INTRODUCTION

Energetic potential of the combustible wastes of the biologic origin from agricultural production and from household which are within area of the Czech Republic and which have not been mostly used for the purpose of the energy production is considerable. Similar quality of above lead waste materials is a wood waste as a rest of wood cutting and processing and/or even having its origin in wood growing and cultivating. All above-stated waste materials have these common sings: diversification all over the state area and they have, however, relative proximity and easily to be processed in the villages and agricultural plants.

Estimation is 40 up to 50% of heat consumption in country side fleets and drying processes in the agricultural production can be covered from these sources, i. e. mainly brown coal be substituted in this portion from these sources (Kára et al., 1992).

Great amount of straw remains in the stacks without any use where step by step is destroyed due to high percentage of the corn on the arable land and high share of cattle breeding without use of straw. Great portion of straw, especially rape straw, is burnt just in the field

even with the risk of ecology difficulties. Significant and classics energetic source is wood. Various remains of wood processing and forest cultivating can be used for heating. It cannot be said that wood remains are the waste in the very sense of the word because stated wood together with other biomass (such as leaves and pine-needles) is a part of natural nutrients circulation in the forest ecosystems and its long-lasting taking away might cause soil quality degradation.

Some portion of energy and costs have to be invested into transport preparation and concentration before these sources are prepared to exploitation. Average energy consumption of production and transport (within distance of 40 km) of 1 000 m^3 of wooden chips is 10.4 t of diesel oil. Energy profit from chips combustion is as much as ten times higher than invested energy in the form of diesel oil (K á r a et al., 1991).

Investigations led out 4 years ago showed that approximately 50 million of cubic meters (25 million tons) of the wood which could be exploited for energy production – in the form of chips, branches, twigs and other remains from tree cutting were in the forests of the Czech Republic. This raw material is, however, in various degrees of decay, so real supply of this source is only partial. These sources are highly probable to be exploited above all by private owners of the forests. Household waste combustible share of which constantly increases due to higher quality of the packing, is very difficult to be stored at the ecology unbearable depots.

There are several reasons causing this state, one of them is still cheap and state-subsidized „classic" energy which does not allow economic exploitation of „non-classics" sources.

MATERIAL AND METHODS

SOURCES OF WASTE MATERIALS EXPLOITABLE FOR POWER PRODUCTION IN THE CZECH REPUBLIC (COUNTRYSIDE)

Information sources say that countryside regions will have available following combustible waste materials in several future years:

waste wood	1 million tons
corn and rape straw	2.5 million tons
quickly growing wood species and products exploitable for energy production	1 million tons
municipal waste	1.5 million tons
other combustible waste (industrial production)	1 million tons
total	7 million tons

Total wood cutting from forests in Czech Republic represents 10 million tons of wooden mass (excluding remains in forests) in several last years (I l a v s k ý et al., 1991).

Total corn straw production represents approximately 10 million tons, rape straw production is more than half a million tons in several last years.

More than 40%, i. e. approx. 4 million of inhabitants live in countryside regions including small towns. Everyone of them produces (on average) 150 up to 300 kg of combustible waste materials per annum, i. e. 0.4 up to 0.8 kg daily.

Combustible waste materials from industry, building and service sphere represent 1 million tons.

Brown coal consumption for household heating was estimated to 6 million tons the Czech Republic in 1970.

RESULTS

APPLIANCES ALLOWING EXPLOITATION OF ORGANIC ORIGIN WASTE MATERIALS IN THE CZECH REPUBLIC

Some portion of quality waste wood and waste paper, maybe even of straw, will be still exploited for industrial processing. Estimation is that this portion would not exceed 10% of the real available quantity.

Number of appliances enabling combustion of minute waste wood, i. e. sawdust, chips etc., was developed and led into production in the CR in recent years. They are especially boilers for small houses (Verner, Červený Kostelec; Cankař, Bělá pod Bezdězem) with thermal output up to 30 kW, more powerful hot-water and hot-air appliances with output of 0.4 up to 1 MW (Agrametal Jeníšov) and huge equipments for heating plants 1 to 2 MW (Sigma Brno, Slatina). Efficient devices are produced in ČKD Dukla Praha plant. Fig. 1 shows combustion prechamber for boilers made by ČKD with output approximately 1 MW. Fig. 2 shows special steam boiler made by ČKD destined for waste
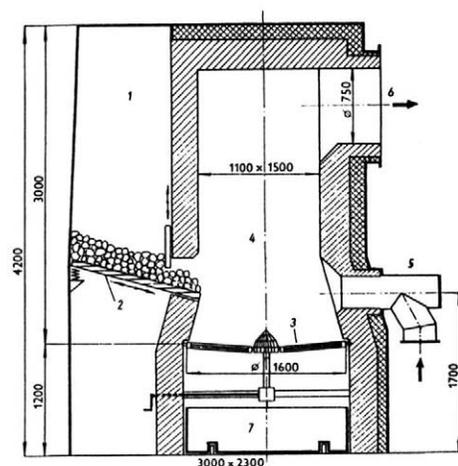
1. Combustion prechamber of boiler made by ČKD Dukla for piece waste material combustion

1 – fuel container, 2 – travelling grid, 3 – furnace grate, 4 – combustion chamber, 5 – burner, 6 – waste gases exhaust, 7 – solid ends outlet
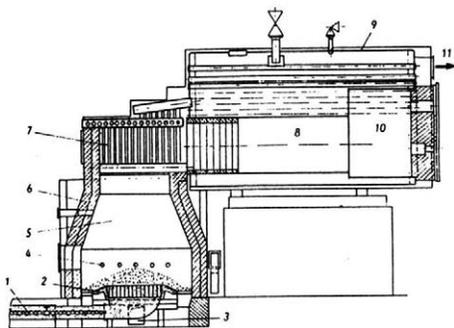
2. Steam boiler with combustion prechamber destined for combustion of fine grain waste

1 – warm conveyer, 2 – furnace grace, 3 – primary air inlet, 4 – secondary air, 5 – combustion prechamber, 6 – fettling, 7 – front chamber, 8 – flue, 9 – boiler body, 10 – reversing chamber, 11 – waste gases exhaust

wood combustion. Boiler output is according to model from 1 to 3 MW. All herein mentioned devices have very good technical qualities and/or are prepared to accept further technical improvement (automation).

Straw combusting appliances are not yet available in the CR, development ensures the research Institute of Agricultural Engineering, Praha. Household waste combustion is solved in cooperation with Austria and Denmark.

Some of herein stated appliances (especially those made by Agrametal Jeníšov) have the shape of additional furnaces which can be built in front current boilers combusting coke or light heating oil (for the time being wood combustion only) (K á r a et al., 1991).

Conception of the technical development and energetic policy in countryside regions is neither directed nor prepared. At the same time situation and time is ready to accept principal rules for further development which can aim directly at the trends topical abroad.

CONCLUSION AND PROGNOSES

BRANCH OF BIOLOGIC WASTE MATERIALS
COMBUSTION IN THE CZECH REPUBLIC
(K á r a, et al., 1991, 1992)

– Supposed transformation of the energy prices onto the market principles based on the production costs (+ profit and taxes) should create conditions for citizens, communities and plants to be interested in exploiting waste material energy sources. Each techno-logy, either forest and agricultural one, should produce no wastes harmful to environment and country. Wastes of all kinds should be liquidated as often as possible with heat production unless they are secondary raw materials for other production.

– Central and/or long-distance heating of the whole provincial plants and housing estates and greater towns via combustion of combustible wastes (household waste, straw surplus and wooden waste, and/or further waste materials from textile industry and various sewage and cleaning plants) is prospective.

– Central refuse incinerating plants should be projected and built up quickly. Current boiler rooms in agricultural plants combusting light heating oils being re-built to be able to furnace secondary fuels could be good base for heating plants in the villages which could be exploited either by agricultural plants and for production (drying) processes and house and fleet heating. Supposed thermal output is 1 to 10 MW.

– In addition attention should be paid even to combustion chambers and to boilers of smaller output (up to 30 kW in family houses, up to 20–500 to 1 000 kW in agricultural and similar plants) exploitable for heat production to rooms, halls and technological purposes.

– Developmental and certifying base should be quickly built for verifying and certifying herein stated new appliances.

– Free way should have development of the auxiliary devices (wood chipping machines, straw presses, transporting devices, etc.).

– Works on relevant standards and rules should be quickly opened or foreign standards should be implemented.

– Biomass production for technical and energetic purposes, especially cultivation of quickly growing wood species, has its own further contributions in social economic sphere, it limits production of emissions and improves stability of climate. Neither positive contribution of enlarging area of verdure may not be ommited.

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THE EFFECT OF CULTIVAR ON APPLE SLICE WHITENESS AND ENZYMATIC BROWNING

VLIV ODRŮDY NA BĚLOST A ENZYMATICKÉ HNĚDNUTÍ JABLEČNÝCH PLÁTKŮ

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ABSTRACT: Whiteness and enzymatic browning of apple slices, which determine the quality of agricultural material for industrial use, were measured spectrophotometrically at 440 nm in diffuse reflectance mode in relation to 33 cold stored apple cultivars. These features are involved mainly in the commercially important variations in apple browning. It was found out that cutting slices performed under water had a differentiating effect on preventing browning, which was related to cultivar properties

apple varieties; enzymatic browning; whiteness of tissue

ABSTRAKT: Bělost a enzymatické hnědnutí jablečných plátků mají vliv na hodnocení kvality dužniny jablek. V práci jsou tyto vlastnosti určovány objektivně prostřednictvím difúzní odrazivosti světla o vlnové délce 440 nm. Měření jsou prováděna s použitím spektrofotometru Spekol 10 vybaveného Ulbrichtovou koulí se vstupním otvorem o průměru 14 mm. Analyzována byla dužnina plodů 33 odrůd jabloní pěstovaných v Sierniewicích (vojvodství Rzeszów). Experimenty se opakovaly pro každou odrůdu celkem třikrát (na začátku skladovacího období, uprostřed něj a na jeho konci – teplota skladování 3 až 5 °C). Všechny testované plody prošly před experimenty 36hodinovým obdobím zotavení při pokojové teplotě. Každý experiment se dělal s pěti plody a u každého plodu šestkrát (celkem 30 plátků). Měřilo se ihned při přípravě plátku a opakovaně po 30 minutách. Plátky byly připravovány nástroji z nerezavějící oceli buď ve vzduchu, anebo pod vodou. Výsledné hodnoty odrazivosti (ve srovnání s etalonem) jsou uvedeny v obr. 1–3. Obr. 1 reprezentuje posloupnost odrůd podle jejich rostoucí difúzní pohltivosti (měření ihned po přípravě vzorku), zatímco na obr. 2 je obdobná posloupnost sestavena na základě rozdílů mezi opakovaným a okamžitým měřením u vzorků připravených na vzduchu. V obr. 3 je vynesen stupeň zhnědnutí vyjádřený jako poměr horního kvartilu rozdělení rozdílů pohltivosti (obr. 2 – pro jednu odrůdu) a mediámu difúzní pohltivosti (obr. 1 – pro tutéž odrůdu). Podle výsledků na obrázcích je patrné, že odrůdy Šampion, Elstar, Ozark Gold a Fantazja nehnědnou. U většiny ostatních, s výjimkou velmi tvrdých odrůd, hnědnutí závisí na způsobu přípravy vzorků (na vzduchu či pod vodou).

odrůdy jablek; biologické hnědnutí; bělost

INTRODUCTION

Browning of apple tissue occurs upon bruising during handling or transportation and also when exposed to air in the cutting, slicing or pulping processes.

An important quality attribute of apple slice tissue prepared commercially is its white colour. In this sense white is the colour of freshness and cleanness, and not only psychologically, but is also currently an indicator of freedom from contaminants (Sapers, Douglas, 1989; Spanos, Wrolstad, 1992) and as such can be a measure of the quality of the product.

The prevalent use od sulfites as inhibitors of enzymatic browning in food technology has been restricted, so alternative inhibitors have been investigated (Sapers, Hicks, 1989). Variety oriented studies in this applied area are notably lacking, despite numerous im-

plications in the literature that great differences occur in the natural potential of apple browning inhibition which the food technology tries spontaneously to utilize (Sapers, Hicks, 1989; McLellan et al., 1990; Aubert et al., 1992).

The cultivar differences are mainly due to the relative balance between hydroxycinnamide derivates and flavan 3-ols in apple tissue (Oszmiański, Lee, 1990; Amiot et al., 1992). This can be naturally affected by many other factors when the fruit is harvested and during other operations involved in post-harvest storage and processing (McLellan et al., 1990).

In studies of the effectiveness of artificial inhibitors, a procedure is used, whereby a cut out control sample is soaked in water for 10 seconds, following which the sample is blotted dry by rolling on absorbent tissue (Sapers, Douglas, 1987). Specific cultivar re-

sponse to use the of water for preventing slice tissue browning has been noticed from time to time in some laboratories (K u c z y ń s k i et al., 1993).

In the study, the genetic and natural potentials of cultivars have received particular attention because of its multiple effects of browning development (A u b e r t et al., 1992; A m i o t et al., 1992; K u c z y ń s k i et al., 1994).

MATERIAL AND METHOD

Preparation of apple slices

Apples of 33 cultivars: Sampion (SAM), Ozark Gold (OZG), Elstar (ELS), Fantazja (FZJ), Jonagold (JOG), Gala (GAL), Golden Delicious (GDL), Ligol (LIG), Jonathan (JON), Starting (STK), Red Fireside (RFS), Gloster (GST), Honeygold (HGD), Melrose (MEL, Macspur (MPR), Wealthy (WHY), Starkrimson (STN), Cortland (CTR), Prinz Albrecht von Preussen (PAP), James Grieve (JGV), Bancroft (BKF), Friedom (FDM), Beforest (BFR), Macoun (MUN), Prima (PRI), Billing Boscoop (BIB), McIntosh (MCI), Boiken (BOI), Florina (FLO), Idared (IDR), Liberty (LBR), Lobo (LBO), Spartan (SPT) grown at the same trial plantation of the Skierniewice Research Institute of Pomology and Floriculture in Albigowa (Rzeszów voivodship).

In September and until the end of October 1993 apples were picked when judged to be of optimal ripeness for cold storage. Fruits representative for the varieties were selected and collected in samples of 40 apples, packed is standard carton boxes of 80 apples, cooled, and stored at 3–5 °C. At three intervals; early, medium and late storage throughout the cold storage life each cultivar, 10 fruits were removed and conditioned at room temperature four 36 hours.

Five apples were processed as slices in air and five under water, according to rigidly controlled method to minimize fluctuations in the texture of surfaces. A manual corer and wedger (stainless steel) was used to prepare slices for fresh fruit salads. Water from the slices was centrifuged in salad spinner, immediately after cutting (K u c z y ń s k i et al., 1993).

Optical changes and browning measurements

A number of scales are used specifically in the measurements of whites. Paper industry has been using blue reflectance as its primary determinant of optical quality of pulp after bleaching, and textile industry has established a similar test procedure used to measure bleaching progress in cotton. So as not to complicate the measurements further by choosing another method of assessment, the authors used reflectance measurement at 440 nm which is in extensive use (S a p e r s, H i c k s, 1989; C i n d y et al., 1991) and is adequate for monitoring processes such as browning.

Each apple – i.e. 6 slices, were immediately analyzed for light absorbance and then stored for 32 min at room temperature, for second readings. Time for second measurement – 32 min was selected as appropriate for good characterization to the variability of the properties of all cultivars and treatments.

Diffuse reflectance at 440 nm was measured on slice surface by a Specol 10 spectrophotometer equipped with Ulbricht Sphere with 14 mm diameter viewing port. The results were collected by a microcomputer which also provided reliability and control of results by continual comparison of readings against an etalon: 57% reflectance at 440 nm and 800 mV data input. Slice surfaces were hand-held to the viewing port. A simple apparatus – i.e. Specol 10, ensured the sphere protection against contamination and its easy regeneration.

No changes in the albedo of the cut surface due to physical processes, such as evaporation of free juice, were observed. The spectrophotometric method adopted for fresh slices was verified in earlier works (K u c - z y ń s k i et al., 1994).

Each calculated value; absorbance at 440 nm – A440, difference of absorbance at 440 nm – DA440, is the results of 90 measurements (6 slices x 5 apples x 3 intervals of cold storage life). For graphic presentation of results we used the Notched Box-and-Whiskers Plot from Statgraphics Win v. 1.0 program. The central box covers 50% of measurements between the lower and upper quartiles while the central line as at the median. The whiskers extend out to the extremes (minimum and maximum values).

RESULTS AND DISCUSSION

Apple slice whiteness

The results – absorbance at 440 nm – A440 of fresh surface varied from minimum 0.2 to maximum 0.5 (Fig. 1). The lowest values of A440 < 0.3, corresponding to the impression of whiteness of tissue, are those of the following cultivars: CTR, SPT, LBO, BOI, LIG, MUN and MCI. Their pomological description is dominated by expressions relating to the degree of whiteness: bright white, light yellow, tan cream (M o h r et al., 1989). The highest values of A440 > 0.4 are those for GAL, HGD, JOG, STN, BIB. Their pomological description includes various references to colour: green, tan, light-tan, cream, yellow (M o h r et al., 1989). Such considerable differences at 440 nm are caused by the physical properties of diffusion and absorption in the tissue and pigmentation of the cultivars under study (P u c h a l s k i, 1989).

The variability within a cultivar is considerable. No relation was observed between the parameters of dispersion and the value of parameter A440. The range covering 50% of the values measured, i. e. between the quartiles (in the figures – box) often exceeds 0.05 ABS

(absorbance), and the range to the extremes (in the figures – whiskers) reaches 0.15 ABS for such cultivars as SPT, MPR, LBR, WHY and STN. The differentiation within a cultivar is due mainly to the different levels of carotenoid content (A u b e r t et al., 1992).

Browing of tissue

Parameter difference in absorbance at 440 nm – DA440 has been introduced for the evaluation pigmentation from enzymatic browning or estimation the effectiveness of inhibition (K u c z y ń s k i et al., 1993). The cultivars presented on Fig. 2 was arranged according to the median of absorbance difference – DA440me of apples sliced in air. Increase of absorbance after 32 min was not statistically significant for the following group cultivars: SAM, ELS, FZJ, OZG. The values of DA440 reach as 0.25 for the LBR, SPT, LBO and BIB cultivars. Variability is considerable – the middle 50% of measurements often exceeds 0.1 ABS, and the range of extremes 0.15 ABS for numerous cultivars.

The application of under water slicing lowered the values of DA440, also the variability being especially reduced in the case of GST, WHY, GAL, IDR and MCI but there was an increase in variability in the case of such cultivars as BKF and LBO.

With the under water slicing technique and with the considerable variability, the browning of slices of c. v. JOG, GDL, LIG, CTR and MCI can be approved to be tolerable browning.

We observed, following the sensory matching, that the consumer judges the whitest slices and automatically selects these from several others, so this discrimination is very sensitive to even slightly more brown slices in tested sample, and finally very rigorous for the quality of given cultivar.
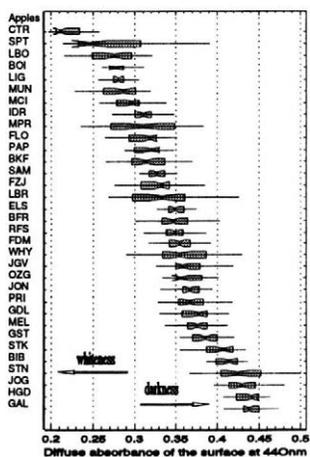
Browning of cultivars

The application of the absorbance difference parameter for the comparison of browning in different cultivars, does not take into consideration the effect of the initial colour on the perception of colour change. It is known that as ABS increases, the perceptibility of colour changes decreases, and moreover, a decrease in quality is considered notable even when a small number of slices has a higher ABS, eg. as for IDR or WHY. These two features of perception are well reflected by the following parameters; the median of difference of absorbance – DA440me and the upper quartile in difference of absorbance – DA440q. No correlation between these parameters was observed. The introduction of the parameter

browning grade of apple slices = DA440q/A440me,

ensures, as we suppose, that results should be in reasonable agreement with sensory rating of apple varieties susceptibility to browning. The values of browning grade determined for browning time 32 min fall within the range of from 0% to 100% (Fig. 3).

Non-browning cultivars are: SAM, ELS, OZG, and among them FZJ, a Polish desert cultivar. Under water slicing notably altered the rating of cultivars, however, cultivars of hard tissue, STK, HGD, JOG, did not respond by an effective decrease in their browning grade. It was cultivars of loose tissue, eg. MCI, BFR, whose

1. Apple cultivars arranged on the basis of tissue whiteness evaluation, i. e. according to increasing absorbance at 440 nm
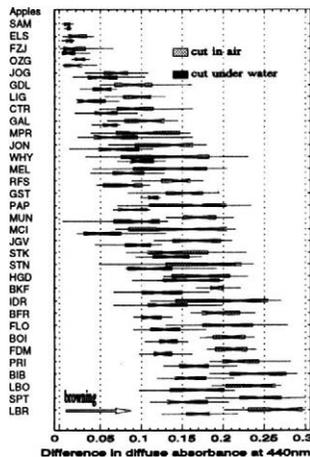
2. Apple cultivars arranged on the basis of progressing from pigmentation from enzymatic browning of surface sliced in air, i. e. according to increasing values of absorbance difference at 440 nm after 32 min from slicing
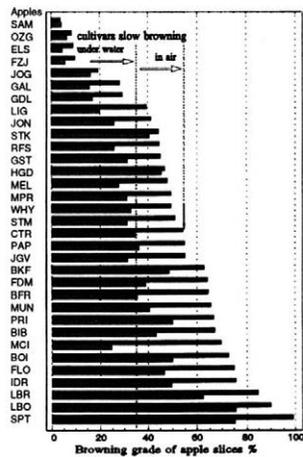
3. Cultivar susceptibility to browning on the surface of slices cut in the air (upper bars) and under water (lower bars). Cultivars rating according to increasing browning grade with air slicing (after 32 min from slicing)

browning grade decreased by a very considerable margin.

Cultivars which were characterized by a high variability and a slight increase in absorbance with under water slicing, were earlier considered to be of tolerable browning: JOG, GDL, JON, LIG, MCI and CTR. The assessment of their browning with under water slicing, in the worst case as eg. for CTR, reaches 35% grade. Also remaining within these range are the following cultivars: RFS, GAL, GST, JGV and JON (assessed as fairly good), MEL (fair but tissue absorbing water), STN (good) (M o h r et al., 1989). For those cultivars, the decisive compound were high values of absorbance – A440 of fresh slices (which decrease the perceptibility of tissue browning) and they brought down the browning grade.

The opinion of the CTR cultivar (browning grade 55% – see Fig. 3 when in air slicing was used) is: exceptionally slow discolour on slicing – bright white (M o h r et al., 1989). Therefore, all the cultivars should be classified in a similar way if their browning grade is slightly below 55% in air slicing.

CONCLUSIONS

The results obtained make it possible to clearly categorize the cultivars into groups; no browning, medium browning, and very strong browning. They allow for an assessment of the effectiveness of the cultivar factor and of the effect of the simplest of browning inhibitions – under water slicing.

Results obtained can be used in the determination of tolerance to quality changes in particular cultivars, especially on the basis of natural variability of the whiteness of fresh slices, acceptable to the consumer.

The present work was an attempt to follow such changes more closely, using 1993 crop and cold storage apples of 33 cultivars commonly grown in Poland, possessing properties that might be expected to result in slices varying in whiteness and enzymatic browning distribution.

Numerous features determine the attractiveness of the surface of sliced apple, and instruments-type evaluation cannot provide for all preferences. However, the method is very accurate in solving detail cultivar problems posed by the process of tissue browning.

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POTENTIAL APPLICATIONS OF CROP YIELD FORMATION KNOWLEDGE IN ENERGY PLANT PRODUCTION

MOŽNOSTI VYUŽITÍ ZNALOSTÍ O TVORBĚ VÝNOSU KULTURNÍCH ROSTLIN PŘI PĚSTOVÁNÍ ENERGETICKÝCH PLODIN

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ABSTRACT: The contribution presents a brief survey of biological principles of crop yield formation. Special attention has been paid to solar energy fixation and utilization by canopies and to conditions enabling high productivity, i. e. breeding new varieties and supply of fertilizers. Possibilities have been discussed about similarities and differences between „food" crops and energy crops with respect to photosynthetic productivity.

energy crops; biomass production; solar energy; breeding new varieties; fertilizers

ABSTRAKT: V tomto příspěvku je pozornost zaměřena zejména na energetické plodiny, tedy plodiny pěstované k získání biomasy následně využívané v různých technologických procesech jako obnovitelný zdroj energie. Komplex problematiky energetických plodin se skládá ze dvou částí: 1. produkce biomasy fixující sluneční energii, 2. zpřístupnění energie či žádané chemické složky vhodnými technologickými procesy. Tento přehled se soustřeďuje na základní problémy fixace sluneční energie a maximalizace produkce organické hmoty rostlinami. Převážná část našich znalostí o tvorbě výnosu byla získána studiem tzv. klasických plodin pěstovaných jako zdroj potravin a krmiv. Přitom pro jakoukoli plodinu platí, že základem jejího růstu a produkce organických látek je fotosyntéza, tedy fixace oxidu uhličitého při využití energie slunečního záření. V tomto ohledu nejsou mezi „klasickými" a energetickými plodinami rozdíly. Existují však rozdíly zejména v podílu hospodářsky nejcennější části z celkové biomasy rostliny. U energetických plodin je využitelná téměř celá nadzemní hmota, takže otázky alokace sušiny a s tím spojená problematika transportu a distribuce látek má svůj specifický charakter. Zatímco teoretické maximum využití absorbovaného slunečního záření v oblasti fotosynteticky aktivní dosahuje 20 až 30 %, celoroční světový průměr využití dopadajícího slunečního záření činí asi 0,1 %. U polních plodin a za období vegetace se využití dopadajícího záření pohybuje kolem 1 %. Je tedy evidentní, že i velmi vysoká produkce některých polních plodin v současné době je dosti vzdálena od teoreticky možného i prakticky realistického maxima. Za uplynulé půlstoletí se u většiny významných polních plodin doslova enormně zvýšily výnosy o 100 i více procent. Proto již první ropná krize počátkem 70. let stimulovala plány na využití kulturních rostlin i jako obnovitelného zdroje energie. Leč první solidní analýzy prokázaly, že vysoké výnosy jsou téměř ve všech případech spojeny s velkými energetickými vstupy. Podíl (sklízená sluneční energie) / (dodaná energie z fosilních paliv) dosahuje u obilnin hodnoty kolem 2 až 4, extrémně malá je tato hodnota u rychlené zeleniny či skleníkových květin. Přitom největší podíl dodávané energie tvoří průmyslová hnojiva. Množství sušiny vyprodukované na jednotce plochy půdy je určeno délkou vegetační doby, pokryvností listoví udávanou celkovou plochou asimilačních orgánů na jednotce plochy půdy a rychlostí fotosyntézy. V současné době a pro nejbližší budoucnost se za jednoznačně nejdůležitější faktor považuje pokryvnost listoví. Rychlé dosažení hodnot 7 až 11 při vhodné prostorové orientaci listových čepelí je základním předpokladem pro vysokou produkci porostem. Trochu překvapivě se vlastní rychlost fotosyntézy, vyjádřená rychlostí fixace atmosférického oxidu uhličitého na jednotku plochy listů za jednotku času, na růstu výnosů nikterak nepodílí. Je však mnoho důvodů k tvrzení, že právě tento faktor představuje významnou rezervu pro budoucí růst produkce plodin. Pro vysoké výnosy polních plodin jsou důležité tyto faktory: 1. šlechtění nových odrůd, 2. dávky průmyslových hnojiv, 3. ochrana proti plevelům, chorobám a škůdcům, 4. závlahy, 5. růstové regulátory. Seznam zdaleka není úplný. Zcela jednoznačný je však význam prvních dvou faktorů. S velmi obecnou platností lze konstatovat, že bez nově vyšlechtěných odrůd a bez aplikace poměrně vysokých dávek průmyslových hnojiv nelze u žádné plodiny a v žádných podmínkách dlouhodobě zajistit vysokou produkci biomasy. V tomto smyslu jsou i dosavadní experimentální poznatky u energetických plodin velmi nedostatečné.

energetické plodiny; produkce biomasy; sluneční energie; průmyslová hnojiva; šlechtění nových odrůd

INTRODUCTION

Plant cultivation to obtain renewable energy or valuable components for industrial non-food use is one of the most important challenges for both research and agriculture. Its importance has been increased because of the surplus of food production in EU and some other industrialized countries as it offers possibilities for utili-

zing economically imposed decrease in arable land. In this contribution, I shall denote the classic crops as „food crops" to simplify their distinction from the energy crops. Furthermore, most of the text will deal with problems of maximizing solar energy fixation. Hence, the topic will not uniformly cover all of the problems of non-food agroproducts use.

In my opinion, the use of plant biomass as a source of energy or raw materials consists of two parts:

1. Solar energy → ENERGY FIXATION BY PLANTS → Plant biomass
2. Plant biomass → INDUSTRIAL TECHNOLOGIES → Various forms of energy and/or economically interesting products.

Most attention has been paid to the second part of the whole complex, i. e. how to use agromaterials most efficiently. However, any industrial use requires a supply of „phytoenergy". More energy per unit plant dry matter or more dry matter available, more of it can be used. And because (1) this first part seems to me to be generally neglected and at the same time (2) it corresponds with my field of studies, this contribution presents a brief survey of principles modulating both the extent and efficiency of solar energy use by plants.

Practically all knowledge on crop productivity and yield formation has been gained in studies aimed at better understanding of crop growth. Knowledge, both empirical and theoretical, has been very successfully applied to crop production as might be deduced from the enormous increase in yields of most crops, i. e. in food production per unit soil surface (B u r i n g h et al., 1975). When applying this knowledge to energy crops, two different aspects have to be taken into account:

1. The very basis of any crop production is photosynthesis. Even when dry matter or energy content of the product is not of prime importance, e. g. in some vegetables or flowers. their production largely depends on radiant energy fixation. The data on principles and factors efficiently modifying solar energy utilization by individual plants or particular canopies could be directly applied in energy crop production. This will be described in more detail in this contribution.

2. There are considerable differences between strategies of „food crop" and energy crop production. For example, in energy crops, the total shoot biomass may be harvested and used while with most food crops only some morphological (kernels, tubers, etc.) or chemical (sucrose, starch, proteins, etc.) plant constituents are economically important. This indicates, that dry matter allocation and translocation processes could limit economic yield in food crops while being of no importance for energy crops. As a consequence, the sink – source relationships in energy crops differ considerably from those in food crops. And finally, in typical energy crops, only the amount of accumulated (fixed) energy is of importance indicating that the amount of mineral nutrients could be kept as low as possible.

It seems to me that the differences deserve a detailed evaluation in order to draw limits for the transfer of knowledge from food crops to energy crops.

SOLAR ENERGY FIXATION

Crop production depends on many parameters characterizing the surrounding atmosphere and soil, e. g. temperature, water and mineral nutrient availability, etc. In order to exemplify the primary and decisive role of just photosynthesis, let us recall the composition of a plant. Most growing plants consist of about 90 per cent water and 10 per cent dry matter. Some water remains in the crop harvested at the appropriate time simply because it would be technologically too difficult to leave it on the field (sugar beet etc.). Hence, dry matter represents the very target of crop cultivation. In most dried plant biomass 5 per cent of dry mass consists of mineral nutrients, i. e. nitrogen, potassium, phosphorus, magnesium, calcium, etc. Although important for nutrition, economic yields and profits largely depend on the amount of produced organic matter forming more than 90 per cent of most dry plant biomass. And plants construct new organic materials from the CO_2 only by fixing radiant energy in photosynthesis.

Crop production aims at maximizing the amount of fixed (solar) energy with minimum input of fossil fuels energy. What possibilities exist for an increase in the amount of solar energy fixation? From what has been established in the biophysics and biochemistry of photosynthesis, the theoretical maximum of efficiency corresponds to 20 to 30 per cent of absorbed photosynthetically active radiation depending on its spectral composition that ranges from 400 nm to 700 nm. However, realistic maxima of the use of global solar radiation incident on canopies vary from about 5 to 9 per cent with experimentally determined values ranging from 0.5 to 4 per cent when only vegetative (growth) period has been taken into account (N i č i p o r o v i č, 1956; P e t r et al., 1988). Finally, it may be interesting to give a value for the mean annual utilization of global solar energy on the whole planet. It yields some 0.1 per cent (C o o p e r, 1975). Of course, this very low value has to be ascribed to periods of the year as well as regions of the Earth unsuitable for growth at all.

Analyzing current data on crop productivity, remarkable achievements by farmers have to be appreciated. However, with most crops, a noteworthy increase in yields begun by the end of the last century and especially in the 1950s. Many hundreds of years of farmers' experience have led to stepwise improved productivity of most cultivated crops. But only the application of scientific knowledge was able to increase yields by a factor of 2, 3 or more during a couple of decades. This fact is also important for energy crops where both an introductory analysis and management including technologies based on current research could not only prevent unrealistic expectations but also ensure the highest possible output.

The highly productive agriculture in industrialized countries, attaining very high yields, requires not only knowledge, but also investments. It still holds that crop production harvests the sun while most industries consume energy from fossil, i. e. non-renewable, resources. However, high yields may be realized only when

considerable amounts of energy provided mostly by the combustion of fossil fuels have been applied. In the 1970s during the first oil crisis, the use of energy crops became exciting and challenging. Detailed analyses revealed that a supply of very high amounts of energy is needed if high yields are to be reached. Let us define the output as the amount of biomass energy fixed in its chemical form and originating from the solar energy. Let us further define the input as the amount of energy originating from fossil resources and needed to manage technologies of high yielding crops, i. e. mechanization, agrochemical production, harvesting, etc. Then the output/input ratio decreased to values of 1 to 5 in modern agriculture. Often, as much energy originating from fossil sources has to be applied as corresponds to the amount of solar energy fixed in the final crop yield. Let us recall that with most cultivated plants, the major component of the added input energy is represented by the production of industrial fertilizers, especially those of nitrogen. In some crops, this output/input ratio approaches zero, e. g. cultivation of flowers or vegetables in heated glasshouses. For most cereals reaching yields of some 4 to 6 t.ha^{-1}, the ratio varies from 1 to 5. Of course, very high output/input ratios are typical for extensive forms of the agriculture. Unfortunately, it seems impossible to combine high crop productivity with high output/input energy ratios (Pimentel et al., 1973, 1983).

Although limits in lowering input energy of highly productive canopies have not yet been reached, major improvements in the output/input ratio be expected by an increase in the output, i. e. by an increase in the amount of fixed solar energy.

SOLAR ENERGY FIXATION IN CROP CANOPIES

With an acceptable simplification it is possible to say (Schwanitz, 1960; Watson, 1962) that the amount of solar energy fixed depends on: (1) the duration of vegetative period (TIME): (2) the size and number of leaves in the canopy (LAI, i. e. leaf area index denoting total leaf area per unit ground area); and (3) the activity of leaves (Pn, i. e. rate of net photosynthesis). Hence, total biomass per unit ground area and growth period:
TIME (days) x LAI [m^2 (leaf area) m^{-2} (ground area)] x
x Pn [g (dry mass) m^{-2} (leaf area) day^{-1}]
The growth period is largely determined by geographic conditions and can hardly be extended. However, two important points emerge: (1) In many cases, only part of the vegetation period is being used by the crop. A purposeful selection and combination of several crops represent promising possibilities for extending the period of solar energy fixation. (2) Resistance or tolerance to low temperature may also contribute to extending the growth period under the given conditions.

Leaf area is by far the most important parameter modifying canopy potential to fix solar energy (Evans, Dunstone, 1970; Dale, 1988). Both mathematical modelling and empirical experiments have shown that a LAI of 7 to 11 is desirable to absorb and efficiently fix solar energy. As a leaf blade absorbs some 70 per cent of the

incident photosynthetically active radiation, the relatively high LAI must be combined with an appropriate spatial distribution of the leaf blades. It is important to expose most of the leaves to moderate irradiations. The efficiency of radiant energy use significantly increases with the decrease in irradiation. Therefore an optimum LAI has to be always related to the canopy structure. Theoretically, higher LAI of vertically oriented leaves enables higher photosynthetic efficiency. On the other hand, higher LAI means that more energy and carbon must be supplied to the leaves. A reasonable equilibrium between these two tendencies identifies the optimum (Ledent, 1989; Marshall, Porter, 1991).

In any case, at present and in the near future, for both food and energy crops, an optimum course of LAI during the growing period could be characterized as follows: after sowing or planting, high rates of leaf growth with horizontally oriented blades should cover the soil surface as soon as possible to avoid wasting radiant energy that falls on the ground. With an increase in LAI the newly emerged leaves should be rather small and in vertical position. Although these requirements seem to be too artificial and difficult to achieve with plants, breeding has proved to be very successful even in this task (Evans, 1975).

Rate of photosynthesis represents the most promising way of increasing yields in the future (Pettigrew, Meredith, 1994). Up to now, this feature has been explored neither in breeding, nor in technologies. It is a quite complex phenomenon deserving detailed analysis (Mokronosov, 1983; Muchow, Sinclair, 1994).

CONDITIONS ENABLING HIGH PRODUCTIVITY

In the previous section I tried to summarize processes determining the efficiency of solar energy utilization by crops. Farmers do not directly manipulate LAI or Pn. However, most of the technological measures have been applied, consciously or predominantly unconsciously, not to „increase a yield" but to modify canopy structure and functioning in a way favourable to an increase in solar energy use and dry matter allocation into economically important plant constituents.

The most important features enabling high crop productivity could be listed as follows:
1. breeding new varieties,
2. supply of fertilizers,
3. protection against weeds, pests and diseases,
4. irrigation,
5. growth substances.

Some more factors could be added when more detailed analyses are being performed for particular crop and conditions. However, the first two items are the most important (Nátr, 1965). No high yields could be achieved without new highly productive varieties and supply of nitrogen, phosphorus and potassium fertilizers.

In 1968, Donald introduced a concept of breeding on the basis of a constructed ideotype (Donald, 1968). In assessment of the prevailing breeding strategies over the previous decades, Donald divided breeders into groups selecting (1) by improving some nega-

tive features of current cultivars or (2) simply and empirically looking for lines with an increased yield. According to Donald, knowledge on plant biology enables the construction of „types denoting an idea", i. e. an ideotype on the basis of what is known of plant genetics, physiology, etc. This concept has been very challenging and by far not fully exploited yet. At present, by the end of this century, knowledge on plant productivity reached considerable level compared with the end of the 1960s. Hence, it would be very interesting to make up ideotypes for representative species of energy crops.

Fertilizers are needed at least to an extent corresponding to the export of mineral nutrients with the harvested biomass (W o l f , 1982). All over the world, no high yields have been reached without considerable input of fertilizers (G r e e n w o o d , 1982). Surprisingly, the role of mineral nutrients in most crops seems to be decisive not so much for an increase in total dry matter but predominantly to modulate dry matter distribution into the appropriate organs (W a r d l a w , 1990). Although the need of mineral nutrients for crops has been recognized in the middle of the last century, there is still considerable ignorance in their effects on physiology and biochemistry. This lack of knowledge makes it difficult to deduce general criteria for the assessment of an optimum nutrient supply etc. (N á t r , 1992). For energy crops where nutrient content has practically no importance, both theoretical research and practical evaluation seem to be most important and very promising in the suggested possibility of increasing the energy output/input ratio.

CONCLUSION

In this contribution a brief survey of principles on solar use efficiency has been presented. Physiology of yield formation offers many principles directly applicable in cultivating energy crops. On the other hand, special targets for energy crop introduce new and important questions, the solution of which will also be beneficial for the general understanding.

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ESTIMATING YIELDS OF BIOMASS CROPS IN THE NETHERLANDS

ODHAD VÝNOSŮ ROSTLINNÉ BIOMASY V NIZOZEMÍ

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ABSTRACT: The use of biomass crops as energy source is frequently mentioned as an option to reduce CO_2 emissions. For evaluation of the possibilities of using crops for energy supply it is vital to have reliable estimates of their yields. Candidate biomass crops like willow and miscanthus are not yet grown on a large scale, therefore it is difficult to assess their production. In this paper a simple method is developed to estimate regional averages of various biomass crops. The method is based on the linear relation between intercepted light and biomass production as found for most agricultural crops. A correction factor is introduced to account for the effects of various yield reduction factors. The quality of the yield estimations was studied by applying the method on several agricultural crops grown in two regions in the Netherlands. A deviation of less than 10% was found between actual and estimated yields. The estimated biomass yields in the Netherlands varied between 9–12 ton/ha and 11–14 ton/ha for the two regions respectively.

biomass crops; energy crops; yields; light use efficiency

ABSTRACT: Použití rostlinné biomasy jako zdroje energie se často uvádí jako prostředek, jak snížit emise oxidu uhličitého. Aby se mohly posoudit možnosti využití plodin k zisku energie, je potřebný spolehlivý odhad jejich výnosů. Reprezentanti těchto plodin, jako jsou vrba a miscanthus, se zatím nepěstují ve velkém, a proto je velmi obtížné hodnotit jejich produkci. V práci je popsána jednoduchá metoda určená k odhadu regionálních výnosů rostlinné biomasy u různých plodin. Je založena na lineárním vztahu mezi zachyceným světlem a produkcí biomasy, jak byl stanoven pro většinu zemědělských plodin (rovnice (1) až (3) a obr. 1). Různé vlivy snižující výnos jsou ve výpočtu respektovány prostřednictvím korekčního faktoru. Přesnost odhadu výnosu byla testována metodou používanou pro několik zemědělských plodin (viz tabulka v dodatku) pěstovaných ve dvou různých holandských regionech (obr. 2). Odchylky mezi skutečným výnosem a jeho odhadem byly menší než 10 %. Odhadnuté výnosy suché biomasy se v uvedených regionech pohybují v rozmezí 9 až 12 tun na hektar a 11 až 14 tun na hektar.

rostlinná biomasa; zisk energie; výnosy; účinnost světla

INTRODUCTION

The present use of fossil fuels as major energy source in the world implies that large quantities of CO_2 are emitted to the atmosphere. CO_2 is a greenhouse gas and increasing CO_2 levels in the atmosphere are likely to affect global climate. The IPCC report on global change (H o u g h t o n et al., 1990) estimated that under the „business as usual scenario" (the present annual increase of CO_2 emissions is retained) the atmospheric CO_2 concentration will reach the 700 ppm level by the year 2050, which may have serious effects on global climate. One of the options to diminish CO_2 emissions in the use of so called energy crops. During growth crops capture CO_2 and when the crops are used for energy supply CO_2 is released again. This means that CO_2 is recycled. Through replacing a part the fossil fuels by energy from crops CO_2 emission can be reduced.

Recently several studies have been published on possibilities of growing energy crops in various regions of the world (L y s e n et al., 1992; H a l l et al., 1993). In these studies the expected yields of these crops determine the results of the evaluation. For agricultural crops like sugar beet or wheat, which can be used for ethanol production, yield data can be obtained from agricultural statistics. The yields of biomass crops (used for electricity production) are more difficult to determine. In the first place because rather unknown crops are suggested as options for biomass production, so that hardly any yield data are available. Secondly, because the yield of a crop is determined by growing conditions during its growing season, and since these conditions vary from one field to another and from one year to another, large variation in yields is observed. This implies that yields obtained in one region in one year cannot easily translated to yields in other regions

or other years. These yield deferences are very large: the present average wheat yield the Netherlands is about 7 ton/ha, but individual farmers are harvesting 10–11 ton/ha in some years. In the third place, with respect to energy supply not the yield of one particular field is of interest but the amount of energy that can be produced for a whole region. This implies that the average yield in a region is required. This regionally average yield cannot be determined in field experiments.

In presently available evaluation studies on this subject the estimated yields are often based on a limited number of field experiments, and data are used for large areas (sometimes even globally). Since the yield in field experiments can deviate considerably from the regional average, and since expected yield is the key factor in most evaluation studies, improvement of the yield estimates can be a valuable contribution to the discussion on possibilities of using crops for energy production.

Here a very simple method is described to estimate regional yields of biomass crops. The method is based on knowledge obtained in agricultural research. The quality of the estimated yields is determined by applying the method to several agricultural crops from which regional averages are available. The regionally average yields of several biomass crops are estimated for two different regions in the Netherlands and results are compared to the yield estimates used in other studies on this subject.

METHOD

From research conducted with various agricultural crops is known that a linear relation exists between the amount intercepted solar radiation by the crop and the above-ground biomass produced (M o n t e i t h, 1977). The name „above-ground biomass", which is used in literature, is confusing since it does include harvestable below ground plant material, like tubers of potato and root of sugar beet. The slope of the line is the so-called Light Use Efficiency (LUE, Fig. 1). The value of the LUE is determined by growing conditions of the crop, the value is lower under poor conditions and higher under good conditions. Under optimal conditions a value of 1.2–1.4 g/MJ of global radiation for the LUE is found for most C3 food crops, but also for fast growing trees (M o n t e i t h, 1977; C a n n e l l, 1989). The value of 1.2–1.4 g/MJ is only applicable to crops that produce mainly carbohydrates, the production of other plant materials like proteins or oils requires much more energy (P e n n i n g de V r i e s et al., 1974). And a lower value for the light use efficiency must be used to calculate production of crops like sunflower or rapeseed. Candidate biomass crops don't produce these „energy expensive" plant materials so that the 1.4 value is appropriate for estimation of their yields. The growth rate of C4 plants is higher than of C3 plants but only in warmer climates. In Dutch conditions values of
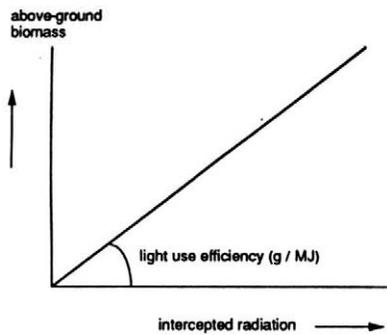
1. Relation between intercepted radiation and above-ground biomass produced

1.3 g/MJ were found for both maize and miscanthus (van der W e r f et al., 1993). Here the value of 1.4 g/MJ is applied to all crops studied.

When the amount of radiation intercepted by a crop is known, the production of this crop under potential conditions can be calculated. The amount of intercepted radiation can be measured in field experiments, but it can also be derived from information on incoming radiation and development of the crop canopy. This latter option is used here. From most crops (even the rather unknown ones) some information can be found in literature on time of the year that leaves start to emerge, that closed canopy is formed that leaves are dropped or that crop is harvested. This information is used to determine the amount of radiation intercepted. It is assumed that a closed crop canopy captures all radiation and that in the period between leaf emergence and crop closure the fraction intercepted radiation increases linearly over time, and at the end of the growing season between start of leaffall and complete leaflessness the fraction decreases linearly over time (see scheme in appendix).

Multiplying the average daily incoming radiation, which can be obtained from climatic data sets, by the fraction intercepted during that day gives the intercepted radiation. Integration over the complete growing season results in the total amount of intercepted radiation in this period (I_{int}, in MJ/m^2). Multiplying by the value for LUE (1.4 g/MJ) results in the potential above-ground biomass (PAGB in g/m^2, dry matter) produced under optimal conditions

$$PAGB = I_{int} \times LUE \qquad (1)$$

Generally not all total above-ground biomass can be used, the leaves of trees for instance remain in the field. The fraction of the total biomass that is finally harvested, is called the harvest index. For most crops the harvest index values can be found in literature. (Values used are given in the appendix.) Multiplying total above-ground biomass by the harvest index, on dry matter basis (HI) gives the obtainable yield (Y_p) in kg

2. Location of regions

1 – Flevopolder, 2 – Veenkoloniën

dry matter/ha. Factor 10 is introduced to recalculate from g/m^2 to kg/ha.

$$Y_p = PAGB \times HI \times 10 \qquad (2)$$

The calculated yield is the production under optimal circumstances, in which crop yield is only determined by crop characteristics and climate. It is a measure of what is potentially possible under given conditions. The yields obtained in practice are generally much lower, due to a combination of water and nutrient shortages and damage done by pests and diseases. These effects could be eliminated by application of irrigation and fertilization and by crop protection measures. The ratio between actual and potential yield can be interpreted as characteristic for the type of agriculture in a region. In high input agriculture the ratio will be higher than in low input agriculture. Here this ratio will be called the Regional Yield Factor (RYF). The value of the RYF can be determined by using the above-described method for an agricultural crop from which yield data are available and divide actual yield through calculated yield:

$$RYF = \frac{Y_a}{Y_p} \qquad (3)$$

in which: Y_a – the average regional yield in kg dry matter/ha

The actual yield data can be obtained from agricultural statistics. These yields are usually published as kg/ha fresh weight, for comparison with dry matter yields calculated here, recalculation is necessary. Data on the average moisture content of harvested plant material can be found in literature, values used are given in appendix.

Here the RYF is calculated for two regions in the Netherlands using yield data of potato: Flevopolder (region 1), this area reclaimed from the sea in the 1950s, with large farms on good soils and Veenkoloniën (region 2), with smaller farms on rather poor sandy soils

(Fig. 2). In general yields in region 1 are higher than those in region 2.

The method was validated through comparison of actual yields of various agricultural crops and the estimated yields of these crops using crop data given in the appendix and the RYF determined from potato. Finally the yields of three candidate biomass crops, willow, poplar and miscanthus, were calculated using crop data given in the appendix. Multiplying the potential yield by the RYF leads to estimates of average regional yields of these crops in regions studied.

RESULTS

In the Netherlands potatoes are planted in April, crop emergence is around May 1st, and crop closure on June 20th, the crop is harvested in September (de Jong, 1985). Assuming a linear increase in the fraction intercepted light between May 1st and June 20th, an interception of all incoming radiation from June 20th to August 1st and a linear decrease in the fraction intercepted light between August 1st and September 15th, the total amount of intercepted light is 1429 MJ/m^2. Using equation 1 leads to a PAGB of 2 000 g/m^2. The harvest index of a potato crop is 0.75 so that a potato yield of 15.0 ton/ha (dry matter) can be obtained. In 1992 the average potato yield in region 1 was 53 ton/ha and in region 2 it was 43 ton/ha (fresh weight) (PAGV, 1993). Assuming a moisture content of 80% this means 10.6 and 8.6 ton/ha dry matter. Applying equation 3 results in a RYF for region 1 of 0.71 and for region 2 of 0.57.

The estimated and actual yields of three agricultural crops in the two regions in the Netherlands are given in Tab. I. In general the deviation between estimated and observed yield is small, only in one occasion the deviation was more than 10%. Estimated for the potential and actual yields of willow, poplar and miscanthus are given in Tab. II. The potential yield varied between 18 and 22 ton/ha for the different crops. The regional yields were lower.

DISCUSSION

REGIONAL YIELD FACTOR RYF

The average regional yield is affected by various factors, physical ones like climate and soil conditions but also by factors like knowledge of the farmers and infrastructure in the region (availability of irrigation water). Here the effects of all these different factors on the yield were not determined individually, only the overall effect on yield was derived by introducing the RYF. Climate and soil conditions remain more or less constant over the years, but the other factors change in time, so that the RYF is time dependent. In 1960, for instance, the average wheat yield in the Netherlands

I. Comparison between actual (Y_a) and estimated (Y_e) yields of three agricultural crops. The deviation (dev) between actual and estimated yield is expressed as percentage of the actual yield. Yields were estimated with the method described in the text, the regional yield factor (RYF) was obtained from potato yield data and was 0.71 for region 1 and 0.57 for region 2. Yields are expressed as ton/ha dry matter harvested material

Crop	Region 1			Region 2		
	Y_e	Y_a	dev	Y_e	Y_a	dev
Winter wheat	7.6	7.3	4%	6.1	5.4	13%
Sugar beet	15.1	15.4	2%	12.3	12.0	3%
Maize	14.6	15.4	5%	11.9	13.2	10%

II. The estimated potential yield and the regionally average yield of three biomass crops in the Netherlands in two regions. Yields are expressed as ton/ha dry matter harvested material

Crop	Potential yield	Regional yield	
		region 1	region 2
Miscanthus	21.9	15.3	12.3
Poplar	18.0	12.6	10.0
Willow	19.6	13.7	11.0

VALIDATION OF THE CALCULATED YIELDS

Since there are no data on average regional yields of biomass crops the validation possibilities for the method are limited. The only available averages are those from the agricultural crops. As shown in Tab. I the deviation between estimated and observed yield of the agricultural crops is very small. This implies that the method described can be very useful for estimating yields. In one situation an overestimation of 13% was obtained (wheat in region 2). This difference in magnitude of the deviation can be understood by the fact that crops differ in their susceptibility to certain unfavourable conditions. Pests, for instance, are crop specific, yield reduction caused by an insect in potato cannot be extrapolated to wheat. When unfavourable conditions occur yield reduction is different for different crops. To eliminate this crop effect on RYF, it is preferable to determine the value of RYF for several crops and use the average value.

CALCULATED BIOMASS YIELDS

As shown in the appendix for all biomass crops studied a harvest index 0.7–0.75 is assumed. This implies that yield differences of these crops are the result of the different PAGB values are caused by differences in canopy development. Differences between the crops at the start of leaf emergence and leaf fall of about 2 weeks occur, which results in differences in PAGB of about 5 ton/ha. For agricultural crops like wheat, potato etc. the average crop emergence date and harvest date over several years are known, it is also observed that large differences between years occur. For the unknown biomass crops such average values are not available so that data from field experiments had to be used. Since large interannual variation can be expected, values found in one experiment can deviate from the average. Also large differences in canopy development between varieties occur. In the Netherlands a difference of one month in leaf emergence between early and late poplar clones is observed (van H a a r e n, 1987). Since it is not known which clone will be used for biomass production in the future, canopy development can deviate from values used here leading to other yields.

The above-mentioned uncertainties imply that given yield data for the biomass crops are only indicative. Therefore it cannot be concluded that miscanthus is the most promising biomass crop since there is too little crop specific information available. However, it can be concluded that the potential annual biomass production of 'a' perennial biomass crop lies between 18 and 22 ton/ha. Regional averages of these crops would be 13–15 ton/ha for the high yielding regions and 10–12 ton/ha for the low yielding regions in the Netherlands.

Biomass estimates given in literature for present conditions in temperate regions are 10–12 ton/ha

was 4.25 ton dm/ha leading to a RYF of only 0.39. When this value is used to determine potato yield in 1960 a value of 5.85 ton/ha is calculated which is in accordance with the average values for 1960 (5.68 ton/ha). Further increase of the RYF can be expected, but the value of 1.0 will never be reached since this would imply that in a whole region the production is optimal.

Besides a variation in time there is also a large spatial variation, which is shown in the difference of the RYF between the two regions studied. To prevent loss of information it is important to keep the size of the region studied limited, and use data of more or less homogeneous regions. It is theoretically possible to apply this method for the whole of Europe leading to an average European yield. But the usefulness of this value is very limited since the enormous variation occurs in yields within Europe (yields in Spain are only a quarter of yields in the Netherlands).

Due to the fact that regional average is affected by so many factors, yields of field experiments in the same region are usually above the average, simply because they are generally laid out on better soils and more measures are taken to prevent the occurrence of water and nutrient shortage or reduction through pests and diseases.

The application of the RYF on biomass crops implies that it is assumed that knowledge on how to grow such a crop is comparable to that of agricultural crops. For the potential biomass crops this is not yet the case. Simple agronomical information as what planting density is best, which varieties should be used in various regions, what are fertilizer requirements of the crop and what crop protection is needed, is lacking. So it is likely that the regional yields of these crops will be lower than calculated here.

which agree with values found here. Estimates for yields in the near future (2000–2010) vary between 13–18 ton/ha (Lysen et al., 1992; Christersson et al., 1993; Hall et al., 1993). Such yields imply a RYF value of at least 0.75 which is a reasonable value for the high yielding regions. For the less favourable regions it is rather unlikely that the present RYF of 0.57 would increase up to 0.75 within 10 years. For the distant future (2 030) values of over 20 ton/ha are mentioned (Okken et al., 1994), these values are even higher than the annual potential production. Further it is unlikely that RYF of 1.0 can be achieved future. On individual fields potential production may be possible but over large growth limitations like water shortage will remain so that RYF will stay lower than 1.

CONCLUSIONS

Based on the fact that yields of agricultural crops are estimated with an inaccuracy of less than 10%, it is concluded that the estimation method described in this paper can be a useful tool in the research to possibilities using biomass crops for energy supply. Biomass crops in the Netherlands will yield about 10–12 ton/ha in present conditions. The estimates for future biomass yields used in recent studies are higher than can be expected on the basis of this method.

Acknowledgement

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CROP	Growing season	Canopy	Development PAGB	H. I.	Potential yield moisture content	Remainder moisture content	References
Winter wheat	A, Nov-Sept	1IV, 15V, 1VIII, 15VIII	24	0.45 grains	10.8 15%	8.8 straw 15%	Jong de, 1986
Potatoes	A, Apr-Sept/Oct	1V, 20VI, 1VIII, 15IX	20	0.75 potatoes	15.0 80%	5 leaf, stems 90%	Jong de, 1985a; Stol et al., 1991
Sugar beet	A, 15 Apr, Nov	1V, 20VI, 1XI	27	0.8 beet	21.6 77%	1.1 leaf, tops 87%	PAGV, 1986
Maize (silage)	A, May-Nov	15V, 20VII, 1XI	22	0.95 all	20.9 73%	stubble remains	Jong de, 1985b
Miscanthus	P, 15 Apr-Nov	15IV, 15VI, 1XI	30	0.73 stems	21.9 20%	leaves remain in field	Werf van der et al., 1993
Poplar	P, Apr-Oct	1V, 15VI, 15IX, 15X	25	0.72 stem, branches	18.0 50%	leaves remain in field	Kolster, 1982; Cannell et al., 1988
Willow	P, 15 Apr-Nov	15IV, 10VI, 1X, 1XI	28	0.70 stem, branches	19.6 50%	leaves remain in field	Nilson, Eckersten, 1983; Cannell et al., 1987

EXPLANATION OF CATEGORY NAMES USED IN APPENDIX

Growing season: period between sowing and harvest for annuals (A) and period between leaf emergence and leaf fall (poplar, willow) or annual dying (miscanthus) of the perennials (P).

Canopy development
1IV = April 1st, 15V = May 15th
3 data: leaf emergence, closed canopy, harvest
4 data: leaf emergence, closed canopy, start of leaf fall, harvest
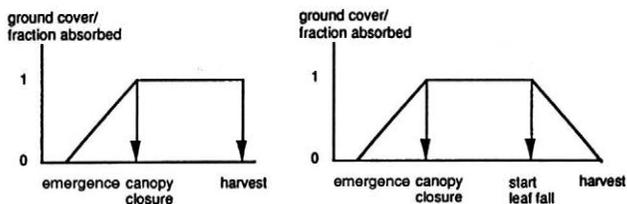
PAGB: potential above-ground biomass expressed in ton dry matter/ha. Value is obtained through multiplying intercepted radiation by light use efficiency of 1.4 g/MJ.

Harvest index (H. I.): the fraction of the above-ground biomass that is harvested, the plant organs harvested are mentioned.

Potential yield: potential yield of the crop based on PAGB and the harvest index. Yield is expressed in ton/ha dry matter. In agricultural statistics the yields are given as fresh weight, moisture content of harvested organs is therefore given.

Remainder: this is the part of the crop that does not belong to the yield. In some cases the remainder can be used for other purposes (for instance the straw of the wheat plant) in those cases the production (in ton/ha dry matter) and moisture content is given.

References: the literature used to obtain information on canopy development, harvest index, moisture content etc. for each crop.

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STUDIES ON THE MECHANICAL PROPERTIES
OF WINTER RAPE STEMS

STUDIUM MECHANICKÝCH VLASTNOSTÍ LODYH OZIMÉ ŘEPKY

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ABSTRACT: In the study the author determined the mechanical properties, as expressed by the maximum bending stress, rigidity, and the dynamic shear energy of the stems of winter rape, Jupiter variety, grown under differentiated agrotechnical conditions (sowing densities of 20, 40, 60 and 80 plants/m^2; nitrogen fertilization at 120 and 240 kg/ha). It was found that the conditions in which the plants grew had a differentiating effect on the mechanical properties of their stems. The studies showed that the strength characteristics of winter rape stems are closely related to the resistance of the plants to lodging.

winter rape; stem; maximum bending stress; rigidity; dynamic shear energy

ABSTRAKT: Předmětem studia byla ozimá řepka, odrůda Jupiter, ve dvou fenologických fázích (počátek květu a plná zralost), pěstovaná při dvou hladinách hnojení dusíkem (60 kg N.ha^{-1} – srovnávací vzorek, 120 a 240 kg N.ha^{-1}) a při různé hustotě výsevu (20, 40, 60 a 80 rostlin na m^2). Testovány byly lodyhy v místě prvního rozvětvení. Počet vzorků určených k měření byl ve všech případech 25, pro každý vzorek byla použita jiná lodyha. Měření se opakovalo ve třech letech. Náchylnost porostu k poléhání byla hodnocena podle klesajícího sklonu porostu prostřednictvím klesající stupnice, která přiřazuje standardním podmínkám hodnotu 10. Laboratorní trojbodový ohybový test byl použit k určení střední ohybové pevnosti lodyhy σ_{max} o ohybové tuhosti EJ (součin modulu pružnosti v tahu E a momentu setrvačnosti J plochy průřezu lodyhy). Obě veličiny byly vyhodnocovány s pomocí matematického aparátu odvozeného pro ohyb pružného isotropického nosníku. Dynamický smykový test byl použit k určení energie Ed potřebné k přestřižení lodyhy. Základní statistické údaje o experimentech jsou uvedeny v tab. I (varianta hnojení 120 kg N.ha^{-1}) a v tab. II (240 kg N.ha^{-1}). Grafické znázornění naměřených hodnot, včetně údajů o poléhavosti (lodging) a hustotě porostu (density), jsou uvedeny v obr. 1 a 2. Experimenty ukazují, že poléhavost je nižší u rostlin s vyššími hodnotami pevnosti lodyhy, s její vyšší tuhostí a s vyššími hodnotami energie potřebné k přestřižení lodyhy. Tento typ rostlin se vyskytuje především při nízkých hustotách výsevu. S rostoucí hustotou výsevu klesají hodnoty sledovaných mechanických vlastností lodyhy a zároveň roste poléhavost porostu.

ozimá řepka; lodyha; maximální ohybová pevnost; ohybová tuhost; energie potřebná k přestřižení

INTRODUCTION

Studies on the mechanical properties of plant stalks have the primary objective of providing information to breeders of new varieties. The mechanical parameters of plants have been demonstrated to be characterized by heritability of features (Ježowski et al., 1988; Doliński et al., 1989). The value of rape, as an industrial plant, has grown in recent years. Apart being utilized for the production of consumable oil of high nutritional qualities, since there are already varieties free of toxic elements, it is also utilized for production of fuel for car engines. Moreover, after diminution, rape stems are used in the production of a construction material. In view of the wide range of applications of rape, it is necessary to perform studies of the mechanical properties of rape stems (Skubisz et al., 1989; Blahovec, Skubisz, 1990; Skubisz, 1991, 1993).

In the present study the author determined, in static tests, the maximum bending stress, rigidity, and the dynamic shear energy of winter rape stems. Using these parameters, the author characterized the mechanical properties of winter rate stems. Also, the mechanical properties of winter rape stems were assessed in the function of differentiated agrotechnical conditions of the plant cultivation in order to demonstrate what conditions are conducive of the appearance of a plant of high strength of stem, resistant to lodging.

MATERIAL AND METHOD

The study was conducted on stems of Jupiter winter rape in two phenological phases – at the end of blooming and at full siliques. The experiment was prepared with the application of differentiated agrotechnical con-

I. Mean values of mechanical parameters of winter rape stems of the Jupiter variety ($\bar{x}$, mediana, W-coefficients of variability, 120 N kg/ha)

The sowing density (plants/m²)	Statistic parameters	Mechanical parameters					
		σ_{max} (MPa)	EJ (N/m²)	ED (J)	σ_{max} (MPa)	EJ (N/m²)	ED (J)
Phenological phases		the end of the blooming phase			the stage of complete filling of siliques		
20	$\bar{x}$	2.81	0.0365	0.6566	2.87	0.0561	0.8845
	mediana	2.56	0.0269	0.6208	2.19	0.0546	0.8523
	W (%)	41	76	40	75	46	52
40	$\bar{x}$	1.75	0.0298	0.2934	2.05	0.0503	0.7478
	mediana	1.28	0.0248	0.2456	1.61	0.0486	0.7024
	W (%)	86	85	48	79	42	55
60	$\bar{x}$	1.71	0.0147	0.2516	2.00	0.0273	0.4756
	mediana	1.49	0.0119	0.2124	1.56	0.0256	0.4318
	W (%)	60	84	68	61	75	57
80	$\bar{x}$	1.73	0.0083	0.1867	1.83	0.0236	0.3634
	mediana	1.69	0.0069	0.1486	1.69	0.0218	0.3186
	W (%)	59	72	73	55	68	71
Standard	$\bar{x}$	1.78	0.0189	0.2819	2.02	0.0343	0.3956
	mediana	1.71	0.0148	0.2526	1.85	0.0332	0.3401
	W (%)	46	68	70	45	66	71

II. Mean values of mechanical parameters of winter rape stems of the Jupiter variety ($\bar{x}$, mediana, W-coefficients of variability, 240 N kg/ha)

| The sowing density (plants/m²)	Statistic parameters	Mechanical parameters					
		σ_{max} (MPa)	EJ (N/m²)	ED (J)	σ_{max} (MPa)	EJ (N/m²)	ED (J)
Phenological phases		the end of the blooming phase			the stage of complete filling of siliques		
20	$\bar{x}$	1.96	0.0372	0.6457	2.11	0.0526	0.8192
	mediana	1.79	0.0248	0.6318	2.03	0.0519	0.7221
	W (%)	48	53	31	53	51	44
40	$\bar{x}$	1.56	0.0203	0.3164	1.74	0.0382	0.7138
	mediana	1.31	0.0189	0.3456	1.64	0.0339	0.5534
	W (%)	43	79	34	71	63	72
60	$\bar{x}$	1.54	0.0107	0.2884	1.72	0.0254	0.3769
	mediana	1.28	0.0086	0.2705	1.46	0.0187	0.3658
	W (%)	81	72	48	59	84	55
80	$\bar{x}$	1.52	0.0079	0.1402	1.71	0.0227	0.2753
	mediana	1.18	0.0096	0.0916	1.42	0.0178	0.2318
	W (%)	85	67	81	56	72	67
Standard	$\bar{x}$	1.78	0.0189	0.2918	2.02	0.0343	0.3956
	mediana	1.71	0.0148	0.2526	1.85	0.0332	0.3401
	W (%)	46	68	70	45	66	71

ditions. Plant lodging-conducive nitrogen fertilization was applied at doses of 120 and 240 kg N/ha, with sowing densities of 20, 40, 60 and 80 plants/m². To ensure that the plots contained the required number of plants per square meter, the plants were repeatedly counted in spring, removing any accessory bud encountered. This procedure was necessary, as the same number of seeds sown every year did not constitute any replicable factor for the density of plants per square meter. This means that every year a different proportion of plants survived the winter. The plots were set up in three replications, in order to obtain high accu-

racy and replicability of results. For test, 25 plants were taken from each plot at a time. At the same time, in order to find a point of reference for the results obtained, it was necessary to determine the mechanical properties of rape stems grown under standard conditions (which did not lodge). In the standard conditions the nitrogen dose was 60 kg/ha and the lodging rate was 10.

Measurements were taken at a characteristic spot on the stems, just at the first branching of the plant. The mechanical parameters were determined in static and dynamic tests. In the static tests the maximum bending
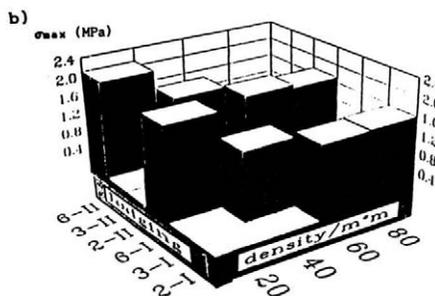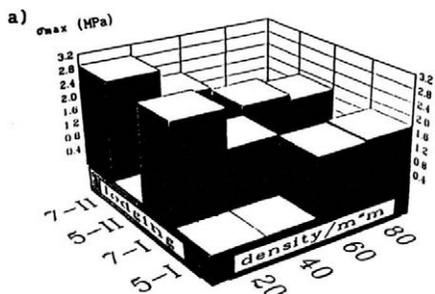
1. Characterization of the variability of the maximum bending stress (σ_{max}) of Jupiter winter rape stems, with an assessment of the plant lodging rate (a – nitrogen dose N = 120 kg/ha, b – nitrogen dose N = 240 kg/ha, I – end of blooming phase, II – total silique filling)
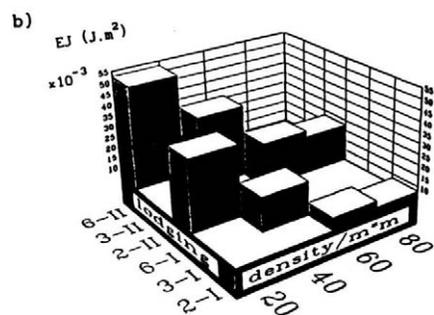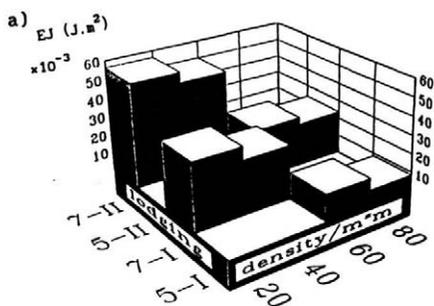
2. Characterization of the variability of the rigidity (EJ) of Jupiter winter rape stems, with an assessment of the plant lodging rate (legend as in Fig. 1)

stress (σ_{max}) and rigidity (EJ) were determined in the process of stem bending, using an Instron strength tester. Samples subjected to bending were freely supported at both ends and a bending force was applied in the middle of the distance between the points of support (S k u b i s z, 1991/1992, 1993). The results were recorded by means of a computer. In the dynamic tests the shear energy was determined using a Dynstat-type apparatus. The area of the stem cross section (S) was determined by means of a ΔT-areometer. Plant lodging was assessed using a 10-step scale, where „10" means no lodging and „1" means the most advanced lodging (stem very close to the ground).
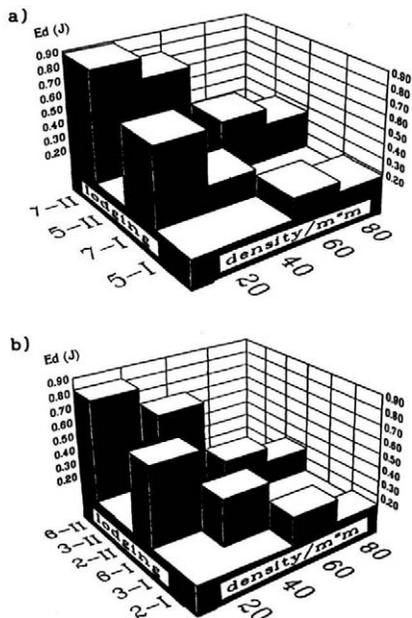
RESULTS

The study provided a comprehensive strength characterization of Jupiter winter rape stems, which allowed also for the determination of the effect of rape cultivation conditions on the resistance of stems to lodging (Fig. 1–3). All of the parameters analyzed displayed a considerable variability in the course of plant development.

It was found that the differentiated agrotechnical conditions of rape cultivation significantly affected the mechanical properties of rape stems (Tab. I, II). At the same time, both the sowing density and the increased

doses of nitrogen fertilization differentiated the plants with respect to their resistance to lodging.

The study showed that the maximum bending stress, rigidity, as well as the dynamic shear energy decreased in values with increasing number of plants per square meter. First of all, the mean values of the maximum bending stress were especially high in the case of stems originating from plots with 20 plants/m², as compared with the level of bending stress in the stems of plants from plots with higher sowing densities. This regularity was observed both during the blooming phase and during the total filling of siliques. It was found that plants which were highly resistant to lodging were characterized by very high values of bending stress σ_{max} (1.75–2.81 MPa at full bloom, 2.05–2.87 MPa at total filling of siliques) as compared to non-resistant plants, by high values of rigidity EJ (resistant plants: 20.2–37.2 x 10^{-3} J/m² at full bloom, 50.3–56.1 x 10^{-3} J/m² at total silique filling; non-resistant plants: 7.9–14.7 x 10^{-3} J/m² at full bloom, 22.7-38.1 x 10^{-3} J/m² at total silique filling), and by high values of dynamic shear energy Ed (resistant plants: 0.29–0.66 J at full bloom, 0.75–0.88 J at total silique filling; non-resistant plants: 0.14–0.31 J at full bloom, 0.27–0.71 J at total silique filling). Comparing the results obtained to the results of the strength properties of plants grown under standard conditions it was established without a doubt that

a)

b)

3. Characterization of the variability of the dynamic shear energy (*ED*) of Jupiter winter rape stems, with an assessment of the plant lodging rate (legend as in Fig. 1)

Therefore, the study showed that the resistance of plants to lodging is closely related to the strength characteristics of rape stems.

CONCLUSIONS

– The study showed a significant relationship between the mechanical properties of stems and the resistance of rape plants to lodging.

– It was found that the plants which were resistant to lodging were characterized by very high values of the maximum bending stress, rigidity, and the dynamic shear energy, and originated from plots with a low sowing density.

– The study also showed that the mean values of the mechanical properties decreased with increasing sowing density (plants/m^2), and at the same time, their rate of lodging grew, i. e. the resistance of the plants to lodging decreased.

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the resistance of plants to lodging is closely related to the strength charactestics of the plant stems. It was found that the mean values for plants grown under standard conditions were high and close to the mean values obtained for the stems of plants growing fairly sparsely, i. e. at 40 plants/m^2 at N fertilization dose (conductive to lodging) of 120 kg/ha, and at 20 plants/m^2 when the fertilization dose was 240 kg/ha.

The assessment of the extent of plant lodging showed that the most resistant to lodging were those plants which were characterized by high mean values of the mechanical parameters under analysis (rating „7" in plots fertilized with 120 kg N/ha and rating „6" at 240 kg N/ha) and originated from plots with the lowest sowing density (20 plants per square meter). The most susceptible to lodging (rating „5" in plots with 120 kg N/ha and rating „2" in plots with nitrogen fertilization dosage of 240 kg/ha) were the plants whose stems were characterized by low rigidity and low values of the maximum bending stress, as well as of the shear energy, and which grew in plots with high sowing density (60 and 80 plants/m^2).

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AGROMATERIALS FOR INDUSTRIAL USE –
ART OF FRACTIONATION

ZEMĚDĚLSKÉ PRODUKTY PRO PRŮMYSLOVÉ UŽITÍ –
UMĚNÍ FRAKCIONACE

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ABSTRACT: Cultivation and processing of agricultural products for industrial non-food use greatly depends on profitability of the whole operation. Simple and formal profit equation (1) shows that creation of profit depends on three substantial components of the whole process: on production of dry biomass, its optimal processing into fractions and costs associated with it. For market evaluation of cultivation technology and processing of products the following criteria are used: *EPL* (energy production limit) expressed by inequality (2), *C* (completeness) mathematically defined by equation (3), *TL* (technological level) with definition in equation (4), *PS* (production shift) expressed by equation (6) and finally, *PC* (profit colour) defined by equation (7). Art of fractionation consists in selection of such technologies which consider *EPL*, have minimal wastes (maximal *C* value), are relatively simple (low *TL* value) and raise receipts from production (high *PS* values) at maximal profits (maximal *PC* values). Fractionation of products is a very complicated process which generally allows only increase in concentration of selected components in some of fractions. The degree of separation of components can be characterized by means of newly-defined quantities: fractionation ratio (λ_i), fractionation efficiency (λ_{ji}) and purity ratio (p_{ij}). In real fractionation processes there is mutual dependence between purity ratio and fractionation efficiency. The growth of fractionation efficiency is associated with drop in purity ratio and vice versa. It can be seen on ficticious example (Fig. 2).

profitability; dry biomass; processing of biomass into fractions; costs of processing

ABSTRAKT: Pěstování a zpracování zemědělských produktů pro průmyslové nepotravinářské užití rozhodujícím způsobem závisí na ziskovosti celé operace. Jednoduchá a formální zisková rovnice (1) ukazuje, že tvorba zisku je závislá na třech podstatných složkách celého procesu: na tvorbě suché biomasy, na jejím optimálním zpracování do frakcí a na nákladech s tím spojených. Pro tržní hodnocení technologie pěstování a zpracování produktů jsou zavedena následující kritéria: *EPL* (energetická hranice produkce) vyjádřená nerovností (2), *C* (úplnost), matematicky definovaná rovnicí (3), *TL* (technologická úroveň) s definicí v rovnici (4), *PS* (posun produkce) vyjádřený rovnicí (6) a konečně *PC* (zabarvení zisku) definované rovnicí (7). Umění frakcionace spočívá ve výběru takových technologií zpracování, které respektují *EPL*, mají minimální odpady (maximální hodnotu C), jsou relativně jednoduché (nízká hodnota *TL*) a zvyšují tržby z produkce (vysoké hodnoty *PS)* při maximálních ziscích (maximální hodnoty *PC*). Frakcionace produktů je velmi obtížný proces, který umožňuje obecně jen zvýšení koncentrace vybraných složek v některé z frakcí. Stupeň oddělení složek je možné charakterizovat prostřednictvím nově definovaných veličin: frakcionačního poměru (λ_i), frakcionační účinnosti (λ_{ji}) a poměru ryzostí (p_{ij}). U reálných frakcionačních procesů existuje vzájemná závislost mezi poměrem ryzostí a frakcionační účinností. Růst frakcionační účinnosti je spojen s poklesem poměru ryzostí a naopak. Je to ukázáno na fiktivním příkladu (obr. 2).

ziskovost; suchá biomasa; zpracování biomasy do frakcí; náklady na zpracování

INTRODUCTION

Non-food use of different products of plant and/or animal origin by man seems to be older than man's ability to speak. They were natural products, and especially some products of agricultural origin, that were for many centuries the main important raw materials for many crafts. Some of them, e.g. wood, plant fibers, starch, plant oils etc. are usually used as the important industrial raw materials. Industrial use of these and of other agricultural products could increase in developed countries in the near future as a consequence of unmanageable surpluses in food-oriented agricultural production. Moreover, sphere of agricultural production could be understood as a renewable and ecological source of raw materials. There is only one effective barrier for wider use of agroproducts as raw materials in industry: too high prices of these products in comparison to the prices of standard industrial raw materials (oil, coal etc.).

In this short contribution I have tried to show the complexity of this problem and the role played by dif-

ferent forms of fractionation of the agricultural products as well as their full utilization for an industrial non-food use.

ECONOMIC ASPECTS

Profitability of each industrial programme depends on a lot of technological details, including the market conditions. In special cases of agricultural production of raw materials for industrial use we can simply analyze this process using the profit measure of unit cultivated area – P (in money unit per square meter and year), that can be expressed by the following equation:

$$P = [\Phi \, E \, . \, (\sum_i c_i \, p_i / 100 - \sum_j n_{rj}) / 100 - n_c] \, . \, (1 - n_t / 100) \quad (1)$$

where: Φ – the mean land production potential in kg of dry matter (d.m.) per square meter and year
E – transformation efficiency (in per cent)
c_i – concentration of product i
p_i – price of product (money unit per kilogram of d.m.)
n_{rj} – relative cost of operation j (money unit per kilogram of d.m.)
n_c – constant cost (money unit per square meter)
n_t – profit tax in per cent

Equation (1) is based on the energy flux coming from sun on one square meter of field area per vegetation period, expressed via photosynthetic equation (15.7 MJ per kg) by photosynthetic matter (simply as d.m.) as the mean production potential (about 200 kg d.m. per square meter and year for the area of the Czech

I. Influence of external process parameters on the quantities in equations (1).

Process parameters	ϕ	E	c	p	n_r	n_c
Geographic conditions						
north latitude	***	**	*		*	**
above sea level	*	***	*		**	**
Climatic conditions						
temperature		***	**			*
rainfall		***	**		*	**
sunshine	***					
Cultivation						
sorts of plants		***	***	***	***	**
methods of cultivation		***	**	**	**	**
methods of harvesting		*	**	**	**	**
extent of cultivation		*	*	**	***	***
Processing						
transport			**	**	***	
storage			**	**	**	
methods			***	***	***	
quality			***	***	***	
Market conditions						
supply – demand			**	***	**	

Symbols: * weak influence, ** strong influence, *** very strong dependence

Republic). Only a part of production potential can be really obtained from one square meter per year in the form of the harvested dry matter, this part is determined by transformation efficiency E, which is very variable for different conditions and for different plants (0.1–5% – D y k y j o v á, 1976). Incomes depend on concentrations c_i of different components (with different prices) obtained by fractionation of the harvested dry matter and outcomes on the other hand are related to different operations that are used for cultivation, processing and market operations.

It is clear, that the profit measure of any production technology strongly depends on details of the technology scheme. Influence of different parameters on profit is in Tab. I. Dry matter yield depends not only on geographic and climatic conditions through the mean production potential and transformation efficiency, but also on a type of the cultivated plant and all the details of the technology used for cultivation, harvesting and primary processing. Tab. I indicates the important role played by the fractionation processes that determine proportions of different partial products with different prices. For reaching the maximal profit it is necessary:
– to minimize outcome of production in the form of losses,
– to arrange the fractionation process in such a manner, that products could be sold under the best conditions,
– to minimize the cost of production.

Profit is determined mainly by market conditions and by prices of the obtained products. It is clear that the fractionation process, i.e. the production of the products that are market desirable or those that can be used for production of market desirable products, plays a crucial role in profit formation. Success in cultivation of plants for an industrial use should be based on a suitable plant (here is important the breeding of suitable plants) cultivated in good conditions and processed by good technologies.

Market evaluation of different cultivation and processing technologies can be done on the base of equation 1. Five the most important characteristics can be used for this purpose. The first one can be denoted as e n - e r g y p r o d u c t i o n l i m i t *EPL*. It is given by the highest production of plant energy biomass for burning (in money units per square meter and year). Higher production requires other methods of production with more complicated methods of processing. This request can be formulated in terms of equation 1:

$$E \, . \, \sum_i c_i \, p_i / 100 \geq E_{bm} \, p_p \quad (2)$$

where: E_{bm} – maximal transformation efficiency for biomass production in the same conditions
p_b – the market price of biomass dry matter for burning

Further important market parameter is c o m - p l e t e n e s s C of the processing that is given by the total concentration of dry matter in the fractions that

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have some market use. It could be expressed by the following formula:

$$C = \sum c_i / 100 \qquad (3)$$

where sum is performed only for the fractions with market price above zero. Increasing value of completeness indicates decrease in losses of processed biomass as well as decrease in wastage in fractionation scheme. Maximum value of completeness is one for schemes without losses of dry metter. T e c h n o l o g i c a l l e v e l TL is another parameter that can be used for description of processing costs by the equation:

$$TL = \sum_j n_{rj} / \sum_k n_{rk} \qquad (4)$$

where: Σn_{rk} – sum of costs spent for production of the raw biomass in the analyzed scheme
Σn_{rj} – sum of all costs spent in that scheme (including processing)

Minimum value of TL is one for production of unprocessed biomass and it increases when the processing scheme is getting to be more complicated.

Economic aspects of the real cultivation and processing scheme can be evaluated through two following market parameters: production shift and profit colour. P r o d u c t i o n   s h i f t PS gives an information how many times higher is the production of the analyzed scheme in comparison to its part that products raw biomass. Mathematical expression of PS is given by the following equation:

$$PS = \sum_i c_i p_i / (100 \, p_e) \qquad (5)$$

where: p_e – price of the whole biomass before its processing (in money units per square meter and year)

P r o f i t   c o l o u r PC shows how many times higher is the profit for the analyzed scheme in comparison to such an alternative scheme that gives raw biomass only (for example for burning) with the highest possible profit. It can be expressed by the following equation:

$$PC = E \cdot \left(\sum_i c_i p_i / 100 - \sum_j n_{rj} \right) / [E_{bm} (p_b - \sum_j n_{rjb})] \qquad (6)$$

where: E_{bm}, p_b, and n_{rjb} – parameters of the alternative scheme giving the crude biomass only

Market aspect prefers technological schemes that respects energy production limit and has the highest values for both product shift and/or profit colour. From ecological point of view the highest values of completeness are desirable. Lower values of technological level are usually welcomed by the both ecologists and economists but this relation is not trivial. From this point of view art of fractionation can be expressed by the following rule: to find fractionation systems with high completeness and low technological level that

have higher production shift and the highest value of profit colour.

Good fractionation system has been developed for flax stem (Fig. 1 – completeness above 0.8). Almost all dry matter is processed for the products that can be managed : seeds as a source of oil, stems as a source of fibers for textile industry and crafts as well as a source of material for the production of boards that are used in building industry. Success in this area is based on the plants of the highest quality and on technologies making possible to obtain the highest proportion of the best quality products – the best fibres for textile industry. Further improvement in this direction can be reached by new varieties of flax of higher quality and by further improvements in the sphere of processing – better methods of fractionation and new types of products from flax stem components.

SOME OTHER FRACTIONATION CHARACTERISTICS

Fractionation is based on division of material into different fractions with different content of different components. It can be described by three characteristics for each fraction, i.e.:

– fractionation ratio $\lambda_i = m_i / m$,
– fractionation efficiency $\lambda_{ji} = c_{ji} / c_j$,
– purity ratio $p_{ji} = c_{ji} + c_{vi}$,

where denote index i fraction, index j component, m mass and c mass concentration (c_{vi} denotes moisture content w.b. in fraction i). Addition of all fractionation ratios (for different fractions) equals to one. Similarly, addition of $\lambda_i . \lambda_{ji}$ for all fractions gives one. In the simplest case of two fractions and two components (dry matter and water) fractionation can be described only by two values: fractionation ratio (for example for liquid fraction) and fractionation efficiency (for example for water).

Good fractionation process is characterized by high values of fractionation efficiencies and by values of purity ratio close to 1 at least for one component and one fraction. Real fractionation processes show that some complementarity exists between separation efficiency and purity ratio evaluated for the same component and fraction. Higher purity ratio is connected with lower values of fractionation efficiency and vice versa.
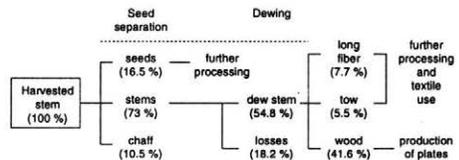
1. Fractionation of flax stem (Quality: First Class). In brackets are given weight concentrations of fractions in per cent of harvested stem
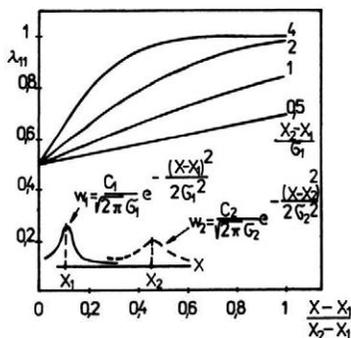
2. Fractionation efficiency of component 1 in separated fraction 1 in a process based on the characteristic parameter x. Content of two components in fractionated mixture is formally described by Gaussian distributions w_1 and w_2 in dependence on x

This complementarity can be illustrated by Fig. 2, in which fractionation efficiency for the component 1, being in mixture with the other component 2, is described in relation to some structural property x that is used as a separation measure. Distributions of the both components in the mixture are described in this case by Gaussian curves (Fig. 2) and fractionation of the mixture is understood as a separation process in which mixture is divided into two fractions. The first of them contains those parts of the both components with x less or equal to separation value x_s and the second one contains other parts. Then fractionation efficiency of the first component into the first fraction (λ_{11}) is given by the following equation:

$$\lambda_{11} = \frac{1}{c_1} \int_{-\infty}^{x_s} w_1 \, dx \qquad (7)$$

and purity ratio is in proportion to the following expression:

$$p_{11} \approx 1 - \int_{-\infty}^{x_s} w_2 \, dx \qquad (8)$$

Equations (7) and (8) show the role playing in fractionation process by components concentrations (c_1 and c_2) and some uncertainty in components determination by property x – for each component some variance in

x exists and is described by values σ_i. Especially the increasing values of standard deviations are the main obstacle in separation processes of the components. Each increase in the fractionation ratio λ_1, connected with an increase in value x_s, causes at the same time the increase in λ_{11} and decrease in p_{11}, as is clear from equations (7) and (8). But relation between these changes depends on variance measures, i.e. standard deviations σ_i.

High purity of the product as well as the high fractionation efficiency in real fractionation processes usually need more complicated and more expensive fractionation technologies. This is why some optimal way of fractionation must be found out for each special case. The measure of the optimization could be profitability of the process. It seems that the right fractionation methods used for the whole production as well as the best methods of product processing are the key points for the further development in production of agromaterials for industrial use.

CONCLUSIONS

It was shown that profitability of production of agromaterials for industrial use is determined by:
– transformation efficiency in production of dry matter, determined by plant types and methods of cultivation,
– methods of fractionation of the obtained production into manageable products with high prices,
– costs of production.
Fractionation parts of technologies have a crucial role for determination of their profitability. Full use of the produced dry matter and gaining of the most valuable parts of the production can be reached only on fractionation principle.

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ENERGY CROPS IN THE UK: A DEVELOPING FIELD

ENERGETICKÉ PLODINY VE VELKÉ BRITÁNII: MOŽNOSTI ROZVOJE

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ABSTRACT: A number of different crop plants are being grown in the United Kingdom for energy purposes. Amongst these are willows (*Salix* spp.), poplars (*Populus* spp. hybrids) for chipping and heating purposes and oil seed rape for biodiesel. Examples of the uses of these crop types, together with the factors affecting their present and future potential productivity, are discussed.

energy crops; willow; poplar; oil seed rape; chipping and heating; biodiesel

ABSTRAKT: Ve Velké Británii se pěstuje mnoho různých plodin využitelných pro energetické účely. Mezi ně patří odrůdy vrby (*Salix* spp.) a topolu (*Populus* spp.) vhodné na štípání a spalování a řepka na výrobu bionafty. V příspěvku jsou uvedeny příklady použití těchto rostlin a možnosti jejich současného i výhledového využití.

energetické plodiny; *Salix* spp.; *Populus* spp.; *Brasica napus*; štípání a spalování; biomasa

INTRODUCTION

The United Kingdom obtains its energy from a number of different sources. These include oil, gas, coal and nuclear power. Some of these energy sources such as the North Sea oil and nuclear power, are available from within the UK, whilst others, such as coal and some other types of oil products, are increasingly being imported. All of these are non-renewable energy supplies and obtaining energy from each of them causes damage to the environment. As environmental awareness increases, more and more people are beginning to question the wisdom of plundering the environment for once only energy gains. This has led to an upsurge in interest in environmentally friendly fuels, from renewable sources, which can be obtained without causing significant damage to the environment. Amongst the possible renewable energy sources are wind power, wave power and the use of bio-fuels, including plant biomass. Crop plant biomass is a readily renewable fuel supply (Mitchell, 1989). Given appropriate management techniques, bio-fuels need not be damaging to the environment. This sustainable energy source is available from UK grown materials which, in addition to reducing the UK energy imports bill, can also have considerable amenity value. This extends from improving the appearance of the countryside, to potentially cleaning up contaminated land (Derelict Land Reclamation Research Unit, 1982).

## ENERGY CROPS AND THEIR UTILIZATION

The ideal energy crop should consist of dry harvestable material, which is easily combustible. Supply should be available in large quantities, preferably in close proximity to some form of processing plant. It should have low establishment costs, including the cost of ground preparation, planting and maintenance spraying etc. prior to harvest. It should have good disease resistance, so that as little as possible biomass is wasted (Culshaw, 1993). The ideal energy crop should have a favourable energy balance, so that as much of the solar radiation intercepted as possible is converted into biomass which is useful for fuel purposes. This property should also encompass efficient utilization of water and nitrogen resources from the soil. Yield should be close to the theoretical maximum, in the prevailing growth conditions. This particular property can be very important in many parts of the UK, where climatic conditions vary considerably from south to north, and spells of extreme weather conditions, particularly in Scotland, are quite common. Furthermore, an ideal energy crop for the UK should provide some environmental benefits, agricultural continuity and economic gain. These last two features are particularly important in rural areas, and apply equally well to the rest of Europe as to the UK.

The ways in which biomass crops can be utilized depend, in part, upon the very nature of the crops themselves (Culshaw, 1993). Trees, such as willow, poplar, or other woody plants can be used as fuels for combustion, gasification or eventual conversion to liquid fuel. Biomass from annual plants, however, can be digested anaerobically, used directly in combustion, fermented to produce ethanol, or, in some cases, such as oil seed rape, part of the plant can be esterified into valuable methyl esters. Examples of each of these energy crop types will be considered in detail.

WILLOW FOR SHORT ROTATION COPPICING

Willow has traditionally been used in the UK for basket-making, coracle building and in the manufacture of cricket bats. In recent years, however, the faster growing types of willow have begun to be used in a variety of new ways. These include the use of willow together with geotextiles in bioengineering programmes, for the stabilization of slopes and river banks, the creation of bio-bunds to screen newly built roads in environmentally sensitive areas, and to provide sea defences (S t o t t, D u r r a n t, 1993). The most promising new uses of willow, however, centre on biomass production for energy purposes from farmland, or contaminated industrial sites. Whilst logs of willow are poor for combustion purposes, chips with adequately controlled water content can be burnt efficiently. Obtaining unrooted cuttings or rods of various willow species (more than 40 different clones are available) for short rotation coppicing, and adequate weed control during establishment are the major costs involved. Other aspects of site preparation, fencing and general site maintenance, together with beating up, the replacement of failed stems, lead to minor expenditure (M i t c h e l l et al., 1993). Typically, 25 cm rods of disease-free material from well-characterized varieties are planted at densities of approximately 10,000 trees per hectare and allowed to grow for one season, before being cut back hard to the bole near ground level during late autumn or winter. In the subsequent growing season, the stems will grow back vigorously, producing large amounts of new growth. Fast-growing willow varieties can be coppiced every one or two years. High biomass yield is associated with tall, thick stems, ideally of even thickness and good wood quality. Even stem thickness can be quite important for the mechanical harvesters used, often utilizing spare capacity from grain or forage harvesters, since unusually for an agricultural crop, willow can be harvested during the winter months. This in itself means that the capital outlay for such energy coppicing is quite low. Harvested rods can be cut into 25cm sections and used for fresh plantings, or chipped for fuel. Yields of 35–45 tonnes/hectare wet weight are not uncommon (Fig. 1), if an appropriate combination of willow clone, site, planting density and cutting cycle is used. A poor combination of these factors can reduce yields by up to 90%. Reducing the water content of the chips in as cost-effective a manner as possible is very important for the economic viability of willow coppicing. Chips are routinely stored in dry, well ventilated stores for several months, until the water content drops to approximately 25% w/v. Such yields can produce 14–18 tonnes of oven dry chips per hectare. The chips produced may be used to provide heat for farms or small communities by direct combustion, returning carbon dioxide to the atmosphere or, if produced on a sufficiently large scale, can be used in power stations. Large scale willow growth for coppicing is more likely to become eco-
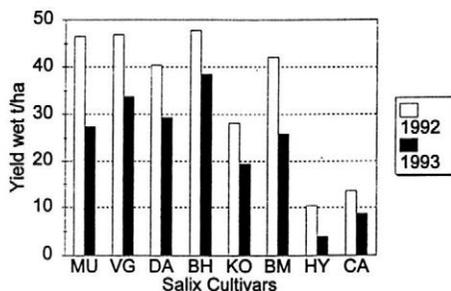
1. Yields from selected willow cultivars from Dunstall Court Farm, 1992 and 1993 (Data courtesy of A. F. H i l l and Son)

MU – Mullatin, VG – Viminalis Gigantea, DA – Dascylados, BH – Bowles Hybrid, KO – Korso, BM – Brown Miriam, Hy – Hymalayas, CA – Candida

nomically viable if electricity generating companies, such as PowerGen and HydroElectric become obliged to obtain significant amounts of their energy from renewable sources. An extension of the Non-Fossil Fuels Obligation by the UK Government for at least 20 years would provide sufficient incentive to achieve this, rather than continuing to burn imported coal (S t o t t, D u r r a n t, 1993). Willow has several advantages over most other trees for energy cropping purposes, including vigorous re-growth, and potential usability of the whole tree for chipping purposes c.f. only 40% usability for most forestry species. Additionally, selected willow clones can produce significant yields from the same bole for 15–20 years. This feature reduces repeat year costs considerably.

Careful selection of appropriate disease-free clones is vital for high willow productivity. Some species, such as *Salix burjatica*, can be very susceptible to willow rusts, whilst others, such as *S. viminalis* which were once thought to be rust resistant, may now be susceptible. Terminal tip death, caused by *Rhabdophaga* gall midges, or damage from grazing mammals can also lead to significant losses (M i t c h e l l et al., 1993). Watermark disease, caused by *Erwinia* species, may also be a threat to high yields. Although some progress has been made in combatting this particular disease, it has not yet been completely overcome.

POPLAR COPPICING

A large number of *Populus* spp. hybrids are also being used in short rotation coppicing for fuel purposes (M i t c h e l l, 1989). Poplar yields from short rotation coppicing can reach 30 wet tonnes/hectare in a good year in the UK climate and 18 wet tonnes/hectare in a poor year (Fig. 2). Poplar benefits from less frequent coppicing, since the main stem may not recover too well from long periods of frequently repeated cutting back. Typically, poplars are left for three, or even four
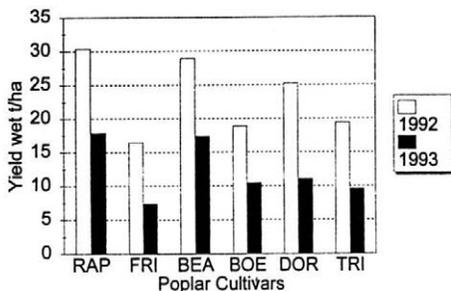
2. Yields from selected poplar clones at Dunstall Court Farm, 1992 and 1993 (Data courtesy of A. F. Hill and Son)

RAP – Rapp, FRI – Fritzi Pauley, BEA – Beaupre, BOE – Boelare, DOR – Dorskamp, TRI – Trichobel

years between coppicings. Reduced yields from too frequent cropping are particularly common with the highest yielding clones, such as Rapp and Beaupre. The bushy habit of young poplars also influences the planting density for these *Populus* hybrids, which require more space than the willows and are typically planted at densities of 6–7,000 trees/hectare (M i t c h e l l et al., 1993). Particular care must be taken when harvesting poplar, also in the winter, to avoid stem regions which are too thick to be handled easily by the available cutting machinery.

MIXED RESULTS WITH *MISCANTHUS*

The perennial rhizomatous C4 grass *Miscanthus*, which is capable of 4.5 m growth in one year and 26 dry tonnes/hectare yields (E l B a u a m , 1994) has been tested under UK conditions. Plant costs of 40 pence ($0.64) each were considered to be high, particularly when densities of 20,000 plants/hectare are used. Projected profitability from the growers' point of view were encouraging, but unfortunately prevailing weather conditions make *Miscanthus*, rather like maize, unlikely to be suitable for biomass crop purposes north of London (S p e l l e r , 1994). This is a pity, since most of the surplus land in the UK is north of this latitude. The potential of this energy crop is therefore very limited in the UK, once regional yield and cost considerations are taken into account. Other C4 rhizomatous perennials, such as *Spartina* species, have been tried, but poor tolerance of low temperature (P o t t e r , 1994), amongst other factors, has limited yields.

SITE SELECTION

Careful site selection can be just as important to the potential viability of a short rotation coppicing operation as the choice of clone. In less hospitable areas,

such as in Orkney, where few trees become well established due to the very windy conditions, sites may be surveyed using tatter flags to give an indication of growth potential. This is achieved by flying 30 cm square cotton tatter flags from metal poles and observing the degree of wind damage, or tattering, caused to the flag over an extended period. Such tatter flags, which were invented on Orkney, can be image analyzed to establish the degree of tattering from large numbers of different sites. There seems to be a strong correlation between the extent of tattering and potential for tree establishment in these windy conditions. Indeed, so good is this predictive test, that these tatter flags have been used throughout the world. *S. smithiana* thrives in the wet and windy conditions found in the Northern Isles, 100 km from the northernmost point of the Scottish mainland and is a good indicator of potentially suitable sites for large scale growth. With reduced demand for pasture products, rural economies such as Orkney's need to find other money-spinners. Currently, UK farmers can earn up to £203 per hectare in set-aside payments from the European Union. Short rotation coppicing of willows or poplars can, in appropriate situations, provide an additional source of income and also reduce farm fuel bills in an environmentally friendly manner (T a b b u s h , 1993).

BIOREMEDIATION

An alternative strategy is to use fast-growing willows on derelict industrial land which may be contaminated with large amounts of pollutants, including heavy metals. Upwards of 200,000 hectares of derelict land are potentially available in the UK for short rotation energy crop uses (Derelict Land Reclamation Research Unit, 1982). The biomass obtained may even concentrate the contaminants, so helping to reduce the problem and return the land for other potential uses. The availability of surplus land in the UK is predicted to reach 2 million hectares in the UK by the year 2000, and perhaps ten-fold greater areas across the European Union. This approach has dual benefits, since the land can be returned into productive or amenity use after bio-remediation, as well as the biomass used for energy purposes (H u n t , 1993).

BIODIESEL FROM OIL SEED RAPE

Brassica napus is being grown in the UK on an increasing scale, with 413,000 hectares planted in 1993. 50% of this production occurs in Scotland, from whence the seed is transported, at a cost of £15/tonne to Liverpool, 450 km away, or to Rotterdam for transesterification (K e r r W a l k e r , 1994). The UK, France, Germany and Spain have in fact, all exceeded their European Union (EU) oil seed rape quotas for this period, and are likely to suffer subsequent subsidy penal-

ties, of approximately 18% for UK farmers. Farmers will, therefore, increasingly be looking for added profits from their permitted oil seed harvest. Ways of achieving this in the UK currently being investigated include the potential of biodiesel production and the genetic modification of the *Brassica napus* genome to produce high grade cutting lubricants for the North Sea oil market. Biodiesel could be a particularly attractive proposition, since additional profits of £115/hectare have been forecast on costs of £450/hectare, 50% of costs being for seeds. The EU produces only 2.5% of its fuel from biomass, as against a world mean of 14%, and 8% of US fuel (equivalent to 9,000 MW) from the use of ethanol in gasoline alone. Additionally, biodiesel has only 25% of the toxicity of mineral diesel to trout, daphnia or cress and less than 1.5% of toxicity to green algae (K o r b i t z , 1994). Obtaining diesel in a relatively environmentally friendly manner like this seems very attractive. Anticipated prices for biodiesel of 33.2–35.4 pence/litre make this option unattractive against the "red mineral diesel" available to licensed farmers at 14 pence/litre or HGV mineral diesel available at 34 pence/litre (K e r r W a l k e r , 1994). Biodiesel from the UK seems then only to have a large scale future if it becomes zero rated for duty purposes (A s k e w , 1994). This would involve the UK government losing up to 26 pence/litre in tax revenue and optimism for this approach must be balanced by realism. However rape seed is used, the stalks can always be put to good use, for example as an adjunct to sewage sludge in composting.

In this paper, a variety of ways of obtaining energy from crops suitable for the UK have been discussed. The potential usefulness of biomass crops for energy purposes is clear. What remains to be seen, however, is whether or not the political will exists for this renewable, environmentally friendly energy source to be taken up by farmers on a sufficiently large scale to become economically, as well as environmentally viable.

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ACTUALITIES

BIODEGRADABLE MATERIALS FROM STARCH-CONTAINING PRODUCTS

PROPERTIES OF STARCH

Most abundant biopolymer is cellulose since it is the main building material of plant body. Consequently, cellulose was one of the materials man was using from the very beginning of his evolution. Cellulose belongs to biodegradable materials, however, its degradation is rather slow and organisms able to its hydrolysis and utilization are scarce. The other plant common polymer – starch – plays a different role. It serves as a storage form of energy and carbon building material for plant. Therefore its mobilization must proceed much faster and enzymes able to depolymerise it are wide-spread in the nature, many being present in mammals particularly in digestive tract. Therefore starch is considered as food rather than construction material.

There is also serious difference in the chemistry. Cellulose is composed of linear nonbranched polyglucose chains which form crystalline organization. This is why cellulose is insoluble and exhibits high mechanical strength.

Starch is in fact a mixture of two very different polymers of glucose – amylose and amylopectin – as defined in 1952 by Karl Meyer. The structure of the former polymer is similar to cellulose, but some degree of branching, even with short side-chains, is present. It is soluble in water, however, the solutions are not stable. After some time the polymer turns to insoluble matter.

Amylopectin is a huge branched structure. The backbone $(1\rightarrow4)$ polymer with the single reducing end of amylopectin carries many $(1\rightarrow6)$ bound long chains which in turn are substituted again through $(1\rightarrow6)$ bound by short chains. Thanks to this structure and size amylopectin forms gels in water.

There are different ratios of amylose and amylopectin in plants. By selection plants rich in either of these components can be obtained.

BIODEGRADATION OF STARCH

The degradation of starch by enzymes proceeds by three types of hydrolysis:

a) exo-degradation which has sometimes the nature of glucose transfer,

b) endo-hydrolysis of linear parts of the $(1\rightarrow4)$ polymer and

c) specific attack to the $(1\rightarrow6)$ bound which causes debranching.

Following is the list of most important degradation enzymes:

STARCH DEGRADING ENZYMES

α-Amylase-Endo-$(1\rightarrow4)$-α-D-glucan-4-glucanohydrolase
Can be found in animals in pancreas, plasma, gut and mammalian tissues. Attacks the chain at random and the fragment at non-reducing end is preferred. Stops at branching point.

Dextranase- Endo-$(1\rightarrow6)$-α-D-glucanase
It is not present in mammals. This is why dextran which used to be given to people as a plasma expander is not degraded in the body. However, it is present in *Penicillium, Streptococcus* and *Lactobacillus* which may explain its presence in human colon.

Amyloglucosidase (Glucoamylase) -Exo-$(1\rightarrow4)$-α-D--glucanglucohydrolase
Not present in mammals, neither in bacteria. It is produced by molds. Removes glucose from non-reducing end. Hydrolyses $(1\rightarrow4)$, $(1\rightarrow3)$ and $(1\rightarrow6)$ α-D-glycosidic bonds. The configuration on the C^1 is reversed after hydrolysis.

β-Amylase -Exo-$(1\rightarrow4)$-α-D-maltohydrolase
Not found in mammals, however very common in plants and bacteria. Removes maltosyl units from non-reducing end. Stops 2 to 3 units from branching point. The configuration on the C1 is reversed after hydrolysis. Used in the characterization of branching degree.

Glucodextranase – Exo-$(1\rightarrow6)$-α-D-glucanase
Not observed in mammals. Isolated from *Arthrobacter or Streptococcus*. Removes glucose from dextran.

Phosphorylase
Starts from non-reducing end and transfers glucose units to phosphate. Stops 6 units from branching. The reaction is reversible.

Isoamylase – Glycogen-6-glucanhydrolase
Isolated from *Pseudomonas and Cytophaga*. Debranching enzyme since it hydrolyses $(1\rightarrow6)$ bonds.

Pullulanase – Pullulan-6-glucanhydrolase
Obtained on preparative scale from *Enterobacter aerogenes*. Routinely used for debranching of amylopectin.

Amylo-$(1\rightarrow6)$-D-glucosidase, α-D-glucotransferase
Debranching enzyme of mammalian source. Degrades glycogen.

CHEMICAL MODIFICATION OF STARCH

Similar to cellulose most of the chemical modification of starch is based on esterification or other forma-

tion. In the former procedure either acylanhydride or salt of the acid with some catalysis is used. Thermoplastic materials has been described based on esterification by lactic acid. Starch acetate has been isolated and used in a similar way as cellulose acetate.

Ether formation is an essence for preparation of hydroxyethyl starch or carboxymethyl starch. The former polymer is very important as a plasma expander in pharmacy. In contrast to dextran is degraded in plasma. The rate of degradation can be controlled in a broad scale by the degree of substitution.

In all these modifications the properties of the final polymer depend on many variables:

a) the ratio of amylose and amylopectin in the starting starch,

b) the degradation prior/during modification,

c) the degree of substitution,

d) the ratio of substitution at C^2 and C^6.

SOME BLENDS AND COPOLYMERS

Many patents are dealing with combination of starch and common synthetic polymers. Two principles can be observed:

1) Starch is added as an additive to the matrix of synthetic polymers, e. g. polyethylene. By the degradation of starch inclusions the material is mechanically disintegrated. Nevertheless, the chemical structure of the synthetic polymer is not changed.

2) The matrix is formed by starch or, more often, by chemically modified starch, and the synthetic polymer is added in minute fraction in order to improve the mechanical parameters. Polyethylene glycol is used as a softener or EVA (ethylene-vinyl acetate) is used for an improvement of mechanical strength. Some of these synthetic polymers are believed to be subjected to biodegradation.

GENERAL PROBLEMS

Any attempt to prepare biodegradable polymers as, e.g. packing material, meet the problem of finding an optimal position between to extremes:

A) The material is sensitive to moisture, does not protect from molds and other deterioration processes. It is readily biodegradable.

B) The resulting material is water-repellent, protect well from spoiling goods during storage. The biodegradation is very difficult.

Another problem is the price. It depends on the starting product. In some technologies pure starch is used. This is not acceptable in our country. We want to use the product of our agriculture. Pure starch manufactured from our products is too expensive, therefore such technology would use imported corn starch which would not help to utilise the overproduction of, e.g. potatoes.

In other technologies the acetyl of starch is prepared directly from, e.g. flour and then is isolated. Such procedure is expensive for ecological reasons. It produces too much of sewage water. Therefore we try to find a way how a useful material can be produced directly from powdered dry potatoes.

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ACTUALITIES

UTILIZATION OF THE FOREST BIOMASS FOR ENERGY PURPOSES IN THE SLOVAK REPUBLIC

The forest biomass is being utilized energetically in the form of fuel wood assortments, timber in self-production and perks. The average annual amount is approximately of 400,000 t with the energetic equivalent of 3,800 TJ which represents less than 0.5% of the whole consumption of energy in Slovakia. The energetic efficiency of its present utilization is low, approximately 55%.

The countries with comparable conditions (Austria, Switzerland, south of Germany) draw the energy from the biomass from 2 to 3%, regionally up to 5% of the total energy consumption.

At the present time there are being developed the equipment for harvest, dimensional homogenization, transportation and production of energy from forest biomass in Slovakia.

UNUSED POTENTIAL OF FOREST BIOMASS CONVENIENT FOR ENERGY PURPOSES

Technological waste unusable in industry (branches, tops, stubs, roots etc.) is being occured at the timber felling. Besides, thin trees are logged at the tending measures in young stands which do not have a commercial utilization at all. Another technological waste occurs in the wood handling. These sources of biomass can be used for energy production.

At the balance of the biomass sources for energy it is necessary to reduce the total sources of biomass by those which are situated in the difficult accessible mountain terrains, in working places with very low concentration of biomass logged and in places with soil poor in nutrients where the degradation of site conditions in consequence of utilization of the whole biomass would appear.

After these reductions approximately 400 thous. t of biomass per year, which represents in energy about 3,350 TJ, are available for energy utilization within the hitherto logging method and the volume of timber logged.

In the nearest future this amount will increase as a consequence of deterioration of logged timber quality from stands damaged by pollution. In these stands the share of timber inconvenient for industry utilization is increasing. Besides, the more intensive treatment of young stands is required where other sources of biomass are being arisen which are a potential for energy. From those sources 110 thous. t of biomass, i. e. approximately 880 TJ per year, will be available for energy purposes.

Another source of wood for energy production is the waste from smaller wood-working plants, which belong to the state-owned enterprises of forestry or in private ownership. The sources of wood for energy there are approximately 90 thous. t annually, i. e. approximately 720 TJ.

In total approximately 600 thous. t of forest biomass, i. e. 4,950 TJ of energy, is available for energy utilization annually.

In this decennium the classical assortment – a fuel wood - will be logged on an average annual volume of 350,000 m^3 of which the energy equivalent is 3,320 TJ.

Another potential source are the so-called energy forests in non-forest land. It would be possible to predict a gain of energy equivalent to 4,200 TJ annually by the year 2005 with the present knowledge and optimum realization of intentions.

TECHNOLOGIES AND MACHINERIES FOR PRODUCTION OF FUEL-BIOMASS

Technologies and machineries have been designed for utilization of dendromass in clearings, thinnings as well as in regeneration fellings in dependence on the place of performance of the individual working operations, composition of machinery sets according to users' subjects (large state enterprises, private firms etc.). The calculations were executed on the base of the annual efficiency of the machinery sets to which the machines were chosen so that their efficiency is comparable. The calculations were made on the level of direct production costs which provide a better possibility of their comparing without an influence of the other costs, especially of overhead costs which deform the resulting values.

Homogenization of the wood waste is a decisive technological operation during its processing. The choice of kind and type of equipment for the size adjustment depends on the locality of occurrence, kind and concentration of raw material and on the method of its utilization – technological, energetical – direct combustion, gasification, briquetting, etc.

The chipper S-800 has been developed and made at the Forest Research Institute and determined for processing of less-valuable wood occurred in lower concentrations with the annual efficiency of 2,000 to 3,000 t of chips. The waste wood chipper D-1000 has been developed for the wood processing in higher concentration.

S-800 is a disk chipper intended for wood process-ing with diameter to 15 cm. It operates as a mobile equipment mounted to the three-point tractor suspen-sion or it is stationary driven by electric motor. It has either two knives – chips of a length 12–25 mm – suit-able for direct combustion at the energy utilization, in the case of raw material of better quality for techno-logical purposes, or it has three knives in disk and produces chips of a length 4–8 mm suitable, i. e. for production of fuel briquets.

Basic technical specifications:

diameter of chipping disk	830 mm
number of chipping knives/counter knives	2 (3)/1 ps
admission aperture	265 x 285 mm
max. diameter of chipped wood	150 mm
chips length adjustable	5–25 mm
drive – electric motor	40 kW
– three-point tractor suspension	50 kW
chipping disk speed – stationary	750 turns.min^{-1}
– mobile	950 turns.min^{-1}
weight of chipper	900 kg

WASTE WOOD CHIPPER D-1000

Waste wood chipper is intended for the dimensional homogenization of wood raw material which is not workable at all or only with large problems. In forestry it is the question of short tail cuts-off (waste wood) which results from roundwood handling, branches of coniferous trees from branch-trimming machines, stems, roots, brushes, etc. In agriculture mainly branches from fruit trees cut, shrubs from pasture lands clearnings and from recultivation, switches from vine-yards cutting, etc. are considered. Waste wood chipper will have also a more extensive use at liquidation of various kinds of wood waste in building trade and in-dustry, for instance sheating units, pallets, rafters, etc. In the long run these equipments will be needed in biomass utilization from forests with a very short rota-tion period (so-called energetic forests).

Basic technical specifications:

diameter of chipping drum	600 mm
number of drum turns (speed)	1,000 min^{-1}
number of knives	20 pieces
admission aperture – width	1,000 mm
– height	350 mm
average size of chipped material	20–40 mm
max. diameter of wood	300 mm
capacity	18 m^3.h^{-1}
weight	8,000 kg

PRODUCTION OF ENERGY FROM FOREST BIOMASS

Forest biomass is classified with considerable di-mensional diversity. For better transport handling and increasing of energy production efficiency it is neces-sary to adjust dimensionally a raw material by chipping (branches, trees) and crushing (manipulation and pro-cessing of waste, stems).

In conditions of Slovakia there are the following prospective forms of energy production:
1. direct combustion of moist dimensionally adjusted raw material
   – hot-water heating of buildings
   – production of technological steam
   – production of electric energy (steam turbine, gas turbine) + heating of buildings
   – hot-air drying in agriculture
2. energetic gasification of dried-out raw material ad-justed dimensionally
   – production of electric power (gas engine + gene-rator)
   – production of electric power + building heating (waste heat)
3. briquetting of dried out fine-grained waste
   – heating of houses, recreational buildings etc.

At the present, the direct combustion of forest bio-mass is energetically and economically the most effi-cient method of its energy utilization in woody regions for heating of buildings by the form of central source of heat (CSH), or individually and in the larger concen-trations of fuel there is also production of energy and heat.

Energetic gasification with production of electric power is usable in wood-working plants or out of reach of public electricity-distributional networks.

Briquets are environmentally friendly substitution of coal in classical furnaces without necessity of their ad-justment where the continous supply of wood fuel is not available.

Realization of intentions of expansion of energy production from biomass depends on the available te-chnologies with acceptable prices and technical level of European standard.

The price policy in fuel and energy applied by the year 1990 in former socialist countries did not stimu-late a development of renewable energy sources utili-zation. Renewal of interest in utilization of renewable energy sources due to liberalization of prices has elic-ited the need of technologies development.

In 1991 the Forest Research Institute designed the scientific and technical project *The Utilization of For-est Biomass for Energy*, included in the programme *The Utilization of the Secondary and Renewable Energy Sources* by the former Federal Ministry of Economy in Prague. In years 1991–1992 the Forest Research Insti-tute in Zvolen completed the above-mentioned project within the framework of the whole Czechoslovak Fe-deral Republic. Since the year 1993 the Forest Re-search Institute has been coordinating and investigating

working place for the project *The Utilization of Forest Biomass for Energy* on the base of requirement of the Ministry of Economy of the Slovak Republic.

The mentioned projects have been intended for solution of the following problems:

– design and development of technologies and machines for harvest, collection, transportation and dimensional homogenization of biomass suitable for energy utilization;

– development of combustion equipments of moist biomass adjusted dimensionally within the range of capacity from 100 to 3,000 kW;

– development of internal combustion engine for wood gas with generator of electricity of capacity from 23 to 50 kW;

– development of gasification generator for wood gas production for gas engines of capacity to 88 kW;

– development of briquetting press, capacity 500 kg per hour.

The results of solution are in the realization and pre-realization phase, respectively, for the time being.

In 1993 the Forest Research Institute Zvolen proposed the Conception of energy utilization of forest biomass in Slovakia. The Ministries of Agriculture and Economy of the Slovak Republic have accepted the submitted conception and it was consequently included in the State energy conception of the Slovak Republic by the year 2005 approved by the Government of the Slovak Republic in July, 1993.

ENERGETICAL BENEFITS

6,250 TJ energy can be produced using 400,000 t of forest biomass unused till the present time and by more effective utilization of fuel wood. 115.2 TJ of energy, i. e. 1.84% of an amount produced, is consumed for preparation and energy production.

By managing of energy forests and utilization of their production it is possible to produce 4,200 TJ in the year of 2005. For managing, felling and own production of energy it is necessary to increase to 3.8% of the given amount. The average annual energetic profit is 4,040 TJ.

ECOLOGICAL BENEFITS

600,960 t of brown coal with the heating value 13 $MJ.kg^{-1}$ and energy production efficiency of 80% will be converted into production of 6,250 TJ of energy from forest dendromass. By this way the pollution load to the environment will be reduced by 3.08 mil. t of CO_2, 93,300 t of SO_2, 7,810 t of NO_x, 30,400 t of fly ash and 120,000 t of slag and ash. The production of CO_2 during the combustion of biomass is the part of natural cycle of substances and it does not increase its share in the air.

In the case of implementation of energy forests' projects 401,000 t of brown coal graded can be substituted in 2005, what will prevent from production of 2.06 mil. t

of CO_2, 62,300 t of SO_2. 5,210 t of NO_x, 20,300 t of fly ash and 80,000 t of slag and ash.

ECONOMICAL BENEFITS

The costs of obtaining raw material in suitable conditions from the point of view of grain size and moisture are one of the decisive economic criteria for profitability valuation of energy production from wood.

According to the grain size the assortment is classified as follows: fuel wood assortment, piece and fine-grained waste from processing and wood handling, respectively, chips and chipped material. Dimensional homogenization of wood by spliting or chipping often increases the costs of fuel, however a direct combustion enables utilization of simpler and cheaper furnaces and better control of combustion process and by this way a higher efficiency of energy production. Energy gasification and briquetiing require utilization of raw material homogenized dimensionally.

Production costs of preparation of wood as a fuel depend on the number and quality of work invested in performances which have to be executed. The least costs are with waste originating during processing or wood handling when the considerable part of cost is included in the price of the main product. Direct costs of preparation of fuel consist only of potential dimensional homogenization and necessary transport.

Preparation of fuel from cutting residues from stands includes all working operations from skidding to transportation to the place of consumption. Counting the economic profitability it is necessary to consider the savings from the removal of the raw material from felling area. The savings resulting from stand hygiene improvement are hard to be calculated in advance.

The direct production costs for preparation of forest dendromass, including transportation, are as follows:

Raw material	Direct production costs (DPC) $(Sk.t^{-1})$	Price per 1 GJ (Sk)/US\$ (1 US\$ = 32 Sk)
Dendromass from clearings	415–600	43.70–63.20/1.4–2.0
Dendromass from thinnings	156–619	16.40–65.20/0.5–2.0
Dendromass regeneration felling	268–489	28.20–51.50/0.9–1.6
Udeground dendromass	410–610	43.20–64.20/1.4–2.0
Sawdust from forest depots and small wood-working plants	100–200	10.50–21.10/0.3–0.7
Cuts-off from forest depots and small wood-working plants	150–300	15.80–36.80/0.5–1.2

The present price of forest chips in Slovakia is 600 to 750 $Sk.t^{-1}$ (18.8–23.4 $US\$.t^{-1}$) what represents 63.20–78.90 Sk (2.0–2.5 US\$) per 1 GJ.

The price of fuel wood is approximately 350 $Sk.m^{-3}$ (10.9 $US\$.t^{-1}$) and it represents 38.90 Sk (1.2 US\$) per 1 GJ.

The average prices of the basic types of fuels in the European Community (EC) countries (Denmark, the Netherlands, Germany), Austria and Slovakia in 1993 and prediction for the year 2000:

| Fuel | Year | EC and Austria | | | | Slovakia | |
| | | FCO price | | Consumer price | | Consumer price | |
		US$.t^{-1}	US$.GJ^{-1}	US$.t^{-1}	US$.GJ^{-1}	US$.t^{-1}	US$.GJ^{-1}
Brown coal	1993	46	2.9	180	11.3	37.5	2.3
graded	2000	64	4.0	250	15.6	–	–
Bituminous coal	1993	75	3.0	295	11.8	62.5	2.5
graded	2000	100	4.0	400	16.0	–	–
Brown coal	1993	55	2.9	220	11.6	43.8	2.3
briquets	2000	75	3.9	300	15.8	–	–
Natural gas	1993	100	3.0	417	12.5	104.7[1]	3.1
(1 000 m^3)	2000	125	3.7	535	16.0	67.2[2]	2.0
Heating oils	1993	190	4.6	460	11.2	162.5	4.0
	2000	270	6.6	650	15.9	–	–
Energy for heating	1993	50	12.9	90	24.8	21.3[1]	5.9
(1 MVh)	2000	65	16.8	470	32.4	11.6[2]	3.2

[1]Price of gas and electric power for enetrprises in 1993
[2]Price of gas and electric power for population in 1993

In evaluation of competitiveness of fuel dendromass it is necessary to consider two basic situations:
– fuel consumed by producer (forestry, forest owners),
– fuel sold to other consumers.

In the first case a producer can add only the necessary overheads to the direct production costs. The price of the fuel sold to other consumers includes overheads and profit.

The price of heat produced in boiler house with installed capacity of 0.5 to 1.6 MW using various kinds of fuel (there are presented the resulting data elaborated by the Forest Research Institute in Zvolen from the study of reconstruction possibilities of coal municipal boiler houses):

| Fuel | Price for 1 GJ | |
	Sk.GJ^{-1}	US$.GJ^{-1}
Brown coal	216–268	6.8–8.4
Natural gas	188–222	5.9–6.9
Forest chips	150–181	4.7–5.7

The production costs for 1 kWh of electric power by power plant of capacity 40 kW with natural gas engine range from 1.96 to 2.55 Sk.kWh^{-1} according to the capacity utilization level of equipment.

By the project realization of energy utilization of forest biomass being prepared in Slovakia the average annual savings of costs of energy production are predicted to be 61 mil. Sk by 2000.

CONCLUSION

Approximately 1% of the total consumption of fuels and energy in Slovakia will be covered by production of energy from utilizable amount of less-valued dendromass. The potential of domestic fuel-energy sources used for the time being will increase by 6.7%.

By utilization of fuel dendromass the import of brown coal graded will be reduced by 500,000 t.year^{-1} or of natural gas by 200 mil. m^3.

In Slovakia a direct combustion, energetical gasification and adjustment of fine-grained waste by briquetting are the most prospective methods of energetical utilization of dendromass.

A wider and more efficient utilization of that fuel will bring the results in ecology as well as in economy. Dendromass as an ecological less-damaging fuel enables a considerable reduction of local pollution load of environment. Relatively equable occurrence of that raw material will enable a supply of fuel from local sources whereby the savings in coal transportation especially to remote regions will arise.

Further advantages of biomass energetical utilization:
– more flexibility of reaction on local changes in amount and structure of energy consumption,
– reduction of negative impacts caused by fluctuation of prices of basic fuels,
– possibility of integration of investments in local and regional level, respectively, and by reduction of state budget load,
– creation of new working places,
– improvement of self-sufficiency of the state in the sphere of fuels.

Measures for utilization extention:
– reduction of state subsidies for heat and energy or their provision for renewable sources as well,
– preferring of ecologically convenient domestic energy sources,
– support of regional projects including local renewable energy sources,
– credit and tax policy supporting utilization of renewable sources,
– charges and increase of air pollution by fossil fuel combustion.

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DISCUSSION

BIORESOURCES – PRESENT STATE AND OUTLOOK

The following contribution presents a description of the Round Table Discussion organized during the Workshop. It cannot be taken as a unanimous conclusion accepted by the participants. The discussion was very live and appreciated by the participants. It also identified many new topics that will emerge as lecture titles in subsequent seminars and workshops on energy crops. The summary mostly reflects the way its authors were perceiving the whole discussion.

Introducing the Round Table Discussion, S. N o n - h e b e l presented a brief survey on possibilities of using agricultural crops for energy supply. It was shown that when crops are used to convert solar energy into biomass and electricity the efficiency of the process is very low: only 1.7% on the basis of radiation during the growing season and only 0.7% on the basis of the annual radiation (Tab. I). The amount of energy that can be obtained from a hectare of land is small in comparison with the quantities of energy required in a western society. As an example, the situation in the Netherlands was given (Tab. II). Under optimal conditions a hectare of poplar can yield 14 tone of wood, when this is converted into electricity 20 MWh/ha can be obtained. For the present electricity consumption level this implies that per person 0.25 hectare of poplar is required for electricity production. This means that

I. Converting solar energy into electricity: efficiency of the process

Total annual global radiation in the Netherlands	3.3 GJ/m^2
Total global radiation during growing season	1.5 GJ/m^2
Light use efficiency	1.4 g/MJ
Total above-ground biomass	21 ton/ha
Wood is 65% of the above-ground biomass	14 ton/ha
Heating value of wood	18 MJ/kg
Energy yield of poplar	0.025 GJ/m^2
Efficiency on the basis of annual radiation	0.7%
Efficiency on basis of radiation in growing season	1.7%

II. The acreage needed to fulfill energy requirements in the Netherlands

Potential annual yield of poplar	14 ton/ha
Converted into electricity	20 MWh/ha
Electricity consumption in the Netherlands	5 MWh/person
Hectares required per person	0.25 ha
Inhabitants	15 million
Required for electricity (0.25 ha/person)	3.5 million ha
Present area under agricultural use	2 million ha

3.5 million ha of poplar plantation is required to fulfill the electricity demands of this country. In the Netherlands the area used for agriculture is only 2 million ha. So even when all the agricultural land is used for growing energy crops it is not enough to meet the electricity needs in this country. (The energy requirements in the form of oil etc. are not even taken into account.) The possibilities of „growing energy" in densely populated areas are therefore very limited.

The subsequent discussion moderated by L. N á t r was based on lectures already presented in previous sessions by S. Nonhebel, L. Nátr, K. Gartland and R. Carlsson (their contributions have been included into this issue and may be consulted by the readers). The discussion itself subsequently treated the six topics as follows:

1. Differences between food and energy crops

In energy crops, the yield formation seems to be simple as compared with classical food crops where mostly only morphological or chemical parts represent the very economic yield. From this point of view, the whole shoot biomass could be used in energy crops. Hence, with the exception of shoot/root ratio, processes determining dry matter allocation and transport are of minor importance in energy crops.

2. The role of input energy for energy crops

There is an absence of data on the effects of fertilizers, pesticides and other agrochemicals on the amount of biomass in energy crops. It seems that practical technologies successfully applied procedures enabling reasonable production of poplar and especially willow biomass. The consequences of long-term cultivation of energy crop monoculture are hardly assessed. There has been neither long enough period for the analyses, nor will or interest to get the data.

3. What is limiting: solar energy use efficiency or efficiency of industrial use of the biomass?

If it turns out that the use of food crop technologies is suitable for energy crops (and it seems to be the case), then more knowledge is needed especially in developing technologies for the industrial use of the biomass. This conclusion seems to be important especially when the tendency prevails of using all harvested plant parts for various purposes, i.e. seed oils as energy, fibers for the textile, remaining parts for nutrition etc.

4. Are new species and genera needed for energy crops?

This question seems to be difficult to answer and no convincing evidence was presented in favour or deny.

The advantage of classical crops consists of already available cultivars, technologies, and breeding. The advantage of unknown species consists of unexpected favorable properties.

5. Special breeding and management for energy crops

The experience with food crops indicates, that special breeding targets and managements for energy crops will be needed. However, at present, this point does not represent the highest priority. Nevertheless, construction of ideotypes of most frequently used species could be very important from both the theoretical (yield formation) and practical (selection and the appropriate management) purposes.

6. Optimization of chemical composition of energy crops

The chemical composition of an energy crop should enable an extremely low content of minerals. Carbohydrate, protein or lipid accumulation reaching a maximum given by the plant metabolism could be aimed at. It indicates, that energy crops might be very effective low input cultivars. It also implies the main feature of an ideotype: relatively small size of the very actively (high nitrogen content) assimilating (photosynthesizing) organs supplying organic matter into the stem (trees) or other plant parts with a minimum amount of mineral nutrients.

During the discussion and at many other occasions, it was stated that cultivation of energy crops benefits from what is known on classical crops. There is a considerable lack of data on specificity of the main energy crop species, i.e. *Miscantus*, poplar and willow. If energy crop is seriously expected to play an important role in the future agriculture, more research will be urgently needed.

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