

CZECH ACADEMY OF AGRICULTURAL SCIENCES

Research in
**AGRICULTURAL
ENGINEERING**

ZEMĚDĚLSKÁ TECHNIKA



INSTITUTE OF AGRICULTURAL AND FOOD INFORMATION

3

VOLUME 47
PRAGUE 2001
ISSN 1212-9151

RESEARCH IN AGRICULTURAL ENGINEERING

formerly ZEMĚDĚLSKÁ TECHNIKA since 1954 to 1999

An international journal published under the authorization of the Ministry of Agriculture and under the direction of the Czech Academy of Agricultural Sciences

Mezinárodní vědecký časopis vydávaný z pověření Ministerstva zemědělství České republiky a pod gestí České akademie zemědělských věd

Editorial Chief

JÍŘÍ FIALA

Research Institute of Agricultural Engineering,
Praha, Czech Republic

ZDENĚK PASTOREK

Research Institute of Agricultural Engineering,
Praha, Czech Republic

JÍŘÍ BLAHOVEC

Czech University of Agriculture,
Praha, Czech Republic

Executive Editor

RADKA CHLEBEČKOVÁ

Institute of Agricultural and Food Information,
Praha, Czech Republic

Editorial Board

J. De Baerdemaeker, Katholieke Universiteit, Leuven,
Belgium

V. Dubrovin, Ukrainian Academy of Agrarian Sciences,
Kyiv, Ukraine

M. Estler, Technische Universität München, Institut für
Landtechnik, Freising, BRD

J. Jech, Slovak University of Agriculture, Nitra, Slovak
Republic

R. Jevič, Research Institute of Agricultural Engineering,
Praha, Czech Republic

D. Kurtener, Agrophysical Institute, St. Petersburg, Russia

J. Mareček, Mendel University of Agriculture and Forestry,
Brno, Czech Republic

R. Markovič, Slovak Testing Centre, Rovinka, Slovak
Republic

A. Mizrach, Institute of Agricultural Engineering, Bet
Dagan, Israel

F. Ptáček, AGROTEC, Hustopeče u Brna, Czech
Republic

M. N. Rifai, Nova Scotia Agricultural College, Truro,
Nova Scotia, Canada

B. Stout, Texas A&M University, College Station, USA

D. S. Strebkov, Russian Academy of Agricultural Sciences,
Moscow, Russia

J. Šabatka, University of South Bohemia, České Budějovice,
Czech Republic

Aims and scope: The journal publishes original scientific papers and review studies on agricultural engineering, agricultural technology, processing of agricultural products, countryside buildings and related problems from ecology, energetics, economy, ergonomics and applied physics and chemistry.

Abstracts from the journal are comprised in the databases: Agris, CAB Abstracts, Czech Agricultural Bibliography.

Periodicity: The journal is published quarterly (4 issues per year). Volume 47 is appearing in 2001.

Submission of manuscripts: Two copies of manuscript should be addressed to: Mgr. Radka Chlebečková, editor-in-chief, Institute of Agricultural and Food Information, Slezská 7, 120 56 Praha 2, Czech Republic, tel.: +420 2 27 01 03 55, fax: +420 2 27 01 01 16, e-mail: forest@uzpi.cz. The day the manuscript reaches the editor for the first time is given upon publication as the date of receipt.

Subscription information: Subscription orders can be entered only by calendar year and should be sent to: Institute of Agricultural and Food Information, Slezská 7, 120 56 Praha 2, Czech Republic. Subscription price for 2001 is 62 USD (Europe) and 64 USD (overseas).

For up-to-date information see <http://www.uzpi.cz>

Cíl a odborná náplň: Časopis publikuje původní vědecké práce a studie typu review z oborů zemědělská technika, zemědělské technologie, zpracování zemědělských produktů, venkovské stavby a s tím spojených problémů ekologických, energetických, ekonomických, ergonomických a agrofyzikálních.

Abstrakty z časopisu jsou zahrnuty v těchto databázích: Agris, CAB Abstracts, Czech Agricultural Bibliography.

Periodicita: Časopis vychází čtvrtletně (4krát ročně). Ročník 47 vychází v roce 2001.

Přijímání rukopisů: Rukopisy ve dvou kopiích je třeba zaslat na adresu redakce: Mgr. Radka Chlebečková, vedoucí redaktorka, Ústav zemědělských a potravinářských informací, Slezská 7, 120 56 Praha 2, Česká republika, tel.: +420 2 27 01 03 55, fax: +420 2 27 01 01 16, e-mail: forest@uzpi.cz. Den doručení rukopisu do redakce je uveřejněn jako datum přijetí k publikaci.

Informace o předplatném: Objednávky na předplatné jsou přijímány na celý rok na adrese: Ústav zemědělských a potravinářských informací, Slezská 7, 120 56 Praha 2. Cena předplatného pro rok 2001 je 352 Kč.

Aktuální informace najdete na URL adrese <http://www.uzpi.cz>

The 50th anniversary of the Research Institute of Agricultural Engineering in Prague

50 years ago was established the Research Institute for Mechanisation of Agriculture. Its name was changed to Research Institute for Mechanisation and Electrification of Agriculture (VÚMEZ) later. Its place of activity was located in a facility in Prague-Vokovice. As stated in the Ministry of Agriculture Decree No. 53 published in the Official Gazette I. No. 52-55/1951, in total five new institutions were established on 1st January 1951. Besides the Research Institute for Mechanisation of Agriculture they were the following: Research Institute for Crop Production, Research Institute for Livestock Production, Research Institute for Forestry Production and Research Institute for Agricultural Economics.

The principal activities of the new Research Institute for Mechanisation of Agriculture were testing of machines, construction of simple types of new machines, research of purposeful utilisation of new mechanisation means and necessary advisory services for agricultural enterprises.

The establishment of a particular Research Institute of Agricultural Machines in Prague-Holešovice in 1953 subjected to the Ministry of Engineering and of the State Station for testing of agricultural machines in Řepy near Prague in 1957 enabled to focus the activities of the institute to the really scientific and research work in the field of agricultural productive technologies.

In 1958 the name of the institute was changed to Research Institute of Agricultural Engineering.

Besides investigative research the workers of the Institute deserved credit in accelerating the development of both crop and livestock production mechanisation. The research results were synthesised into the so called Complex of machines for Czechoslovak agriculture. Let us remind the share of the problem solutions regarding the timely soil preparation (putting through of heavy-duty wheel tractors in practice), the providing of sufficient amounts of roughage (program of silage, haylage and hay production), increasing performance of grain, oil crop and root crop harvesters and reduction of quantitative and qualitative losses during harvest and at product storage. The workers of the institute took part in development of progressive transportation and material handling systems within agriculture. The truck-and-tractor container system, interchangeable bodies, pick-up trailers equipped with cutting device for forage crops. From the recent period may be remembered the research of renewable energy sources resulting in the basis for departmental programs Biodiesel, Bioethanol and for the prepared research program Biogas.

The Research Institute of Agricultural Engineering had to change its location twice within its 50 years history: from Prague-Vokovice to Řepy near Prague in 1956 and from Řepy to Prague-Ruzyně in 1998. The establishers of the institute were successively the following: Ministry of Agriculture, Czechoslovak Academy of Agricultural Sciences, Czech Agricultural Academy,

Federal Ministry of Agriculture and Nutrition, Federal Ministry of Economics and finally again the Ministry of Agriculture of the Czech Republic.

The long-term purpose of the institute, i.e. to contribute to increasing of the technical and technological level of agricultural production, has not changed, but methods how to fulfil that purpose has changed considerably. Gradually were formulated new scientific issues as agro-physic, agro-bionics, bio-technics and mechatronics.

The content of the scientific section of agricultural engineering and technology is created by following issues at present:

- technology and engineering for sustainable farming;
- agricultural energy, energy savings, renewable energy sources, bioenergy;
- technical and economical evaluation of production systems, information technologies;
- agro-ecology, environment and natural resources protection;
- investigative research, theory of technological and transporting systems in agriculture, bionics, biotechnics, agro-physics.

The Research Institute of Agricultural Engineering in Prague has conformed to this trend similarly as the major part of foreign institutions. At present the institute has four research divisions:

1. Division of technological systems for productive agriculture
2. Division of energy and logistic of agricultural technological systems and biomass utilisation for non-food purposes
3. Division of economy of agricultural technological systems
4. Division of ecology of agricultural technological systems.

The long-term conception of the Research Institute of Agricultural Engineering involves following basic research fields:

1. Strategy of technical and technological development of Czech agriculture.
2. Technology for sustainable methods of farming.
3. Reduction of negative impacts of agricultural mechanisation and technology onto environment.
4. Utilisation of renewable energy sources and raw materials in agriculture and in countryside.
5. Research of agricultural materials properties necessary for projects of technology and design of agricultural machines and devices.

We trust that the structure of research institutes newly established 50 years ago has not been random and can be considered as the corner-stones of agricultural research also in the 21st century.

ZDENĚK PASTOREK
Director of the Research Institute
of Agricultural Engineering

Composting as possibility of toxic gases emissions reduction, mainly ammonia, generated during manure storage

A. JELÍNEK¹, M. ČEŠPIVA¹, P. PLÍVA¹, G. HÖRNIG², U. STOLLBERG²

¹Research Institute of Agricultural Engineering, Prague, Czech Republic

²Institute of Agricultural Engineering, Bornim, Germany

ABSTRACT: The base of aerobic composting is biodegradation of organic matter caused by aerobic micro-organism combined with some other reactions, oxidation and hydrolysis particularly. The aerobic process of composting needs air and oxygen supply, because it is one of conditions of effective and rapid process. Generally, in the humification process are active mostly heterotrophic micro-organisms which degrade the organic matters and part of them is oxidated up to CO₂ and H₂O. At the same time occurs a partial bond of nitrogen and the compost use value increases. On the basis of these facts we consider composting as very suitable method of livestock excrements and remaining biomass processing into high-quality humus out of soil environment, but also possibility how to decrease ecological burden of landscape including burden gases emissions reduction. That is why many experiments were carried – out providing dependence of toxic gases emissions generation, mainly ammonia, during composting process.

Keywords: ammonia; toxic gases emissions; measuring devices; sensors; stable climate

The composting process is, with little exceptions, the same for all methods of aerobic composting. It varies only by the process velocity (VÁŇA 1996). It depends mainly on:

- optimization of raw materials composition,
- observance of process conditions (temperature, moisture, aeration degree),
- mechanisation of principal operations within technological process,
- covering of compost by geotextile.

When all these conditions are maintained, than we call the process “controlled composting” where each interference into composting process is precisely conjugated and has its own importance. The controlled composting significantly accelerates the course through the three phases necessary for correct performance of the process (ŠROUBKOVÁ 1990).

At spontaneous start of micro-organism biodegradation begins the 1st phase – mineralization.

First phase – mineralization

Is characterized by rapid growth of temperature (in the core of composted material it reaches over 60°C) followed by relatively rapid decrease. The micro-organism decay complicated organic compounds into simpler of anorganic character. As well chemical degradation reactions proceed. At the beginning sugar, starch and proteins are degradable, later also cellulose and other parts of wooden material. The final products of that degradation are water, CO₂ and other substances.

The nitrogen surplus in the mixture could cause the ammonia generation. The transformation proceeds at

high consumption of oxygen and generation of carbon dioxide. The micro-organisms are not able to degrade organic acids, therefore relative amount of these acids rapidly grows and pH value drops down.

At the beginning there are developed the mezophil microbes reaching top activity at temperature 20–30°C. They decay easy degradable organic matter. At temperature increase to 45°C there are active the thermophil micro-organisms, able to increase temperature up to 80°C. In these processes are applied mainly the rod bacteria – micromycetes decaying cellulose. The thermophilous fungi play important role within the composting process concerning humus generation. It is necessary to prevent temperature above 70°C because some micro-organisms die at this temperature and compost ripeness time is longer.

The mixture volume decrease is relative fast. This is caused not only by sedimentation and compaction of material, water evaporation, but mainly this indicates the balance reduction of total weight resulting from CO₂ and other gases production. The total weight loss can reach in the first phase up to 30%. The weight balance during whole composting process is evident in Fig. 1.

During mineralization the appearance of material does not change, smell is the same like at the start of the process. So far, compost has not the humus properties and can not be applied into the soil. Sometime it can display a certain signs of phytotoxicity. But important is, that within this phase occurs hygienization of the compost. The temperature kills the putrefactional and pathogenous bacteria and liquidates the seed germination.

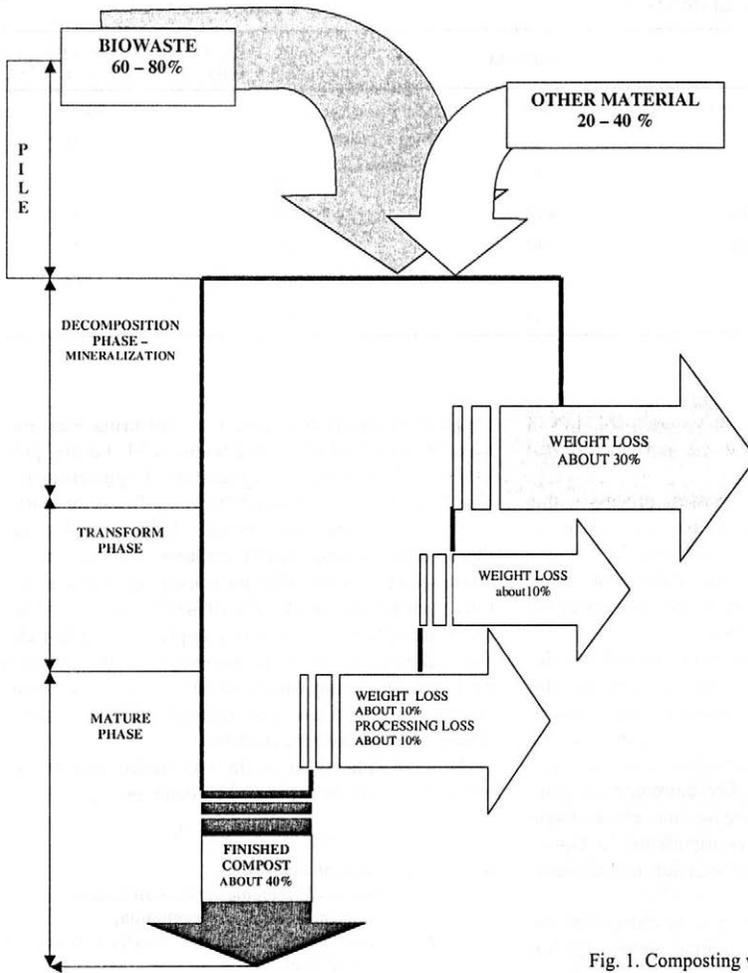


Fig. 1. Composting weight balance (Senkey's diagram)

Second phase – transforming

Is characterized by gradual decrease of temperature to 25°C. The thermophil bacteria are substituted by other group of micro-organisms. In this phase is changing the period of development and suppression of microbe activity. Within the worse accessible compounds decay the actinomycetes are activated. Organic materials are gradually transformed into humus compounds. These are bonded to clay particles and transformed to stabile forms resistant against microbial decay. In this phase can appear even insect or other organism.

The original look, structure and smell of the material fade away. The compost gets brown, individual particles decay. In this phase is decayed about other 10 wt % of mixture. The phytotoxicity fades away and compost leaches are not hygienically defective. At the end of the second phase the compost may be used as fertilizer.

Third phase – compost maturity

Temperature decreases to ambient value. Bonds between anorganic and organic materials set in and the high-quality and stabilized humus generation performs. In this phase is not observed any loss of weight. The compost is matured, the autochthonous microflora bacteria appear as well as insects, earth worms e.t.c.

The total weight reduction from the composting start including losses within processing can reach up to 60% (GRODA 1996). The volume reduction is even higher because material compaction. If the original specific weight of the basic material was $400 \div 600 \text{ kg/m}^3$, the specific weight of matured compost is about 700 kg/m^3 in dependence on the used technology and the weight of compost with higher ratio of earth is $1,000 \div 1,200 \text{ kg/m}^3$.

The particular phase duration is influenced by technology, raw material composition, conditions of composting

Table 1. Parameters of composts of different type

Indicator	Vitahum	Diverse raw material composition + TDO	Monotechnological composition + TKO
Number of bacteria (mil. l g. of d. m.)	330	3,600	1,650
Time of maturity (days)	20	40	25
Max. time of maturity (days)	25	50	30
CO ₂ production (mg/100 g. of d. m)	4.25	180	240
NH ₄ production (mg/100 g. of d. m)	65	140	120
Temperature during maturity	33	60	64
Organic matter losses	15	25	30

but also by other factors, e.g. year's season (ZEMÁNEK 2000). Survey of some values in compost of different type is presented in Table 1.

In order to ensure correct composting process within all the three phases, it is necessary for micro-organism development to create optimal conditions by suitable adaptation of the main factors. One of the most important factors influencing the composting process is the ratio of carbon and nitrogen (C:N).

The microflora needs for its development besides carbon also nitrogen resource which is necessary for protein synthesis. The nitrogen absence causes significant deceleration of humification. Contrary the nitrogen surplus leads to excessive mineralization and nitrogen leakage in form of ammonia. The ammonia development leads to pH – value increase into environment unfavourable for life of micro-organisms. In consequence of this the bio-chemical reaction could totally end.

The aim of aerobic composting is to change the organic materials into stabilized humus matter. The resulting product is resistant against next intensive decay.

The C:N ratio should be max. 30 for matured compost. During the process the ammonia ions should be transformed into more resistant nitrogen bond. The nitrogen immobilization into macro-molecules of generating humus materials is a proof of correctly managed composting process.

The composting process is accompanied by creation of various gaseous substances in which are indicator of the process phase and how this process environmentally burdens landscape by toxic gases emissions, mainly ammonia (JELÍNEK 1999).

All the presented dependencies were found out within experimental measurements at some composting plants.

THE MEASURING METHOD

The ammonia emissions and other gases measuring at composting plants differs from those in stables. During these measurements is necessary to eliminate weather effect onto surface of compost and effect of changing

temperature inside the piles. For measuring was used a verified method of L. Svenssona a M. Ferma, published in the Journal of Agricultural Engineering Research in 1993, No. 1 under title *Coefficient of matter transformation and concentration balance as key factors in a new access to find out ammonia emissions in farm – yard manure*. This measuring method successfully used Kovaříček (VÚZT 1994) for ammonia emissions measuring during slurry application onto field. The difference against the original work, Kovaříček's work and measuring which we have performed, is particularly in investigation of updated ammonia concentration in the measuring chamber.

The method is based on the knowledge, that ammonia emission can be expressed by equation:

$$E_{NH_3} = (C_{vz} - C_o) \cdot K_{H,V}$$

where: E_{NH_3} – ammonia emissions,
 C_{vz} – balanced ammonia concentration in air,
 C_o – ambient ammonia concentration,
 $K_{H,V}$ – coefficient of material transfer between air and manure.

All the three values may be obtained by measuring. For measuring is prepared a single measuring chamber (Fig. 2) adapted from big plastic box. In the chamber is installed sensor for ammonia concentration measuring and air ventilator, rich in ammonia emissions, or some other gases discharging from the chamber. The air flow



Fig. 2. View of the measuring chamber

through the chamber is regulated by the ventilator revolutions. After the theoretical analysis of the problems and verification of obtained results the authors determined relationship between the measuring chamber size and the air flow through the chamber. For the used chamber was computed the air flow value $5.6 \text{ m}^3/\text{h}$.

This value was used for all the measurements.

THE MEASURING RESULTS

Measuring of toxic gases emissions at the composting plants

For comparison will be described two composting plants which belong into group of the composting plants where the rapid composting process is carried out and where the identical drawing rotary digger is used.

Measuring at the JENA company composting plant (Fig. 3)

The composting plant is situated between villages Velké Přílepy a Tursko within area of former missile base. The plant is processing the wooden residua, mowed grass and leaves from Prague's parks and manure from the co-operative farm Tursko. Wooden waste is crushed onto chips before their insertion to the compost, mowed grass is in form of crushed material, leaves and other rests are added in untreated state. The basic pile is always untreated and consists of 6 volume parts of leaves, 2 volume parts of mowed grass, 2 volume parts of wooden chips and 2 volume parts of manure. There is used technology of rapid composting and the compost piles are covered by geotextile. The composting plant workers measure regularly the temperature inside the pile and the compost dry matter is observed in laboratory. According to found values the pile's dry matter can eventually be adapted. For the pile turning the JENA company used the drawn digger of NUCLEA Třebíč. The compost piles are of trapezoid cross-section with base of 2.2 m and height of 1.3 m.



Fig. 3. Measuring at the JENA company composting plant

Because the piles are always identical at the composting plant both the formerly based compost and those based just before measuring are used for investigation.

The newly based compost pile was homogenized by turning just before measuring. In the current piles the turning was provided two days before measuring. According to the operator data this compost was 40 days old, i.e. in the middle of the composting period. The following measurements were carried out always in the newly based and old compost up to the finish in the old pile. By this approach it was possible to acquire the ammonia complex emission within all composting cycle.

The graphical dependence of gases concentrations leaked into atmosphere on the time are presented in part *Comparison of results from both composting plants*.

The main result of the measurements after emission summation from particular turnings and calculation to the pile volume is ammonia amount leaked into atmosphere (Table 2).

Measuring at the HUCUL composting plant (Fig. 4)

On the farm focused on Hucul horse breeding the main component of the compost is a horse manure, grass from mountain meadows and wooden chips or saw dust. The horse manure composting solves reduction of environmental burden created by manure storage on the farm and by following distribution on

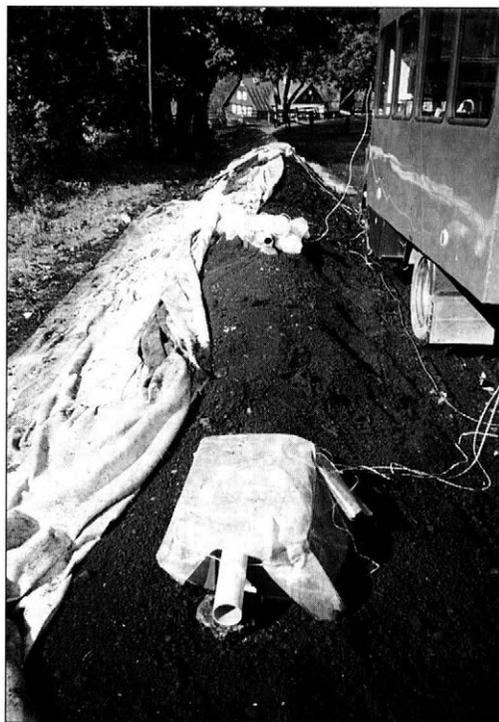


Fig. 4. Measuring at the HUCUL farm composting plant

Table 2. Resulting ammonia emissions at JENA composting plant

Measuring chamber volume	0.047 m ³
Air flow through the chamber	5.6 m ³ /h
Chamber area	0.2 m ²
Total compost pile emission area of trapezoid cross-section – base width 2,6 m, height 1,2 m, length 20 m and 60° angle of side walls	78 m ²
Compost pile volume	43 m ³
Emissions found within investigation time	At compost weight 420 kg/m ³ the compost emission is 336 g NH ₃ /t
Resulting emissions within the composting cycle	6.5 kg of NH ₃

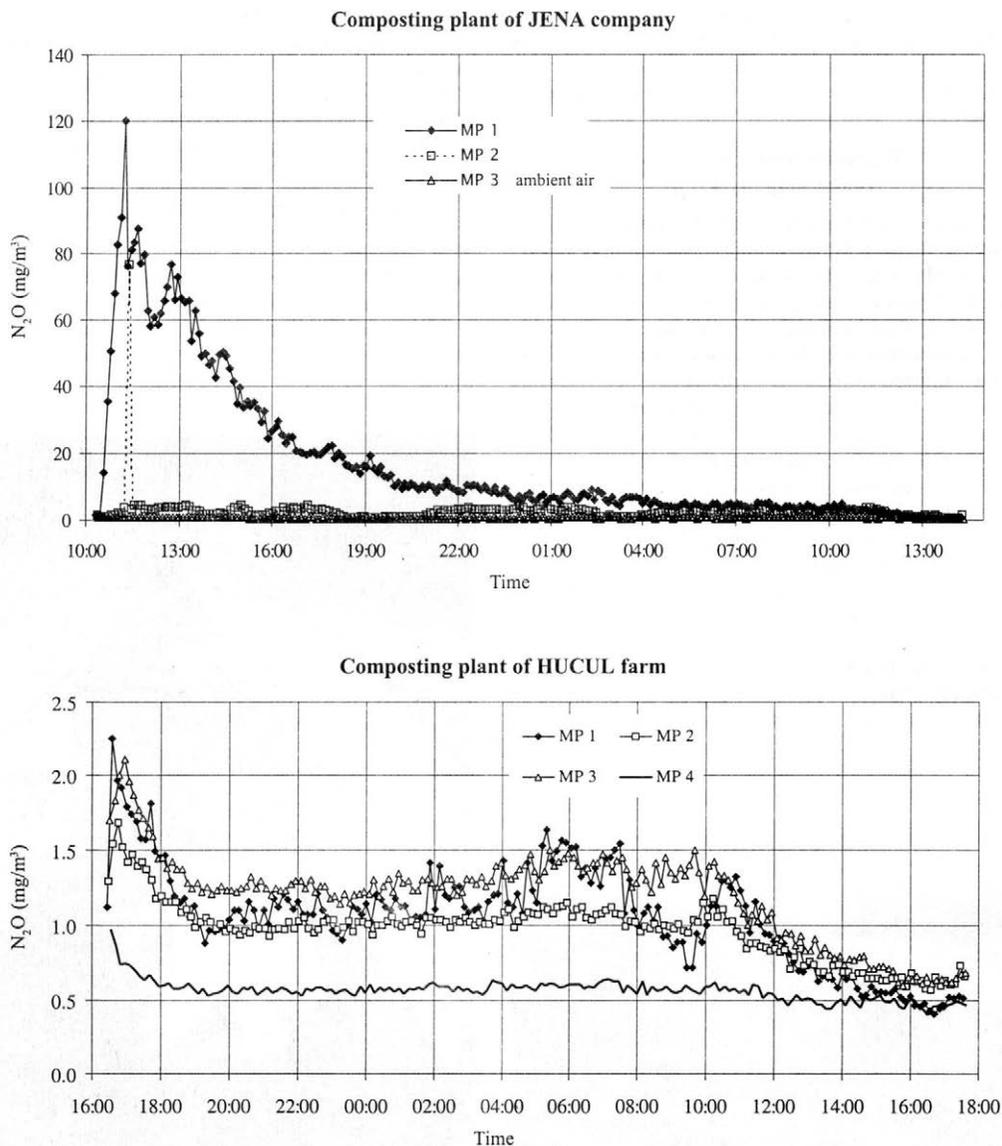


Fig. 5. N₂O concentrations – composting plant of HUCUL farm, composting plant of JENA company

Table 3. Resulting ammonia emissions at HUCUL farm composting plant

Measuring chamber volume	0.047 m ³
Air flow through the chamber	5.6 m ³ /h
Chamber area	0.2 m ²
Total compost pile emission area of trapezoid cross-section – base with 2.6 m, height 1.2 m, length 20 m and 60° angle of side walls	310 m ²
Compost pile volume	173 m ³ , i.e. 74.4 tons (bulk density 450 kg/m ³)
Found emissions within the composting cycle	At compost weight 450 kg/m ³ the compost emission is 504 NH ₃ /t
Emissions resulting within the composting cycle	37.5 kg of NH ₃ composting plants

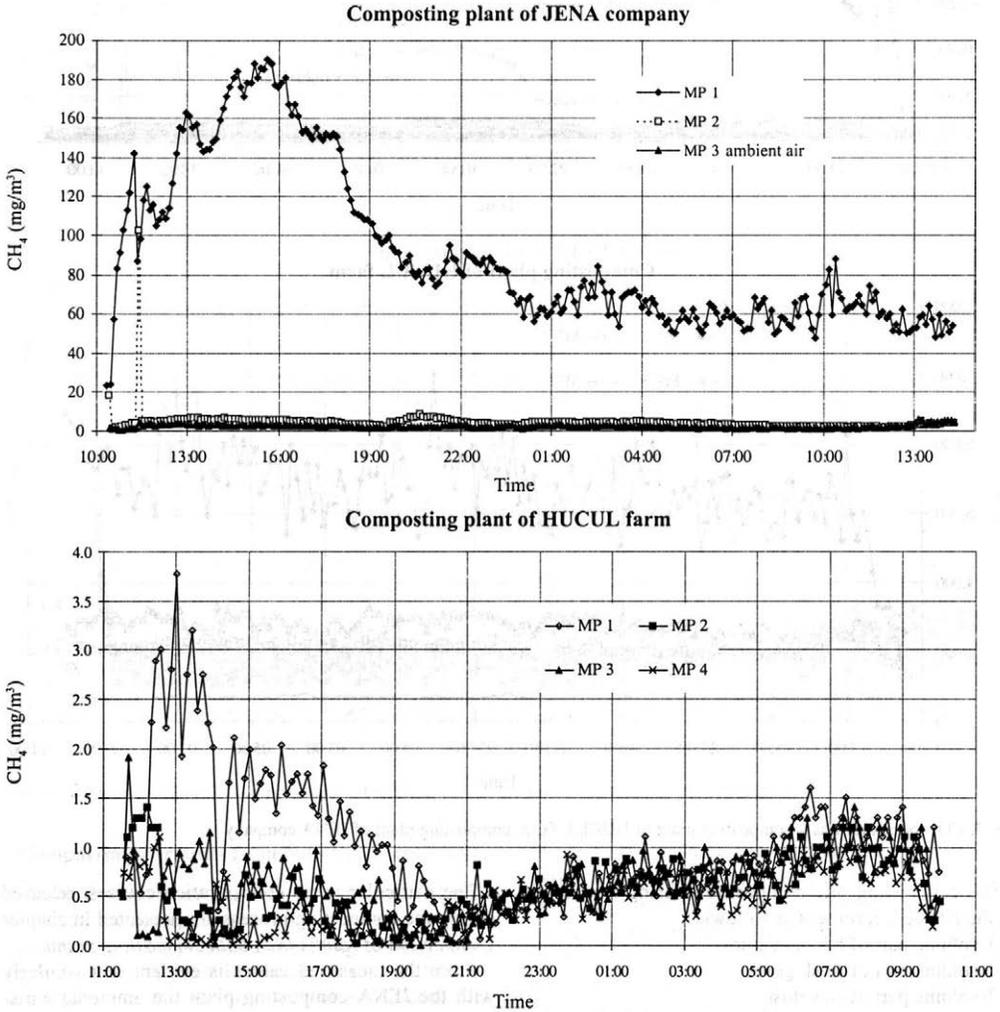
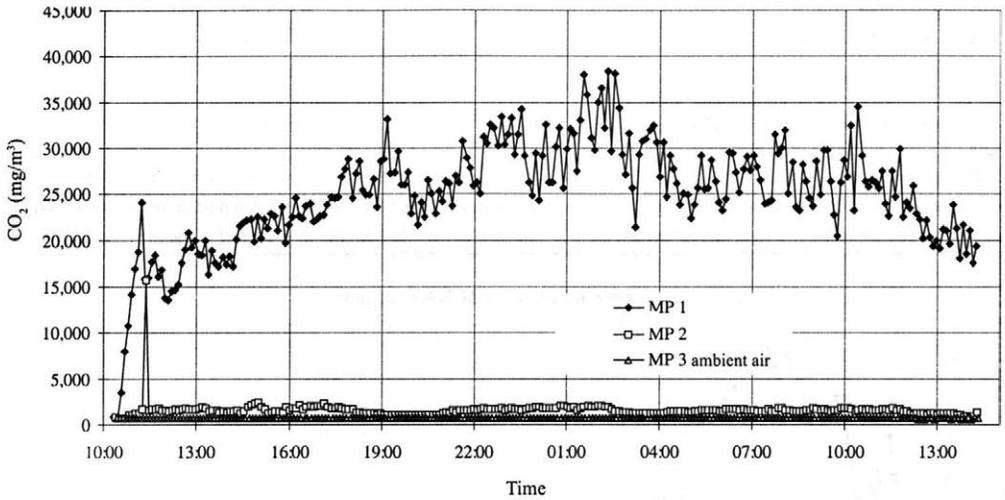


Fig. 6. CH₄ concentrations – composting plant of HUCUL farm, composting plant of JENA company

the mountain meadows. Still expanding livestock rearing causes manure volume growth and dunghill capacity is insufficient for whole year production. The strict farming conditions in KRNAP request also investigation into the environment load from the composting plant.

With respect to relative short time period when is possible to layout the compost and to provide turning (April–November) this is feasible by the rapid composting reaching implementation of 2–3 cycles.

Composting plant of JENA company



Composting plant of HUCUL farm

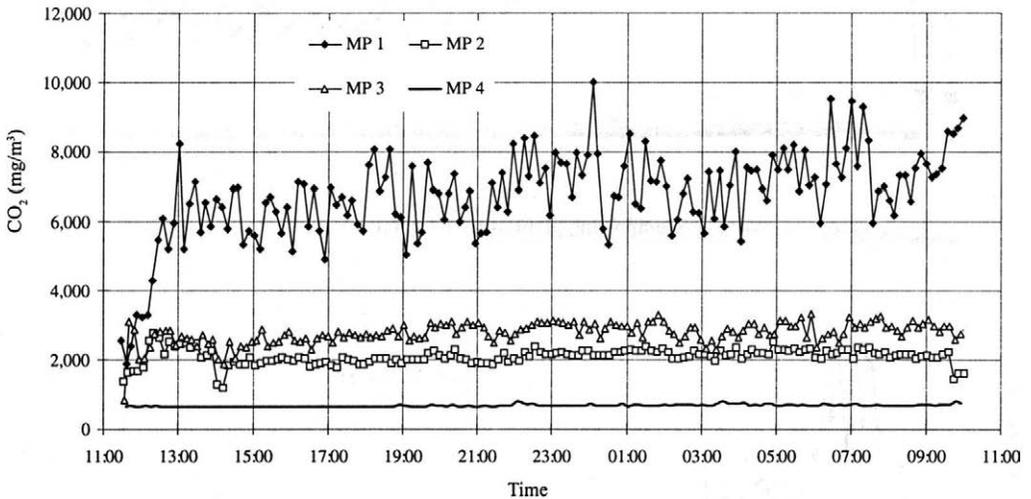


Fig. 7. CO₂ concentrations – composting plant of HUCUL farm, composting plant of JENA company

The composting pile composition during measuring on the HUCUL farm was as follows:

- 1 volume part of horse manure,
- 1 volume part of fresh grass,
- 1 volume part of saw dust.

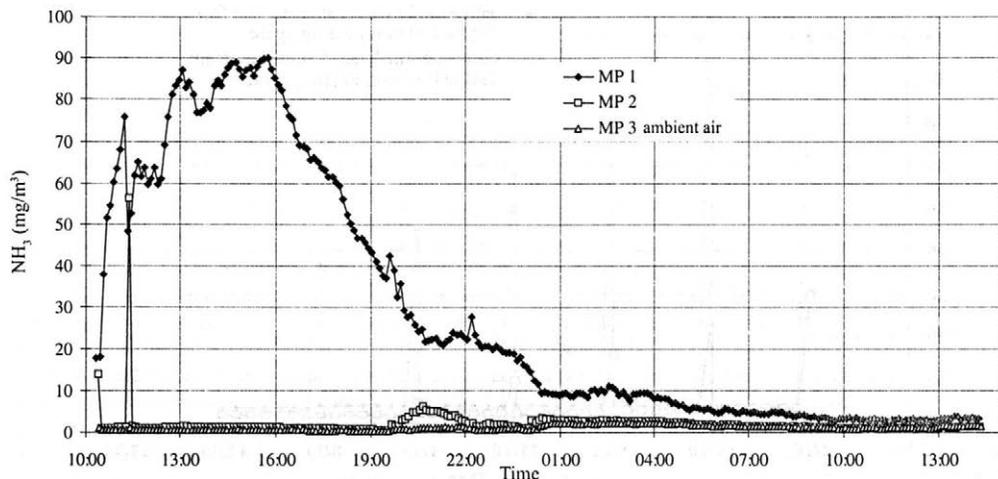
The turnings are performed regularly once a week. After each turning the pile is always covered by geotextile. Temperatures inside the pile and compost moisture in laboratory are measured regularly.

The basic technical data are identical with the JENA composting plant. The HUCUL farm is using an identical digger and therefore the compost pile shape is the same. The pile length was 80 m.

The particular gases concentration courses, released during the composting process are presented in chapter *Comparison of results from both composting plants*.

From the measured values is evident that similarly with the JENA composting plant the ammonia emissions decrease with each next turning. Similar course have also other gases, only the time of decrease to minimal value is different. From this point of view it is interesting the CO₂ emissions course which in one case kept relative high value even on the second day after turning. The final result of total emission of ammonia is presented in the following table (Table 3).

Composting plant of JENA company



Composting plant of HUCUL farm

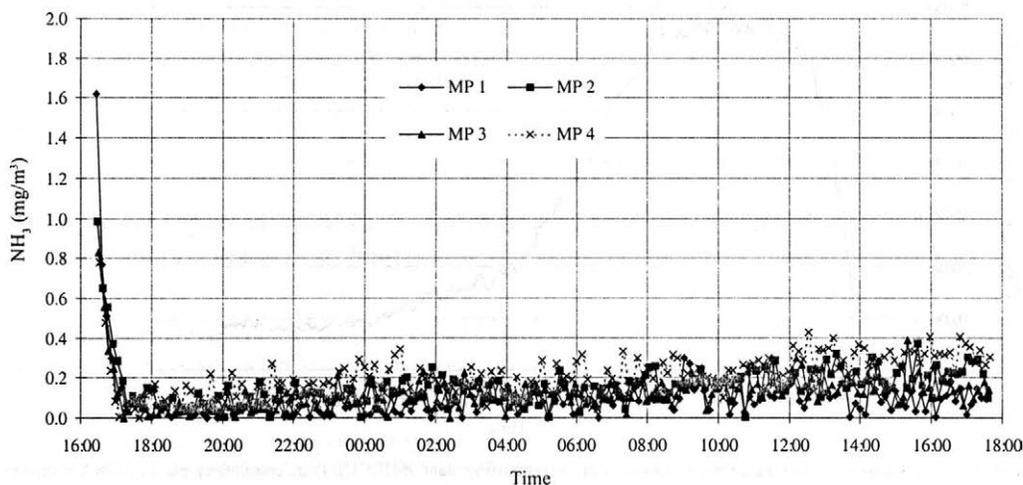


Fig. 8. NH_3 concentrations – composting plant of HUCUL farm, composting plant of JENA company

Comparison of results from both presented plants

At the both composting plants were measured emissions of basic burden gases. The courses of the gases concentrations are presented according to the gas type for the both investigated composting plants always in one figure, i.e. in Fig. 5 are compared N_2O concentrations, in Fig. 6 CH_3 concentrations, in Fig. 7 CO_2 concentrations and in Fig. 8 NH_3 concentrations. In Fig. 9 are compared total ammonia emissions.

It is evident from the results comparison, that compost composed from leaves, grass and manure (336 g NH_3 /t of compost) has different emission than such from horse manure (504 g NH_3 /t of compost). These emissions are comparable with emissions from the manure storage

(e.g. pig manure 248 g NH_3 /t of manure), because during following handling with manure or compost (field spreading) the spread compost emissions are by 75% lower than those of the spread manure. It is evident that the nitrogen bond is confirmed by the composting process and that the technological process is one of the possibility how to reduce emissions.

DISCUSSION

From all values found at both composting plants a curve was constructed connecting the peak points (max. values of ammonia emission) of particular curves.

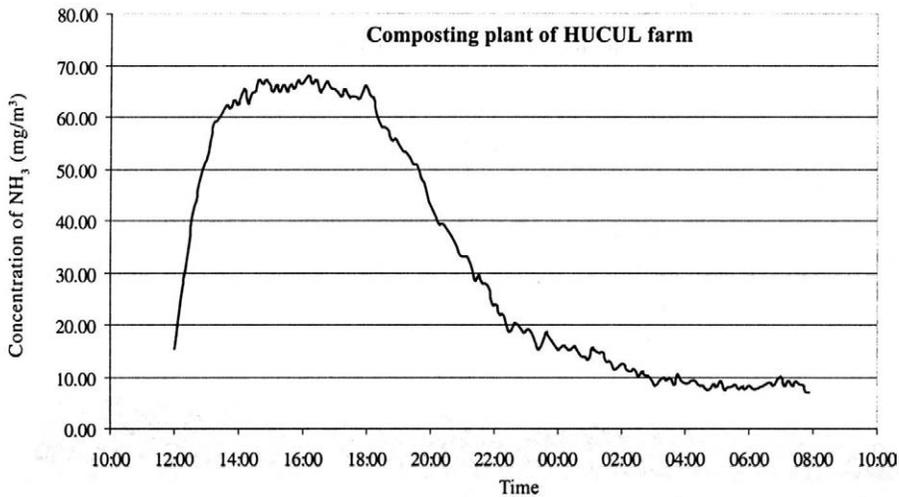
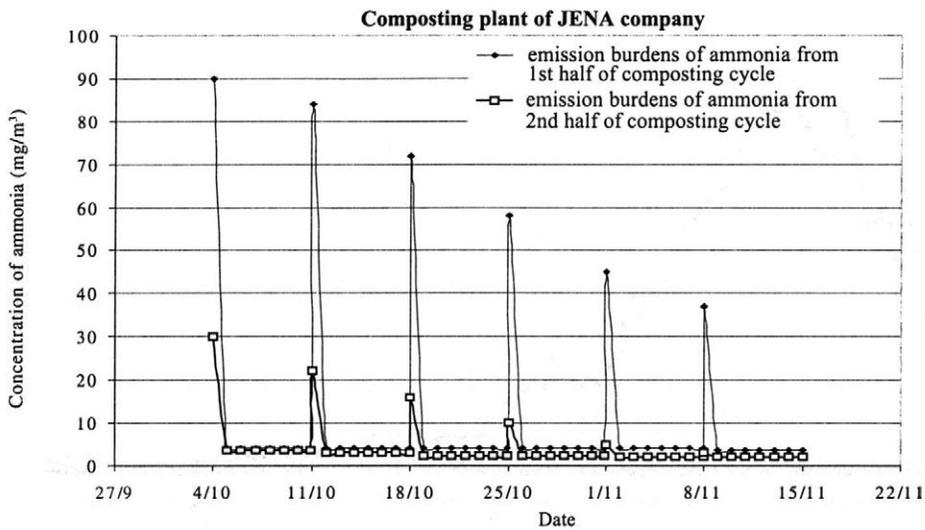


Fig. 9. Total expression of ammonia emissions in numbers – composting plant of HUCUL farm, composting plant of JENA company

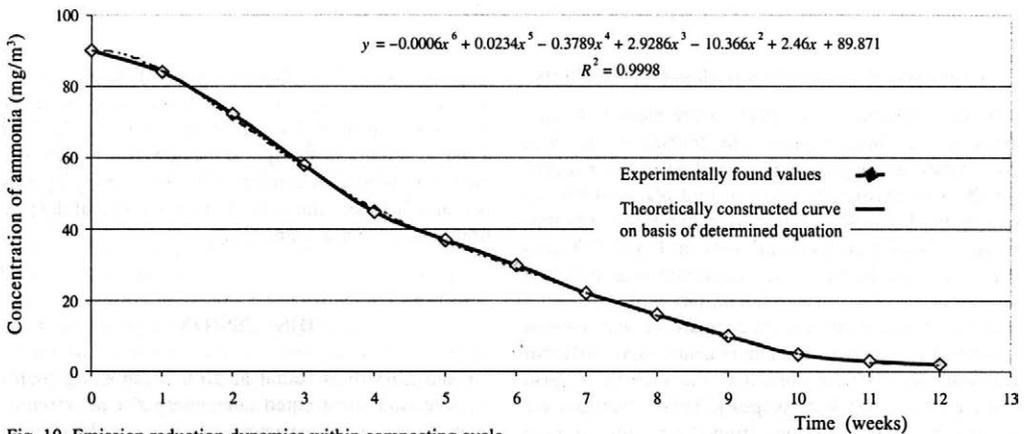


Fig. 10. Emission reduction dynamics within composting cycle

This curve demonstrates decreasing ammonia emissions (reduction dynamic) after each turning. From this graph is possible to determine the time when the process of composting is no more a load for the environment. For better imagination there was found out a theoretical course corresponding experimentally with the found curve. In Fig. 10 are both the curves (experimentally found and theoretically constructed on base of created equation) entered into the graph.

It is apparent that for each pile the parameters of the equation are different, but the curve shape is identical. By compilation of the set parameters for the most used piles it is possible to determine the total emission of the composting process with sufficient accuracy in advance.

These problems are still approached within the institute project *Biomass utilization for industrial and energetic purposes* in the part *Experiments establishment of waste biomass composting for utilization of different start substances and different composition of composting pile*, and gradually the knowledge base of load gases generation will be created.

Composting is one of the possibilities how to decrease the load gas emissions, particularly ammonia, from degradable processes into atmosphere. The research projects will be useful for assessment of manipulation with organic residua from agricultural activity in the scope of the law on wastes and atmosphere protection.

Kompostování jako možnost snižování emisí toxických plynů, zejména amoniaku, vznikajících při skládkování hnoje

ABSTRAKT: Základem aerobního kompostování je biodegradace organické hmoty účinkem aerobních mikroorganismů, kombinovaná s některými dalšími reakcemi, mezi které patří zejména oxidace a hydrolyza. Aerobní proces kompostování potřebuje přísuv vzduchu a kyslíku, neboť je to jedna z podmínek efektivního a rychlého procesu. Obecně platí, že se na humifikačním procesu podílejí převážně heterotrofní mikroorganismy, které degradují organické látky a část z nich oxidují až na CO_2 a H_2O . Současně dochází k částečné vazbě dusíku a zvyšuje se užitná hodnota kompostu. Na základě těchto faktů lze předpokládat, že kompostování je nejen vhodný způsob zpracování exkrementů hospodářských zvířat a zbytkové biomasy na kvalitní humus mimo půdní prostředí, ale také možnost snižování ekologické zátěže krajiny včetně snižování emisí zátěžových plynů. Proto byla provedena řada experimentů, které zjišťovaly závislosti vzniku emisí toxických plynů, zejména amoniaku, v průběhu kompostovacího procesu.

Klíčová slova: amoniak; emise toxických plynů; měřicí zařízení; čidla; klima stáje

Corresponding author:

Ing. ANTONÍN JELÍNEK, Výzkumný ústav zemědělské techniky, Drnovská 507, P. O. Box 54, 161 01 Praha 6-Ruzyně, Česká republika
tel.: + 420 2 33 02 21 11; fax: + 420 2 33 31 25 07, e-mail: jelineka@bohem-net.cz

- GRODA B., 1996. Zpracování odpadu. MZLU Brno.
- JELÍNEK A. et al., 1999. Omezení vlivu emisí toxických plynů ze stáji na životní prostředí. [Výroční zpráva.] Praha, VÚZT, č. 2357: 1–45.
- ŠROUBKOVÁ E., 1990. Zemědělská mikrobiologie (Speciální část pro fyto technický obor). [Skriptum.] Brno, VŠZ: 61–65.
- VÁŇA J., 1996. Optimalizace procesu kompostování. Sbor. ref. z konf. Komposty, biohnojiva, biopreparáty, Deštné v Orlických horách: 6–8.
- ZEMÁNEK P., 2000. Využití technických prostředků při kompostování zbytkové biomasy. [Habilitation práce.] Lednice, MZLU: 5–20.
- ATERAKI E.J., MATTHEWS R.A., PAIN B.F., 1997. Ammonia emissions from beef cattle bedded on straw. Lectured at international symposium in Holland, 6. – 10. 10. 1997. Institute of Grassland and Environmental Research, North Wyke Research Station, Okehampton, Devon, EX 20 2 SB, UK: 343–348.

Received 11 June 2001

The batch process of maize drying by mobile drier

R. PAWLICA, P. KOVAŘÍČEK

Research Institute of Agricultural Engineering, Prague, Czech Republic

ABSTRACT: For reconstruction of technological lines for grain crops treatment are applied the mobile driers with batch process of drying. The reason for this are favourable economical parameters. The purchase price and low operational costs enable rapid investment return ability and provide to return the drying technology on the farms and thus to contribute to the prior production competitiveness. The operational parameters of the drier MUF 70 were observed during the maize drying. Within the cycles of filling, drying, cooling and unloading of the driers there was realized the kernel sampling to determine its temperature, moisture content and germination, the operational sensors of drier, electricity meter and gasometer. At average dried matter 9.5% the average unit temperature consumption was 2,888 kJ/kg of evaporated water. The kernel moisture content and temperature at output from the drier were equalized. It proved the correct mixture of material during the drying process. The dried maize does not show any flour or meal share nor any colour change caused by the thermal overload. The drying air temperature from 96 to 128°C enables to reach the high performance of drying, but the ¾ hour corn exposition decreases the germinating ability under 10%. In normal business contact such treated corn for the feeding purposes is being evaluated as being of the top quality, without any reduction of the mass or price.

Keywords: grain crops; dosing; drying; performance quality

The drier is the key machine of the technological line for grain crops treatment. For the stationary post-harvest the drier is the dominant component of the whole configuration, i.e. it determine the dimensioning of transport routes, the reception capacity of the hopper or receiving stand-by areas, the number and unit size of handling containers.

It can be expected, that in a near future the post-harvest process of treatment will be liberated from the rigid stationary solution by means of mobile machines for post-harvest operations as for example mobile receiving hoppers, mobile cleaners or mobile driers. Solution of reliable and functional mobility for all components of the line is a basic presupposition for implementing such conceptions (PAWLICA 1997). It is evident, that the progress will be gradual, some components will be able to be used in mobile form earlier than the other ones.

The knowledge of practice confirm the presupposition, that for the mobile post-harvest treatment the most suitable are the mobile driers with a batch system of drying. It is so because the highest economical effect is achieved when drying products with high content of water, mainly maize and rape. Despite this fact, stationary driers are not used in the areas with prevailing maize production. Thanks to the mobile type of driers with batch operation it is possible to solve problems of the maize and rape growers in a simple and rapid way.

This solution brings exceptional economical effects because of its simplicity and independence upon other

components of the post-harvest lines (PAWLICA 2000). There some exist suitable ways of the mobile drier application into current situation of farm each having its own advantages and disadvantages or limitations. The model solutions may be characterized as follows:

I. Loading by front loader, unloading by trailer (Fig. 1, model Čierny Brod)

This variant is a basic design layout. The MUF 45 drier has a receiving hopper for reception of maize from the inter-storage on the free surface by front loader. The transport from the hopper into the drier processing chambers is provided by special rake conveyor with rubber carriers, the conveyor output is 40 tons per hour. After the filling the automated process of drying is started, followed by the process of cooling and machine stopping. The discharging is provided by the rake conveyor gradually loading the drier content into the prepared trailer.

II. Loading by tipper, transport to heap in the hall (Fig. 2, model Třebovle)

The MUF 70 drier is equipped by receiving hopper of capacity 1.5 m³. The width of the hopper 2.4 m is linked with the transport system width (rear tippers) constraintly. The drier direct filling by tipper through the dosing chute situated in rear part is quite suitable and within the terrain slope or loading platform of level difference at least 0.3 m this system of filling is very convenient.

The lorry may transport material either from the field or from the inter-storage site situated in a distant hall. It

The results presented in this article were obtained within the approach of the Research project of the Ministry of Agriculture No. EP 0960006500 and Research scope MZE M05-99-01.

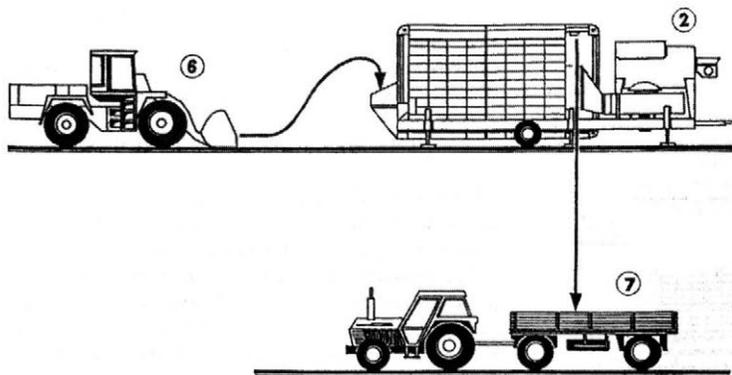


Fig. 1. The batch drying models – mobile driers MUF
2 – drier MUF, 6 – front loader,
7 – tractor with trailer

means that the MUF 70 drier capacity 16 tons of corn needs two lorries for 1 drying batch. The period of drying cycle for wet maize (moisture content over 30%) is 4–5 hours. This time is sufficient even for transport of material from a remote contractor. The natural gas burner connection pre-determines this variant for operations at one place and material transportation from the supplying territory.

After the drying and cooling of corn there is in this variant provided transport to the adjacent hall. For this purpose is used a mobile conveyor (or set of such conveyors) for dried material stacking to the height above 4 m.

The mobile drier application according to the model Třebovle is suitable for situations, when the enterprise has properly large hall for planned storing capacity. This hall may be used at the season beginning also for material inter-storage between flow of material from

the field and drier. This variant is exceptionally suitable for full utilization of the seasonal capacity of drier for other customers when they can transport the wet maize by their vehicles and to transport back the dried maize.

III. Accumulation of harvested corn into piles in the hall, filling by loader, discharging by trailer (Fig. 3, model Slatina)

The third variant of the mobile drier application nearby the hall is unsuitable for long-term storage but sufficient for material accumulation for night operation or more-day supply for drying. In these cases the drier is filled by front loader shovelling material from the piles in the hall into the receiving hopper of the drier.

In that variant the heating medium is heating oil stocked in a mobile tank. It enables to change the drier position during the season or all the year in dependence on the harvest level to dislocate it sometimes within

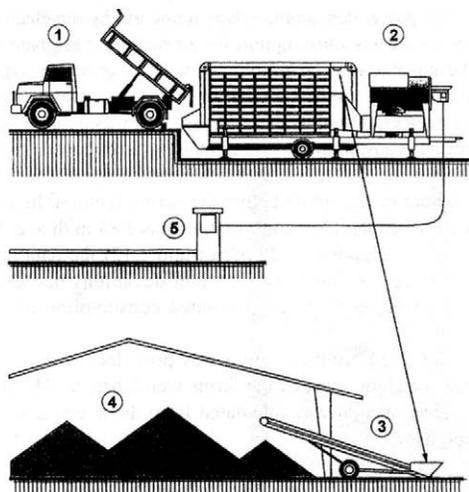


Fig. 2. The batch drying models – mobile driers MUF – model Třebovle
1 – wet material reception, 2 – drier MUF, 3 – loading conveyor,
4 – storing hall, 5 – gas connection

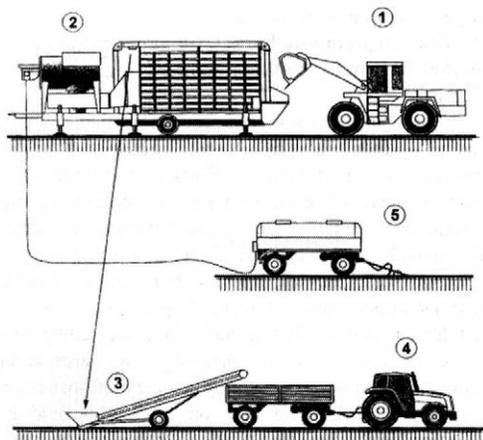


Fig. 3. The batch drying models – mobile driers MUF – model Slatina
1 – wet material reception, 2 – drier MUF, 3 – unloading elevator,
4 – dry material transport, 5 – transporting tank with LTO

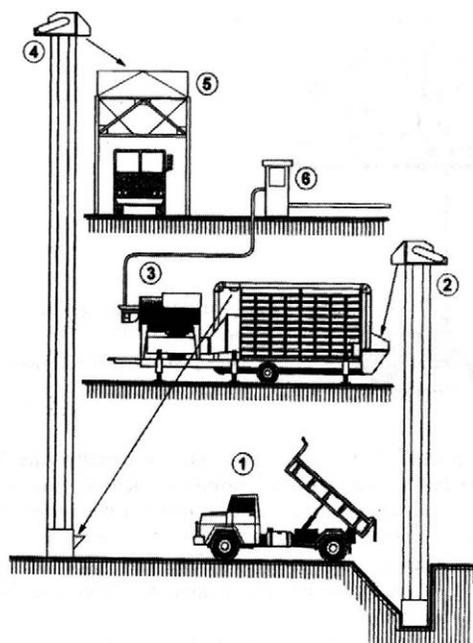


Fig. 4. The batch drying models – mobile driers MUF – model Čejč

1 – wet material reception, 2 – filling elevator, 3 – drier MUF, 4 – unloading elevator, 5 – expedition hopper, 6 – gas connection

one enterprise. Therefore the drier may dry rape at site A, wheat at site B and maize at site D (example). The dried product is transported by vehicles to a remote store hall (e.g. trade company). To master a gradient the conveyor must be used for material loading into large capacity trailers or lorries.

IV. The reception into basket, filling by elevator, discharging into expedition hoppers (Fig. 4, model Čejč)

This variant solves the incorporation of the mobile dosing drier into a current reconstructed post-harvest line for drying of huge amounts of rape and grain crops. Generally the drier change is not sufficient but certain reconstruction of transport routes for loading and unloading of drier is necessary due to the increase of the nominal output to 60 t/h. For current lines the original under-surface basket (hopper) may be used also for the supply constitution in the front of the drier.

The drier can be heated by natural gas from distribution network, by propane butane or by heating oil from stationary tank. The MUF drier location, in case it would dry maize or sunflower; is suitable under shelter out of the hall. During drying of these crops there is released a huge amount of water vapour quite filling the hall space.

For unloading of the dried material there is used a battery of expedition hoppers in this variant. For their filling is used an effective bucket conveyor and distrib-

uting pipe system or reverse belt conveyor. The expedition equipped by this technology is able besides material loading into storage of the post-harvest line by stationary conveyor also to transport material by the large-capacity trailers, e.g. to the trade company.

THE MEASURING METHODICS

Both practical and laboratory tests were carried out on the family farm Čejč. The farm is aimed to maize, sunflower, feeding wheat and rape production.

The measuring methodics was adapted for the batch process of the drier. During all the cycle there were measured temperature and moisture content of the maize kernels each 3 minutes simultaneously with drier filling (about 10 samples during the filling). After the start of the drying, when material circulates in the drying shaft, the sampling interval was 15 minutes and again 3 minutes in the discharging part of drier. For each sample was measured the moisture content by the apparatus PFEUFFER HE 60 using the isomeric homogenizator LABOMILL. After the drying the maize samples were subjected to the airtight storage due to the temperature decrease under 25°C and to obtain correct values of the output moisture content.

The kernel temperature was measured by the calorimetric method by means of the battery in the thermo bottle. After the period of the post-harvest ripening there was determined the germinating ability according to the valid Standard CSN 46 1011, part 19 (for peroxide) in the laboratory of the Research Institute of Agricultural Engineering. The operational parameters of drying and cooling medium as well as the drier adjustment were recorded by registration in 15 minute intervals from the drier indicational devices.

The power consumption was found out by the electricity meter, gas consumption for air heating was given by the gasometer. The gasometer was equipped by automated compensation for barometric pressure and ambient temperature, thus the meter reading was given by the normal consumption. The remaining farm consumption screening was provided by measuring of the last 0.5 hour consumption before the burner ignition. In situation when the farm consumption was 3.84 m³/h and the drier consumption 45.25 m³/h (ratio 1:12) the data reliability is very high. The random deviations non-existence was controlled by repeated consumption of the farm.

The dried product weight was provided by the content weighing through the farms weigh bridge. The wet material weight was calculated from the average moisture data.

RESULTS OF MEASUREMENTS

Within the framework there were realized two successful repeated measurements marked Test 1 and Test 2. The Test 1 results will be evaluated by means of Table 1 and Fig. 5. The drying air temperature measured in the

Table 1. Results of practical and laboratory tests (Čejč 1999) maize MUF 140

Parameter	Unit	Measuring No. 1	Measuring No. 2
Material	–	maize	maize
Drying air temperature – Duo I	°C	126	128
Drying air temperature – Duo II	°C	96	98
Time Duo – Term I	hour	2.58	2.59
Time Duo – Term II	hour	0.58	0.74
Cooling time	hour	0.32	0.30
Idle time interval	min	1.8	1.0
Filling time	hour	0.35	0.33
Drying time	hour	3.16	3.33
Unloading time	hour	0.33	0.33
Cycle time	hour	4.16	4.29
Wet filling	kg	15,100	15,328
Dried filling	kg	13,500	13,580
Evaporated water	kg	1,600	1,748
Input moisture content – average	%	11.19	23.00
Output moisture content – average	%	12.97	13.09
Dried cake	%	9.22	9.91
Drying output	t.%	139.22	151.90
Power consumption per 1 cycle	kWh	90.2	94.91
Gas consumption per 1 cycle	nm ³	142.9	144.36
Consumption per 1 t and 1%	kW/(t.%)	0.648	0.625
Gas consumption per 1 t and 1%	m ³ /(t.%)	1.026	1.035
Specific heat consumption	KJ/kg of evaporated water	2.992	2.767

first phase of the drying (automation Duo Term) was 126°C within 2.58 hours, then the burner was switched to lower output – temperature 96°C within 0.58 hour. Then followed the cooling part, where the drying chamber was supplied by the ambient air of temperature 11°C.

The synthetic results of measuring may be observed in Table 1:

- during the cycle there was evaporated 1,600 kg of water, total average dried amount was 9.2%, total output was almost 140 t.%,
- total time of cycle 4.16 hours gives drier output 33.5 (t.%) /h,
- power consumption was 90 kW, specific consumption 0.65 kW/(t.%) per 1,

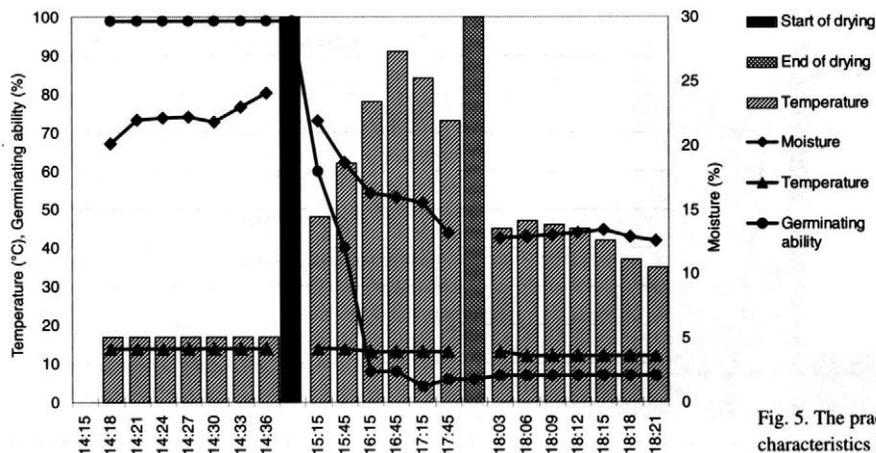


Fig. 5. The practical and laboratory characteristics MUF 70, test No. 1

- gas consumption per 1 cycle 142.9 m³, specific consumption was 1.03 m³ per 1 t and 1%,
- specific consumption 2,992 kJ per 1 kg of evaporated water.

Test 2 was following the repetition of test 1, material parameters were almost the same, other quantitative parameters were similar, second stage of Duo Term was extended by 15 minutes, ambient temperature has decreased to 9°C. The measured temperature of drying air was 128°C within 2.58 hours the first phase of drying (Duo Term automatics), then the burner was switched for lower performance – temperature 96°C within 0.74 hour. Then followed the cooling process when the air of temperature 9°C was loaded to the drying chamber.

The synthetic results of test 2 may be observed in Table 1:

- during the cycle was evaporated 1,748 kg of water, total average drying amount was 9.91%, total performance 152 t,
- total cycle time of 4.29 hours gives drier performance 35.4 (t.)/h,
- power energy consumption was 95 kW, specific consumption 0.62 kW/(t.%),
- gas consumption per 1 cycle was 144.4 m³, specific consumption was 1.03 m³ per 1%,
- specific consumption 2,767 kJ per 1 kg evaporated water.

DISCUSSION OF RESULTS

The basic parameter changes within the drying process may be observed in Fig. 5. The material temperature at input to drier was 17°C, after drying start it has increased significantly in 15 minutes interval to 48, 62, 78 and top value was 92°C, after the burner lower output initiation it decreased to 84 and 73°C. The discharging temperatures ranged between 46–36°C. This temperature is relatively high for storage, nevertheless the operator requested to decrease the time, because of

his dependence upon performance and he was relied on the temperature decrease at the kernel spreading into the storage hall.

The maize grain moisture content is given by the curve in Fig. 5. The initial moisture content ranging between 20–24% corresponds by its dispersion to the fresh harvested material. During the drying cycle there is evident a sudden decrease to about 16%. The operators estimated correctly the Duo Term cycles ratio – from the graph is evident the reduced speed of drying in the post of lower temperature and finishing of drying during the cooling process, which is of the same intensity due to the inertial water diffusion from the kernel core to surface. The output moisture – during the drier discharging – is surprisingly equal within level 13–14%. It gives evidence about appropriate material mixing during the drying process.

The material temperature at the drier input was 17°C, after the drying process beginning it adequately increased in 15 minute intervals to 42, 67, 86 and the value was 90°C, after the burner lower output it decreased to 83°C. The discharging temperature ranged between 43–25°C. The maize kernel moisture content is shown by the curve in Fig. 6. The initial moisture is in range 22–23%. During the drying cycle there is evident the significant decrease to about 15% during the higher temperature, during lower temperature the decrease continually continued to level 14%. The output moisture content – at drier discharging – is equal on level 12.5–14%.

The maize grain dried in Čejč is determined for feeding purposes. The criterion of the quality maintenance is a feeding experiment, despite its low reliability, caused by the biological effects. Therefore, in practice there are used the derived parameters signaling quality influence.

As the exterior physical parameters are concerned it is particularly the kernel homogeneity and resistance against breaking during manipulation (GUNASEKARAN et al. 1985). The comparison of the output material

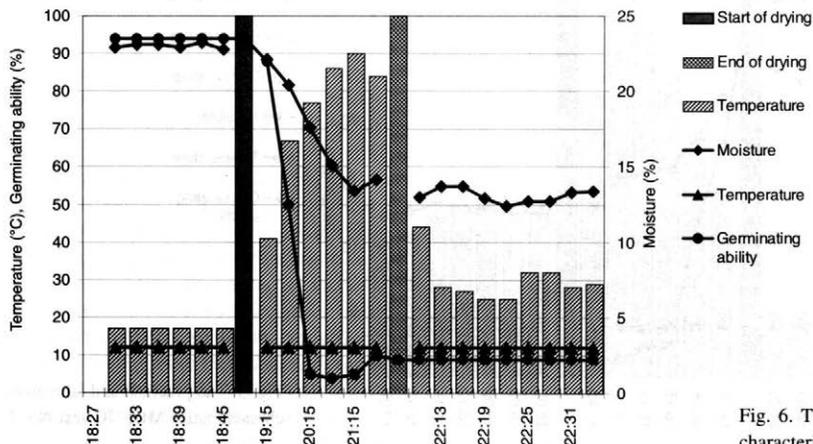


Fig. 6. The practical and laboratory characteristics MUF 70, test No. 2

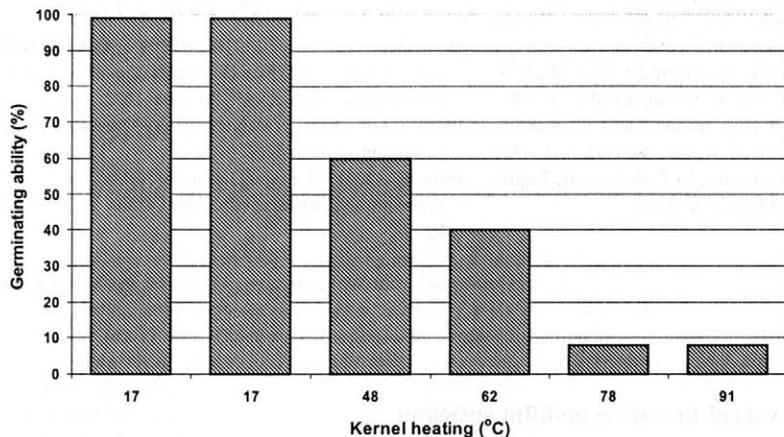


Fig. 7. The kernel quality parameters during drying

from current driers (e.g. type LSO – Chrlice) and the material from the drier in Čejč the difference is quite evident. The maize from Čejč does not present any flour or meal share, is clear, full and without colour changes. In common business contact such grain is evaluated as the first class quality, without any mass or price cut down.

From point of view of the maize quality the vitality changes could occur during thermal overload and the higher loading also can reduce effectiveness of the grain enzymatic potential. It is known from practice that the maize seed is much less resistant against heating in comparison with the small grain crops. The vitality is reliably indicated by the germinating ability. The samples from Čejč were exposed to germination tests – the results are shown in the Test 1 a Test 2 characteristics (Figs. 5 and 6). From the graphs is evident that just after the kernel heating, at exposition about 0.5 hour the significant decrease of germination occurred. The following drying for 0.75 hour caused considerable loss of the level about 10% of residual germination.

The more detailed germination influencing by the kernel heating is presented in Fig. 7, where the germination decrease is presented in relation to the grain heating. The input values of germination range on the level 100%, at heating on 48°C the germinating ability decreased on 60%. At further heating on 62°C the germinating ability decreased on 40% and almost complete germinating ability loss occurred at temperature 78°C.

Of course, the germinating ability decrease is besides the heating also caused by the exposition. The synthetic knowledge may be formulated by opinion, that even in the first third of the cycle occurs the considerable decrease of the germinating ability and that decrease continues with further drying, but the output material does not drop down to zero value even when the exposition still lasts.

The residual germinating ability after the drier passing through is kept in range 5–10% (PAWLICA 1997). The germinating ability is an adequate parameter for

seed stock. The maize seed stock has quite different technology of its treatment (spikes harvest, slow spikes drying in the frosty environment or in the (chamber drier). Other crop according to the demanding is the food maize, designated for starch production, where the customers demand the germinating ability (because any other operative parameter does not exist) on the level 50%. Nevertheless, starch may be successfully produced also from material with the germinating ability 25%. The requirement for 50% involves reserve of other signs. For the feeding purpose the germination parameter is insignificant but for our research analysis it gives us a subsidiary assessment. The relationship between the germinating ability and maize feeding effectiveness is out of this project possibilities. From the realized analysis has resulted the knowledge, that the drying process causes almost total loss of the maize germinating ability, but for the feeding purposes this loss is not significant.

CONCLUSION

New technological processes connected with the driers mobility and with introduction of the closing drying as a new technology brings also great economical benefits for the primary producers. The first owners had opportunity to make sure about exceptionally favourable economical parameters of the new mechanization for drying changing view on the drying technology, which has been considered expensive and thus unavailable for the primary production. This was caused by the price of 65 CZK per drying of 1 t by 1% of moisture content. But the real price of the MUF driers is 15 CZK/t.%. These economical facts return the drying technology back to the farms and enable to our farmers a competitive grain production with a high water content as e.g. rape, sunflower and maize.

The drier in Čejč was installed on 10. 7. 1999 and influenced the rape drying season. It dried 375 t of rape within 11 days and interfered the harvest by drying of

550 t of food wheat. The dried material of rape has reached about 3% and wheat 2%. The drier MUF 70 has reached under normal operational conditions on average output 50 (t.)/h. The daily output of the drier MUF 70 in Čejč was 1,200–1,500 t.%, at limiting conditions 600–1,000 t.%. The maize drying season has continued to 17. 11. 1999. The total dried amount was 6,050 t. This output corresponds with the need of concentrated agricultural production in the Czech Republic.

References

- GUNASEKARAN S., DESHPANDE S.S., PAULSEN M.R., SHOVE G.C., 1985. Size characterisation of stress crack in corn kernels. *Trans. ASAE*, 28:1668–1672.
- PAWLICA R., 2000. Rentabilita výroby slunečnice je určována sušením. *Úroda*, 48, č. 3: 20–21.
- PAWLICA R., 1997. Projekt technicko-technologických doporučení pro aplikaci dávkového sušení. Praha, VÚZT: 32, přílohy.

Received 11 June 2001

Dávkovací proces sušení kukuřice mobilní sušičkou

ABSTRAKT: Pro rekonstrukci technologických linek pro ošetření zrnin se používají mobilní sušičky s dávkovacím způsobem sušení. Důvodem jsou příznivé ekonomické parametry. Nákupní cena a nízké operativní náklady umožňují rychlou návratnost investice a zajištění návratu sušící technologie na farmy a přispívají tedy k výrobní konkurenceschopnosti. Pracovní parametry sušičky MUF 70 byly sledovány v průběhu sušení kukuřice. Během cyklu plnění, sušení, chlazení a vyskladňování byly realizovány odběry vzorků zrna pro stanovení jeho teploty, vlhkosti a klíčivosti, operační čidla sušičky, měření spotřeby elektrické energie a měření spotřeby plynu. Při průměrné sušině 9,5 % byla průměrná spotřeba sušící jednotky 2 888 kJ/kg vypařené vody. Vlhkost zrna a teplota při výstupu ze sušičky byly vyrovnané. To dokazuje správné míchání materiálu během sušícího procesu. Usušené zrna nevykazují ani žádný podíl mouky nebo šrotu, ani změnu barvy způsobenou vyšší teplotou. Teplota sušícího vzduchu v rozmezí od 96 do 128 °C umožňuje dosáhnout vysokého výkonu sušení, ale vystavení zrna po dobu ¾ hodiny snižuje schopnost klíčení pod 10 %. Z obchodního hlediska se takto ošetřené zrna pro krmné účely hodnotí jako zrna nejvyšší kvality bez jakéhokoliv snížení hmoty nebo ceny.

Klíčová slova: zrniny; dávkování; sušení; kvalita provedení

Corresponding author:

Ing. RUDOLF PAWLICA, CSc., Výzkumný ústav zemědělské techniky, Drnovská 507, P. O. Box 54, 161 01 Praha 6-Ruzyně, Česká republika
tel.: + 420 2 33 02 24 56, fax: + 420 2 33 31 25 07, e-mail: vuzt@bohem-net.cz

Storage of wet maize in sealed containers in CO₂ protective atmosphere

P. KROUPA, J. SKALICKÝ

Research Institute of Agricultural Engineering, Prague, Czech Republic

ABSTRACT: The aim of the research was to verify methods of the wet maize storage in CO₂ protective atmosphere sealed in the Vítkovice containers of unit storage capacity 400 tons. The paper presents results of measuring of CO₂ development speed after loading and sealing of the container and results of laboratory analysis of maize quality during container unloading. The loaded maize moisture was 30–35%. The summarized results demonstrated, that quality of stored wet maize in sealed container and CO₂ protective atmosphere depends mainly on fermentation process and speed of generation of sufficient amount of CO₂. The decisive are two days when fermentation start and CO₂ creation must be very rapid. The process must be finished within 10 days. From measured figures resulted that within 11 months of storage the CO₂ concentration has decreased by 9.1%, i.e. to 69.8% of CO₂. This concentration has ensured sufficient protection of stored maize corn what has been proved by the laboratory analysis of corn for presence of undesirable microorganisms.

Keywords: sealed tower container; carbon dioxide; equalizing bag; CO₂ concentration; mycoflora determination

Maize is a very important common raw material for the food industry and feeding. Large volumes of harvested, stored and treated maize cause a rise of new problems. The importance of maize for nutrition is given by its high content of nutrients and particularly by its ability to be stored for a long time.

At present both feeding and food maize are treated at current post-harvest lines with an insufficient technical level. Great losses are obvious within storage of mainly wet maize. This problem is solved in practice by post-drying of maize for feeding to the storing moisture level. But there is a problem with the costs for wet post-drying which are increasing exponentially and this aspect affects even the market price, of feeding mixtures.

The wet maize stored in the storage site produces carbon dioxide and if the storage is air-tight then CO₂ pushes out the air from the storage and prevents development of undesirable bacteria and moulds which need oxygen for their living. Searching for CO₂ in practice is provided by "gas lighter" (either burns or not), nevertheless this is a very primitive method. The CO₂ regulation when corn is stored in the PE bags is performed by the "artificially created hole" in the bag, CO₂ pushes out the air and the hole is then glued. Therefore research of main resources negatively influencing the stored corn quality in CO₂ protective atmosphere must be considered the most important and determination of optimal CO₂ concentration and optimal technological approach to the wet maize storage in air-tight containers are the basic research problems.

SYSTEM DESCRIPTION

The storage of maize at storage moisture up to 35% is based on the process of fermentation which occurs in the non-dried kernels, e.g. harvested grain maize, when a huge amount of maize is stored in the air-tight containers. The stored kernels produce CO₂ by their respiration and generate a protective atmosphere above the stored kernel layer CO₂ being heavier than air. The fermentation process causes conservation of stored maize and keeps its value. CO₂ in the storage space pushes out the air and then starts the process of self-conservation of stored maize when the harmful bacteria and moulds development is impossible (without air supply). That is why the basic requirement for a successful conservation of wet maize is to ensure the sealed storage space to maintain optimal amount of CO₂.

Containers, silos and towers can be built from steel, enamel, reinforced concrete or other material the container size being arbitrary. The maize loading into container can be made from the reception container by bucket elevator and gravity pipe, pneumatic manipulator or special device. A part of this technology is the equalizing bag for accumulation of higher content of CO₂ situated close to the container and connected by pipe to the container. CO₂ regulation between container and equalizing bag is ensured by regulating valve which controls the adjusted pressure and reacts on temperature inside the storage room. The grain unloading is solved by stainless auger conveyer situated in bottom of the container. From the outer side it is equipped by the air-tight closure.

The results presented in this paper were obtained during solution of the Research project of the Ministry of Agriculture of the CR No. EP 7273.

When the pressure drops under 0.03 Mpa, during unloading CO₂ is automatically refilled through the regulating valve from the equalizing bag to the container.

METHOD

The goal of the research was to verify the method of maize and feeding wheat storage in CO₂ protective atmosphere in sealed containers of Vítkovice type of unit storage capacity 400 tons.

The research was aimed into:

- investigation of protective atmosphere generation speed after loading and container sealing,
- investigation of maize quality during unloading.

For finding out of the protective atmosphere quality there was used the infra-red analyzer of carbon dioxide, oxygen and relative humidity Air-XX, purchased for purpose of this research. The storage atmosphere analyzer enables measuring of CO₂ concentration on two levels, oxygen and relative humidity. The obtained data are stored in the memory of the infra-red analyzer with capacity 4,000 records and with ability to transfer data into PC.

The measuring method is based on the CO₂ amount searching in various levels of the tower silo specially adapted for measuring by installation of discharging valve and complex of PE pipes reaching different levels (container heights). This solution enables permanent sampling and control of protective atmosphere level during whole period of maize storage in container.

The speed of protective atmosphere generation was investigated by continual measuring of CO₂ content increase in tower container after its filling up by maize. For the measuring there was again utilized the analyzer Air-XX. The protective atmosphere generation process was evaluated and displayed in tabular and graphical form.

For the maize quality verification after its unloading the samples were analysed to find undesirable micro-organisms, moulds and bacteria. The analysis was provided by the laboratory Research Institute of Crop Production Prague-Ruzyně. There was performed quantitative evaluation according to factor CFU (colony forming units) per 1 gram of tested sample of maize and qualitative evaluation for finding of isolated micromycetes.

MAIZE KERNEL

The micromycetes isolation was carried out by means of surface mycoflora rinsing. Twenty kernels were inserted into Ehrlenmayers flask (volume 300 ml) with 100 ml of sterile water and one drop of humectant (tween 20). The flask was shaken about 1 hour on shaking device Elpan at speed 230 c.p.m. From the flask was discharged 0.5 ml sterile cleanings, then followed the grinding in Petri dish with nutrient medium.

Other method of micromycetes isolation was cultivation of kernels in wet chambers. The incubation was

performed always in darkness at 21°C in climabox. After four days was carried out quantitative evaluation and after six and more days qualitative evaluation and micromycetes isolation into clean culture.

Used nutrient media

Malt agar (MEA) – 3%; pH 6.8:

composition: see JESENSKÁ (1993); application: isolation and determination of brightly coloured micromycetes.

Malt agar (MEA) – 3%, pH 4.5:

composition: see JESENSKÁ (1993); application: isolation and determination of brightly coloured acidophil micromycetes.

Potato-carrote agar (PCA):

composition: see JESENSKÁ (1993); application: isolation and determination of dark coloured micromycetes.

Soil agar (SEA):

composition: see JESENSKÁ (1993); application: isolation and determination of dark coloured micromycetes. Notice: Streptomycin for bacteria growth reduction was added to all nutrient media.

RESULTS

The research was focused to operative investigation of function and tightness of tower containers adapted maize corn storage in protective atmosphere, CO₂ content during all storage time at simultaneous gradual unloading of maize. The loaded maize humidity was 30–35%, unit storage capacity of tower container 400 tons. The tower container was loaded up and sealed on 20. 10. 1998. During the rest of the year it was kept in rest. The maize unloading started in February 1999, when the average month discharge was about 60 tons up to the total discharging of the container on 25. 8. 1999. The course of CO₂ concentration change in dependence on storage time and maize kernel weight in container is presented in Table 1.

Table 1. CO₂ concentration change course in dependence on time and weight of maize stored in container

Month/year	CO ₂ content		Weight (t)
	at point A	at point B	
October 1998	78.9	58.9	400
November 1998	75.5	58.8	400
December 1998	72.0	58.6	400
January 1999	72.3	58.6	400
February 1999	71.9	58.2	350
March 1999	72.3	58.2	290
April 1999	71.8	58.2	230
May 1999	70.6	58.0	140
June 1999	70.5	58.0	110
July 1999	70.1	57.9	50
August 1999	69.8	57.2	–*

*unloading finished on 25. 8. 1999

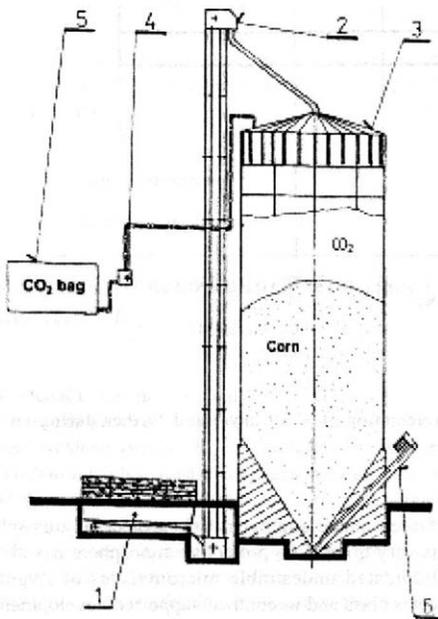


Fig. 1. Treatment and storage of wet maize in CO₂ protective atmosphere in sealed containers

1 – maize reception, 2 – bucket elevator, 3 – maize container, 4 – regulating valve CO₂, 5 – CO₂ bag, 6 – unloading auger conveyer

The measuring points (A, B) were chosen to characterize the CO₂ concentration course within all volume of the container. Thus point A was chosen in the conical part of the container, point B in upper part of the container mantle (i.e. in the level of maize loading height). The distance A–B was at wholly loaded container 16.5 m, by gradual unloading this distance has become shorter in such a way, in order to CO₂ concentration finding would always be during unloading about 1 m

above the stored maize layer. The presented CO₂ concentration figures are always given by average value of 3 measurements of each month.

The measured values have proved that maize can be stored successfully in the protective atmosphere within all the year. During investigation of maize storage in sealed container within 11 months the CO₂ concentration has decreased only by 1%. Concentration 69.8% of CO₂ on the end of storage period ensured sufficient protection of stored maize because its qualitative analysis for undesirable micro-organisms presence was satisfactory.

SPEED OF THE CO₂ PROTECTIVE ATMOSPHERE GENERATION AFTER CONTAINER LOADING AND SEALING

For investigation there was again used the same tower container which after discharging in August 1999 was cleaned, technological devices for maize loading and unloading were checked. In such way the container was prepared for maize storage of harvest 1999. The harvest was performed in the period of 14.–17. 10. 1999 by combine harvesters CLAAS Mega. The tower container was loaded and sealed on 18. 10. 1999 when started the measuring of the CO₂ protective atmosphere development. The measuring was carried out again at two points:

- Measuring point A at maize output from tower container close to the gas-proof flap of the discharging auger conveyer.
- Measuring point B in upper part of the container mantle (above surface of stored maize).

The time interval of measuring was 4 hours, measured values are presented in Figs. 2 and 3.

The measured results demonstrate that:

- Within perfectly harvested and stored maize occurs a rapid fermentation and development of CO₂.
- After 48 hours (2 days) the whole space of the tower container was filled by sufficient amount of CO₂.
- At the end of the 10th day of storage the CO₂ concentration was about 80% and within further storage the

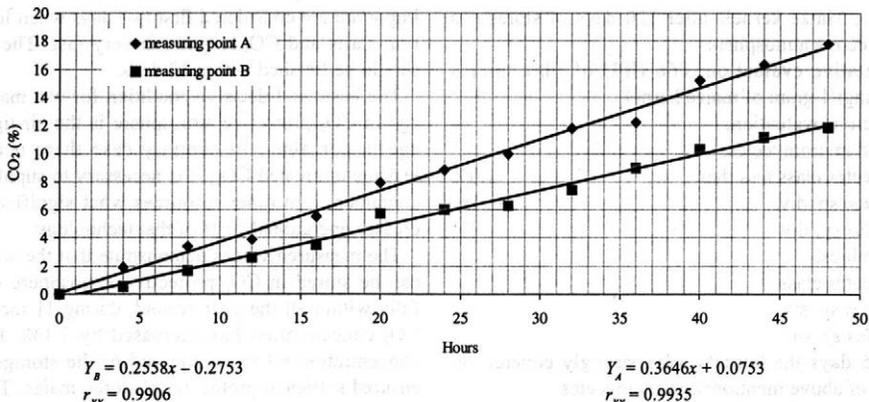


Fig. 2. Development of CO₂ protective atmosphere within first two days

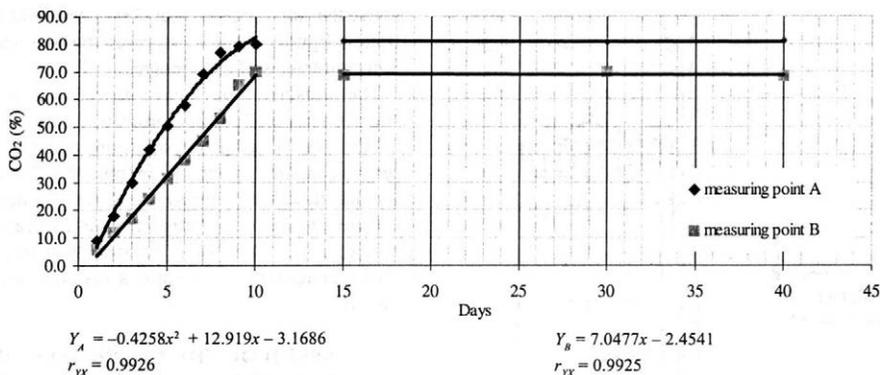


Fig. 3. Development of CO₂ protective atmosphere during fermentation (1 + 10 days) and further during storage (10 + 40 days)

concentration was almost constant. The fermentation process was in progress until the 10th day.

- It was not necessary to refill the CO₂ protective gas from bottles.

LABORATORY ANALYSIS OF MAIZE STORED IN SEALED CONTAINER – MYCOFLORA DETERMINATION

Sample: fresh maize kernels from harvest

Quantitative evaluation: 1,362 CFU (colony forming units) of fibre microscopic fungi/1 gram of fresh maize kernel (A: 1,314 CFU/1 gram, B: 1,409 CFU/1 gram).

Qualitative evaluation:

Isolated micromycetes:

Zygomycetes class	62.7%
Milk white mycelium – so far sterile, not determined	14.7%
<i>Cladosporium</i> (herbarum, cladosporides)	13.2%
<i>Penicillium</i> sp. div.	4.7%
<i>Alternaria</i> sp. div.	2.2%
<i>Epicoccum</i> + bright sterile mycelia not determined	2.5%

Sample: Maize kernels after 120 days of storage in CO₂ protective atmosphere

Quantitative evaluation: 866 CFU of fibre microscopic fungi/1 gram of maize kernel

Qualitative evaluation:

Isolated micromycetes:

Zygomycetes class less than	1.0%
<i>Penicillium</i> sp. div.	98.1%
<i>Aspergillus</i> sp. div.	1.3%
Wet chambers:	
Zygomycetes class	
<i>Penicillium</i> sp. div.	
<i>Aspergillus</i> sp. div.	

After 5 days the kernels were strongly covered by colonies of above mentioned micromycetes.

It was proved by samples evaluation after 120 days of storage that:

- Stored maize quality in CO₂ protective atmosphere is very good. CO₂ protective atmosphere has almost liquidated undesirable micromycetes of Zygomycetes class and in contrast supported development of *Penicillium* sp. div. Micromycetes.
- The unloaded maize should be processed in short time (e.g. milling, crushing e.t.c.) and immediately used in form of macrocomponents in feeding mixtures. The longer storage period supports development of undesirable microorganisms.
- It is possible and more suitable to store maize in CO₂ protective atmosphere of higher harvest humidity 30–35%. In contrary the lower humidity under 20% makes the fermentation process slower.

DISCUSSION

Evaluating the summary results, we can claim, that stored wet maize quality in sealed container in CO₂ protective atmosphere depends on fermentation course and speed of sufficient CO₂ amount. As most important are considered first two days when fermentation starts and CO₂ creation is very fast. The process should be finished within 10 days.

The basic and decisive condition for wet maize storage in CO₂ protective atmosphere is the air-tight storage in container. In contrary case there occurs the leakage of created CO₂, it is necessary to supply it into container from other resources what significantly increases operational costs of that technology.

The measured values demonstrate that the wet maize can be stored in CO₂ protective atmosphere successfully within all the year around, during 11 months the CO₂ concentration has decreased by 9.1%. The CO₂ concentration 69.8% at the end of the storage period ensured sufficient protection of stored maize. This conclusion resulted from laboratory kernel quality analysis related to the undesirable microorganisms.

JESENSKÁ Z., 1993. Micromycetes in foodstuffs and feed-stuffs. Institute of Preventive and Clinical Medicine, Bratislava, ČSFR.

Received 11 June 2001

Skladování vlhkého kukuřičného zrna v hermeticky uzavřených zásobnících v ochranné atmosféře CO₂

ABSTRAKT: Cílem výzkumu bylo ověření metody skladování vlhkého kukuřičného zrna v ochranné atmosféře CO₂ v hermeticky uzavřených zásobnících Vítkovice o jednotkové skladovací kapacitě 400 t. V práci jsou uvedeny výsledky měření rychlosti vývinu CO₂ po naskladnění a uzavření zásobníku a výsledky laboratorních rozborů kvality kukuřice při vyskladňování. Vlhkost naskladňované kukuřice byla 30–35 %. Zhodnotíme-li souhrnně získané výsledky, lze konstatovat, že kvalita uskladněného vlhkého zrna kukuřice v hermeticky uzavřeném zásobníku v ochranné atmosféře CO₂ závisí především na průběhu fermentace a rychlosti vytvoření dostatečného množství CO₂. Rozhodující jsou dva dny, kdy nástup fermentace a tvorba CO₂ musí být velmi rychlá. Proces musí být ukončen asi do 10 dnů. Z naměřených hodnot vyplývá, že za dobu 11 měsíců skladování se snížila koncentrace CO₂ o 9,1 %, tedy na 69,8 % CO₂. Tato koncentrace CO₂ zajišťovala ještě dostatečnou ochranu uskladněného kukuřičného zrna, což dokumentují laboratorní rozborů kvality zrna na přítomnost nežádoucích mikroorganismů.

Klíčová slova: hermeticky uzavřený věžový zásobník; oxid uhličitý; vyrovnávací vak; koncentrace CO₂; stanovení mykoflóry

Corresponding author:

Ing. PAVEL KROUPA, CSc., Výzkumný ústav zemědělské techniky, Drnovská 507, P. O. Box 54, 161 01 Praha 6-Ruzyně, Česká republika
tel.: + 420 2 33 02 23 01, fax: + 420 2 33 31 25 07, e-mail: vuzt@bohem-net.cz

Optimal drying of energetical wooden chips

P. HUTLA, V. SLADKÝ

Research Institute of Agricultural Engineering, Prague, Czech Republic

ABSTRACT: In the Czech Republic are built-up considerable volumes of large-capacity haylofts which are not exploited in consequence of the cattle number decrease. They can be used for post-drying and storage of bioenergetical raw material, e.g. energetical wooden chips. There were compared two methods of drying ventilators control in the large-capacity hayloft mutually with regime of time switching during chips drying. Both methods are derived from the values of input or output relative air humidity. The power consumption for ventilators drive practically does not depend on the method of their control but significantly decreases at a high humidity of input air as compared with time switching of ventilators, this occurring from the value of the input of relative air humidity of about 50%. The management method or time switching have no effect on the result of drying, i.e. moisture reduction in dried material. Under operative conditions there was investigated the possibility of energetical wooden chips drying in the large-capacity hayloft.

Keywords: drying; energetical chips; large-capacity hayloft; ventilator control

In the Czech Republic there is a certain part of unutilized capacity of the large haylofts. These storage capacities were built in the 70s and 80s and have storage volumes of 6,000–8,000 m³ of hay. Their number and total capacity were considered for the cattle number of the respective period. The haylofts construction is either steel with roof and aluminium or galvanized coating, or reinforced prefabricated facilities with wooden roof structure. Their standard technological equipment are floor grates with axial ventilators and a crane path with a fork grab crane.

Typical dimensions of these haylofts are: width 16–18 m, length is a multiple of the 6 m module, e.g. 66 m, clearance height about 10 m. The cattle number reduction within past 10 years resulted in lower utilization of that haylofts for hay post-drying and storage. In 1989 the total number of cattle was about 3.5 mil. but up to present days it was reduced to less than a half of that amount. The large haylofts capacities are therefore at present either unused, or are being used for other purposes. In addition, the hayloft is normally loaded during summer and then is gradually discharged within the year. Even when the hayloft is completely filled-up every year its average volume utilization for feeding materials is only 50% within the year.

As an alternative utilization there was considered the possibility of post-drying and storage of bio-energetical raw material, e.g. energetical wooden chips. An advantage of such solution is the use of current technology, i.e. grates, drying ventilators and cranes. This technology needs relative simple adaptation. The grates and crane grab have to be adapted to small dimensions of

the chips to avoid their sagging during manipulation and storage on the grates. The ventilator operation should be optimized to reach an effective drying at minimum power consumption.

Similar systems specially constructed for energetical drying of chips were published (OBERHUBER, SIMADER 1999).

The bio-energetical raw materials drying before their combustion is suitable or necessary due to energetical, economical or operational purposes (KÁRA et al. 1995). The suitable moisture content (w.b.) value of energetical chips is about 20–30%.

The drying processes controlling is in principle similar to forage drying. Basically this is a typical plant with decisive controlling process. The regulation systems of drying ventilators were developed in the past from a simple analogous models with activity derived from material (hay) temperature and input air relative air humidity measuring. Basically the function of these systems consists in principle in the activity of ventilators in the time when the input relative humidity of forage is lower than the balanced air humidity and forage moisture content, what is given by the known physical dependence (SLADKÝ et al. 1985). The more sophisticated systems are based on the micro-processor regulators with measuring of air humidity discharged from hay.

The problem of technical applications always was the insufficient accuracy and sensor reliability for relative air humidity scanning. As absolutely unuseable are recognized the air humidity meters and those based on the animal skin dilatation. The capacity sensors also are unsuitable for presented purposes because of their low

The study was supported by the National Agency for Agricultural Research through the Grant No. EP 7075 *Optimal Processes During the Energetical Crops Post-Drying*.

reliability and time instability and necessity of their regulator calibrating. In principle the convenient solution seems to be the psychro-meters utilization but only those of high operational reliability.

Very interesting way of controlling based only on the input air temperature measuring is described in PERTUŠEVIČIUS (1997a), based on the fact, that in dusty and dirty environment all current sensors of relative air humidity were unuseable. It was found out that in the given climatic region (Lithuania) in June, when air temperature is higher than 14.3°C, it is possible to use this controlling method for hay drying. The improved controlling method is based on the input and output air temperature measuring (PETRUŠEVIČIUS 1997b). The drying intensity is described according to these both temperatures difference under certain conditions.

The second method of the drying process consists in the input and output air humidity investigation (HUTLA et al. 1997). During the drying process when the dried material loses water, the absolute air humidity of output air must be higher than that of the input air. This condition expressed mathematically is

$$\varphi_i > \varphi_e + \Delta\varphi \quad (\%)$$

where: φ_e – relative humidity of input air,
 φ_i – relative humidity of output air,
 $\Delta\varphi$ – difference of relative air humidity.

Because φ_i value finding in the point of air output is difficult to implement the output air parameters are found out during ventilators reverse run after convenient time pause within scanning by an identical sensor as φ_e .

In practice has been shown, that sorption dependence of wooden chips allow even simple methods of drying processes controlling. For example from the sorption curves of poplar chips (ŠTENCL 2000) is evident that at a drying relative air humidity $\varphi_e = 65\%$ there is provided a drying process with requested value of water content in material. On this fact the proposal is based of the controlling method of hay drying by outdoor air (ŠTENCL et al. 1999). The interval controlling logical structure is based on ambient relative air humidity. If its value is lower than the in advance adjusted maximum allowed value corresponding with stored material balanced moisture, than the post-drying is always possible when the ventilator is switched-on. If the relative air humidity has reached a higher level than those adjusted in advance, the aeration process becomes the material temperature function. If the temperature is lower than the allowed one (usually in range 34–39°C) the ventilator is switched-off, if the temperature is higher the aeration is launched.

OBJECTIVES

This work is focused on the comparison of two controlling methods, i.e. mutual switching of the drying ventilators in the large-capacity hayloft with regime of time switching. The dried material are energetical chips from poplar plantation.

The purpose is to compare energy consumption of different controlling regime and effect on the drying process behaviour.

MATERIAL AND METHODS

For drying of energetical chips were chosen three methods of active ventilation system controlling compared from the point of view of drying properties and necessary energy. The dried material are fresh chips from energetical poplar plantation. Used was hybrid *Populus maximoviczii* × *Populus nigra*, clone numbers J-104 and J-105. The trees age was 4 years, trunk diameter to 12 cm. The chips particles size was to 8 cm, medium length 2.7 cm. Starting moisture (w.b.) was 49.9%.

The drying process was implemented in the large-capacity hayloft of Agrotel, joint stock company – farm Chrásťany, where one drying bay was reserved for experimental purposes. The ground plan dimensions of that bay are 18 × 6 m. The drying grate in this bay is divided into three particular sections. Each of the sections is self-supporting and bedded on four power sensors M 203, manufacturer Rukov – Rumburk. Scheme of the sensors placing is shown in Fig. 1. For the ground stabilization are used the steel rods of circle cross-section, 1 m long, connecting grate with the base. These rods are horizontally placed under the grate.

Each section of the drying grate is individually balanced and information about its weight is available continually. The peak moisture (w.b.) in measured material can be found out the peak by the formula:

$$w_e = \frac{m_v}{m_s + m_v} = 1 - \frac{m_s}{m_c - m_R}$$

where: m_s – dry matter weight in dried material (kg),
 m_v – water weight in material (kg),
 m_c – drying grate section and dried material weight (kg),
 m_R – drying grate section weight (kg).

Each section is ventilated by an axial ventilator charging the outdoor air into the undergrate space. The undergrate space is divided by two partitions to avoid

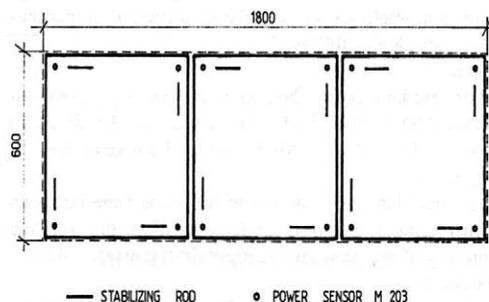


Fig. 1. Scheme of drying grate (ground plan) and its placing on power sensors

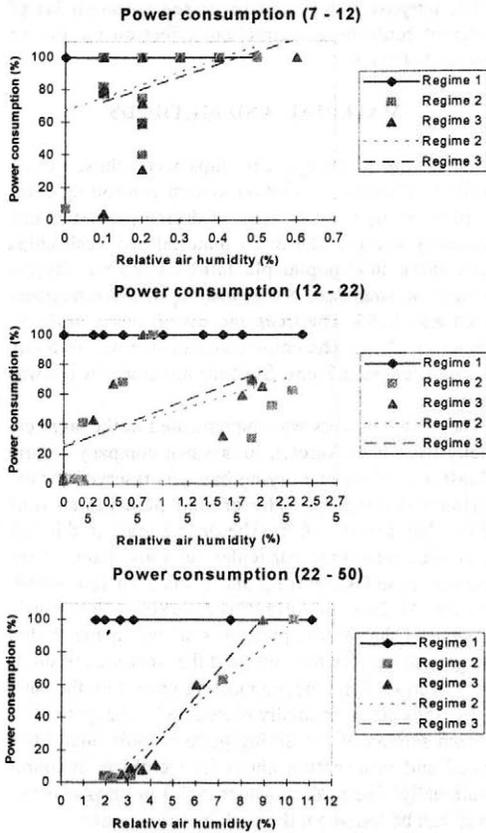


Fig. 2. Power consumption of drying ventilators drive in dependence upon drying relative air humidity during drying of fresh energetical chips

affection the charged air under each section by the air from adjacent sections. In two sections is installed sensor of relative air humidity in undergrate space. It is a psychrometric gauge developed by the Research Institute of Agricultural Engineering in Prague with converter of type 9206. The output is a current signal 0–20 mA. The controlling methods, i.e. ventilators switching in particular sections are as follows:

Regime 1:

The ventilator is switched on by the time switcher in intervals 8.00–9.30 o'clock; 10–12 o'clock; 12.30–14.30 o'clock; 15–17 o'clock (MET), totally 7.5 hours a day.

Regime 2:

The ventilator is switched in the same time intervals as in regime 1, but only under condition, that relative humidity of outdoor, air i.e. input drying air $\phi_e < 65\%$.

Regime 3:

The ventilator is switched on in the same time as regime 1 a 2, but only under condition, when relative humidity of air getting out from material is $\phi_i > \phi_e + 2\%$.

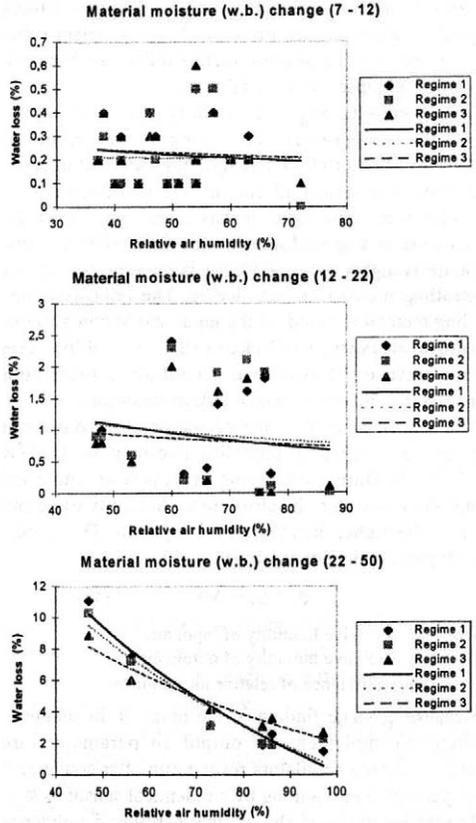


Fig. 3. Material moisture (w.b.) change in dried fresh energetical chips

The ventilator switching in regime 2 is technically provided by simple comparative regulator. Information on value ϕ_e is being acquired by psychrometric sensor in undergrate space. The ventilator switching in regime 3 is technically provided by microprocessor regulator MRS 12 of A.P.O. – Elmos company. Information on input and output relative air humidity is being acquired by psychrometric sensor in undergrate space. The ventilator is switched on in intervals of 0.5 hour and the ϕ_e value is found out. Then the ventilator is switched in reverse run and thus the undergrate space is filled by air passing through the dried material layer. The relative air humidity value acquired by the psychrometric sensor in undergrate space is substituting ϕ_e value (NEUBERGER, HUTLA 1996).

Within the drying time, i.e. from 8 to 17 o'clock of MET the relative air humidity was measured within ambient environment. From the measured values was computed an average value for morning (M) and afternoon (A) moisture.

Table 1. Drying of fresh energetical poplar chips according to particular regimes (1, 2, 3)

Date ³⁾	Φ_{emid} (%)	Moisture content (w.b.) of material ¹⁾ (%)			Moisture content of material change (%/d)			Power consumption for ventilator drive ²⁾ (%)		
		1	2	3	1	2	3	1	2	3
28. 8. M	73	49.9	49.9	49.9	3.2	3.1	4.2	100	4	11
28. 8. A	84	46.7	46.8	45.7	1.9	2.0	3.1	100	4	9
29. 8. M	97	44.8	44.8	42.6	1.5	2.3	2.7	100	3	5
29. 8. A	86	43.3	42.5	39.9	2.6	2.9	3.6	100	4	8
30. 8. M	56	40.7	39.6	36.3	7.5	7.2	6.0	100	63	60
30. 8. A	47	33.2	32.4	30.3	11.1	10.3	8.9	100	100	100
31. 8. M	68	22.1	22.1	21.4	1.4	1.9	1.6	100	30	32
31. 8. A	73	20.7	20.2	19.8	1.6	2.1	1.8	100	52	59
1. 9. M	60	19.1	18.1	18.0	2.4	2.3	2.0	100	62	65
1. 9. A	76	16.7	15.8	16.0	1.8	1.9	1.9	100	68	70
2. 9. M	77	14.9	13.9	14.1	0.3	0.1	0.0	100	4	2
2. 9. A	87	14.6	13.8	14.1	0.0	0.0	0.1	100	3	3
3. 9. M	75	14.6	13.8	14.0	0.0	0.0	0.0	100	4	4
3. 9. A	66	14.6	13.8	14.0	0.4	0.2	0.2	100	3	2
4. 9. M	62	14.2	13.6	13.8	0.3	0.2	0.3	100	41	43
4. 9. A	48	13.9	13.4	13.5	1.0	0.9	0.8	100	100	100
5. 9. M	53	12.9	12.5	12.7	0.6	0.6	0.5	100	68	67
5. 9. A	47	12.3	11.9	12.2	0.9	0.9	0.8	100	100	100
6. 9. M	72	11.4	11.0	11.4	0.0	0.0	0.1	100	7	4
6. 9. A	54	11.4	11.0	11.3	0.5	0.5	0.6	100	100	100
7. 9. M	63	10.9	10.5	10.7	0.3	0.2	0.2	100	40	31
7. 9. A	57	10.6	10.3	10.5	0.4	0.5	0.4	100	100	100
8. 9. M	60	10.2	9.8	10.1	0.2	0.2	0.2	100	60	59
8. 9. A	46	10.0	9.6	9.9	0.4	0.4	0.3	100	100	100
9. 9. M	54	9.6	9.2	9.6	0.2	0.2	0.2	100	75	72
9. 9. A	41	9.4	9.0	9.4	0.3	0.2	0.3	100	100	100
10. 9. M	47	9.1	8.8	9.1	0.3	0.2	0.3	100	100	100
10. 9. A	38	8.8	8.6	8.8	0.4	0.3	0.4	100	100	100
11. 9. M	54	8.4	8.3	8.4	0.1	0.1	0.1	100	82	79
11. 9. A	37	8.3	8.2	8.3	0.2	0.2	0.2	100	100	100
12. 9. M	49	8.1	8.0	8.1	0.1	0.1	0.1	100	78	78
12. 9. A	41	8.0	7.9	8.0	0.1	0.1	0.2	100	100	100
13. 9. M	51	7.9	7.8	7.8	0.1	0.0	0.1	100	80	81
13. 9. A	40	7.8	7.8	7.7	0.1	0.1	0.1	100	100	100
14. 9. M	44	7.7	7.7	7.6	0.1	0.1	0.1	100	100	100
14. 9. A	32	7.6	7.5	7.5	-	-	-	-	-	-

¹⁾Morning or afternoon before start of measuring²⁾Related to ventilator consumption in regime 1³⁾M (morning) 8–12 o'clock of MET

A (afternoon) 12.30–17.00 o'clock of MET

For every half-day the drying process determined moisture (w.b.) of dried material, moisture change of material and power energy amount consumed for ventilators drive and presented value of outdoor relative air humidity.

RESULTS AND DISCUSSION

The drying was performed from 27. 8. 1999 to 14. 9. 1999 simultaneously in the three sections of drying bay of the hayloft. In every section were used for drying

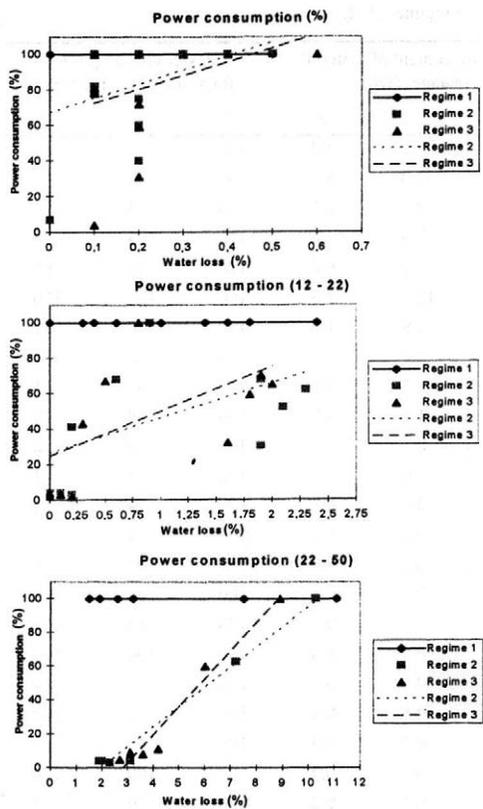


Fig. 4. Power consumption of drying ventilators drive in dependence upon water content change in dried energetical chip

two ventilators VE 630/2. Amount of stored fresh chips in one section is 3,780 kg, height of their layer is about 0.4 m.

The measuring results are presented in Table 1. In Figs. 2, 3 and 4 are presented some dependencies of the drying process in graphical form. The power consumption dependence in Fig. 2 was substituted by exponential function so for regimes 2 and 3 no values of full power consumption were included in the graphs design at low relative air humidity. The resulting graphs for regimes 2 and 3 are valid for values situated between point of intersection with the graph of regime 1 for increasing values of air humidity. The moisture change of material in Fig. 3 was approximated by logarithmic function and dependence in Fig. 4 by linear function. The graphical dependences in mentioned figures are divided into three parts according to moisture (w.b.) in dried material.

From dependence in Fig. 4 resulted that drying regimes 2 and 3, i.e. two methods of drying ventilator controlling do not vary in fact as concerns the effect on the power consumption. In contrast, very considerable

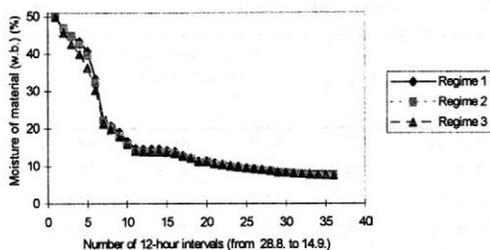


Fig. 5. Time dependence of fresh energetical chips drying course

result is evident against regime 1 when at the high relative humidity of outdoor air, characterized there by low loss of water the power is applied without any effect on the drying process. The similar conclusion can be derived from Fig. 2 where from a certain value ϕ_{esmid} , situated closely to the value of 50% a considerable reduction of power consumption occurs in regimes 2 and 3 which do not differ each from the other. From the graphs in Fig. 3 is evident, that the drying ventilator controlling method has not any effect on the drying result, i.e. on the moisture and its reduction in dried material.

From Table 1 was created a graph of time dependence of drying process presented in Fig. 5. There is again evident a very similar course of moisture reduction in dried material without dependence on the regime of drying ventilators controlling. But since 6. 9. there were very convenient meteorological terms for drying – the outdoor relative air humidity was significantly lower than 65%. The moisture (w.b.) of material was lower than 12% and the ventilators were switched on coincidentally, i.e. within the whole time of switching by time switcher.

CONCLUSION

Under operative terms there was verified the possibility of bioenergetical material drying, espec. chips from energetical poplars plantation in a large-capacity hayloft. For drying ventilators controlling is necessary to eliminate forced ventilator by too wet outdoor air which has a negative impact on the power consumption. The both chosen regimes of ventilator switching are derived from drying air parameters. The difference between both regimes in the effect on the power consumption has not been proved, but significant is a difference in comparison with non-controlled ventilation. The power consumption reduction in the controlling drying was evident during the period of late summer at average relative air humidity in the range above 50%.

During the experiments no effect of the ventilator controlling method including its time switching without dependence on the drying air parameters was proved on the drying intensity.

References

HUTLA P., NEUBERGER P., ADAMOVSÝ R., SLADKÝ V., 1997. Control of final stage of hay drying by cold air. *Scientia Agr. Bohemica*, 28: 171–185.

KÁRA J. et al., 1995. Využití dřevního odpadu k energetickým účelům. [Výzkumná zpráva.] Praha, VÚZT: 54.

NEUBERGER P., HUTLA P., 1996. Řízení provozů sušení sena. In: Možnosti využití energetických zdrojů v zemědělství. Praha – Č. B., TF ČZU – VÚZT: 56–64.

OBERHUBER B., SIMADER G., 1999. Solargetrocknete Hackschnitzel. *Erneubare Energie*, 5: 26–27.

PETRUŠEVIČIUS V., 1997a. Šieno dziovinimo aktyviaja ventilacija automatizavimo paieškos (Possibilities of hay drying automation by active ventilation). *Žemės ūkio inžinerija*, 29: 43–52.

PETRUŠEVIČIUS V., 1997b. The variants of drying automation of agricultural production by active ventilation. *Zemėd. Techn.*, 43: 129–136.

SLADKÝ V. et al., 1985. Manipulační a automatizační zařízení pro halové seníky. [Výzkumná zpráva.] Praha, VÚZT: 72.

ŠTENCL J., HOMOLA P., SLADKÝ V., 1999. Proposal of new method of control of the near ambient air drying process of forage in deep layer in real time. *Zemėd. Techn.*, 45: 37–40.

ŠTENCL J., 2000. Influence of temperature on moisture sorption isotherms of poplar chips under storing conditions. *Zemėd. Techn.*, 46: 67–71.

Received 11 June 2001

Optimalizace sušení energetické dřevní štěpky

ABSTRAKT: V České republice jsou vybudovány značné objemy velkokapacitních seníků, které se v důsledku poklesu stavů skotu nevyužívají. Je v nich možné dosoušet a skladovat bioenergetické suroviny, např. energetickou štěpku. Byly porovnávány dva způsoby řízení sušících ventilátorů ve velkokapacitním seníku navzájem s režimem časového spínání při sušení energetické dřevní štěpky. Oba způsoby řízení jsou odvozeny od hodnot relativní vlhkosti vstupního, příp. výstupního vzduchu. Spotřeba elektrické energie pro pohon ventilátorů prakticky nezávisí na způsobu jejich řízení, avšak výrazně se snižuje při vysoké vlhkosti vstupního vzduchu oproti časovému spínání, a to od hodnoty relativní vlhkosti vstupního vzduchu asi 50 %. Způsob řízení či časového spínání přitom nemá vliv na výsledek sušení, tedy na snižování obsahu vody v sušeném materiálu. V provozních podmínkách byla ověřena možnost sušení energetické dřevní štěpky ve velkokapacitním seníku.

Klíčová slova: sušení; energetická štěpka; velkokapacitní seník; řízení ventilátorů

Corresponding author:

Ing. Petr HUTLA, CSc., Výzkumný ústav zemědělské techniky, Drnovská 507, P. O. Box 54, 161 01 Praha 6-Ruzyně, Česká republika
tel.: + 420 2 33 02 22 38, fax: + 420 2 33 31 25 07, e-mail: vuzt@bohem-net.cz

Operation and emission parameters of tractor engine at rape oil ethyl esters application as alternative fuel

J. BOUČEK¹, J. KÁRA²

¹*Czech Agricultural University, Technical Faculty, Prague, Czech Republic*

²*Research Institute of Agricultural Engineering, Prague, Czech Republic*

ABSTRACT: The study describes results of smokiness and emission measurement of Zetor 7701 unadjusted compression ignition engine operating on alternative fuel (ethyl ester of rape oil – REE) and diesel oil. As following from comparison of emission and smokiness (according to EHK 41 and EHK 21 standards), the impact of rape oil ethyl ester is favourable by decreasing smokiness and the whole harmful components (COM, NO_M, HCM, CM). Resulting assessment of the 13-points tests by weighted average of emission parameters has already shown surprising effects of REE additives into diesel oil in 5% concentration, when decreasing the whole noxious substances in 4–10% range. The most favourable effect was reached for 100% pure REE with 50% decreasing carbon monoxide emission (COM). Positive results of experimental blends of NM + REE and pure REE from the point of view of harmful components of tractor engine emission show that its application in practice is possible. The most favourable effect was reached for 100% pure REE with 50% decreasing carbon monoxide emission (COM). Positive results of experimental blends of NM + REE and pure REE from the point of view of harmful components of tractor engine emission show that its application in practice is possible. It is, first of all, necessary to manage high-quality REE production (sample used from experimental production did not have good quality) and to guarantee an economic rentability of REE production.

Keywords: tractor engine; rape oil ethylester

One of possibilities of fermented ethanol (bioethanol) use for motor fuel production is ethanol processing on rape oil ethyl ester (REE). REE is not produced in high quantity anywhere in the world in spite of known operation principle alike to rape oil methyl ester (RME) production. The main reason is the bioethanol price which is higher than the price of methanol produced from crude oil. Use of ethyl-tert-butyl-ether (ETBE) for REE production is more realistic after formation of subsidy for bioethanol use on ETBE production where it substitutes methanol in process of production. We assume that the utility properties of REE will be very similar to RME, a fully renewable motor fuel from biomass.

METHODICS OF MEASUREMENT

Z-7701 tractor usual engine testing was chosen for the estimation of impact of REE possible application in agriculture. The testing method was the thirteen-point test according EHK 49R (see ČSN EN ISO 8178-4). This method, as distinct from homologation eight-point one for tractor engines, was preferred from these reasons:

a) it is possible to compare tractor engines with car motors with aid of the thirteen-point test,

b) it does not concern homologation the test of tractor engine,

c) in practice, share of tractors use in agriculture transport is growing, that is why thirteen-point test is more suitable for this character of loading.

At this test, engine parameters are measured at five different loadings with rise at middle engine revolutions and five loadings with descent at rated speeds, meanwhile three times at idling revolutions (see diagram).

After REE testing, four tests were chosen as a fuel alternating with diesel oil with the following composition of used fuel:

Table 1. Fuel composition for thirteen-point test

Test number	Fuel composition	
	usual NM	REE
1	100	0
2	95	5
3	70	30
4	0	100

Approximately usual diesel oil according to ČSN EN 590 served as a basis for comparison in the first case.

This report was performed on the base of implementation of the National Agency for Agricultural Research project of Grant No. EP 096 099 65 04 *Production and Use of Ethanol from Agricultural Crops – Utilization, Economy, Legislation.*

In the following two cases, there is formulation of REE with the same diesel oil which composition easily simulates analogous blended fuels on RME bases according to standardization of fuel in accordance with the Standard ČSN 65 6509 (5% RME) or Standard ČSN 65 6508 (30% RME). The fourth tested fuel is separate REE which is taking a leap in the dark at engines testing.

Equipment of engine testing laboratory at the Department of Cars and Tractors, Czech University of Agriculture, Technical Faculty in Prague was employed during measurement.

DESCRIPTION OF LABORATORY EQUIPMENT – MEASUREMENT TECHNIQUE

ENGINE PARAMETERS MEASUREMENT

Output brakes:

VD-110 whirling electric dynamometer with 0–6,000 l per min running speed range;

100 W engine output; torque ranges: 0–200, 200–400, 400–600 Nm.

Manufacturer: MEZ Brno, TRANSPORTA Úpice.

V-250 whirling electric dynamometer with 956 N.m ranges at $n = 2,500$ l/min resp. 299 N.m at $n = 8,000$ l per min. Numeral output of torque values.

Manufacturer: MEZ Brno, METRA Blansko.

Coupling of dynamometer with engine:

PERIFLEX with 1,050 N.m max. lasting torque.

Speedometers:

TESLA BM 445 universal counter with 60-claws reader of revolutions on dynamometer shaft.

Manufacturer: TESLA Brno.

Measurement of fuel supply:

automatic mass fuel gauges with possibility to switch over the 0–50 g and 0–100 g ranges.

Manufacturer: Technical Faculty Czech University of Agriculture in Prague.

Measurement of temperatures:

resistance platinized thermometers and diode devices were used for temperature measurement.

Table 2. Results of REE analysis (ethyl ester of rape oil)

Measured value:	Units:	Values:
Density at 15°C	kg/m ³	879.3
Viscosity at 40°C	mm ² /s	5.074 cSt
Attention! Change of temperature at measurement of viscosity and density according to EN590!!		
Fuel properties	Distillation curve	
Beginning of distillation	°C	90 (!)
5% point	°C	328
10% point	°C	343
50%	°C	349
95%	°C	364
Aniline point	°C	72
Diesel index		59.6
Cetane index (ISO 3310)		62.4
Saponification number (mg of KOH/g)		188.0121
Ester number		179.6331
REE (purity %)		94.928%
Acid number (mg KOH/g)		8.379 (!)
CCR _{100%} (% mass)		0.065
Impurity content (ppm)		38
Water <small>according to Carl Fischer</small> (ppm)		579
Peroxide number, <small>meg/kg according to ISO 3960</small>		28.673
Cool properties:		
C.F.P.P. (loss filter)	°C	-3
Freezing point	°C	-12
Sulphur content according Kréckelera		0.02987%
Flash point according to P.M.	°C	71

Color and appearance: brown-bronze color, clear appearance, unbound or emulsified water free, visible impurity free.

Commentary: Sample of this ethyl ester presents relatively contaminated ester, that is ethanol and glycerine because of REE purity % being relatively lower which would be suitable from the point of view of fuels! Hydrolysis caused by higher water content and VMK (free fatty acids) formation increased acidity to value which could result in high corrosion! Peroxide number suggests small antioxidant resistance!

Conclusion: experimental batch of REE does not correspond to the standard, but it could serve to research purposes!

Table 3. Results of elemental analysis of diesel oil and REE

Fuel type	Element contents in fuel, %mas.			
	carbon	hydrogen	sulphur	oxygen
Diesel oil	86.266	13.690	0.0439	0.000
EEEO	77.475	12.125	0.0378	10.362

Thermoelectric thermometer was used in measurement of exhaust gases temperature.

Manufacturer: ÚVMV Prague, Technical Faculty Czech University of Agriculture in Prague, ZPA Nová Paka.

Measurement of pressure:

U-tube with water filling Kavalier Sázava.

Measurement of test conditions:

hair hydrometer 0–100%; manufacturer: METRA Blansko;

recorder of micropressure; manufacturer: METRA Blansko.

Measurement of exhalation:

– engine smokiness:

HARTRIDGE MK 3 opacimeter; manufacturer:

Leslie Hartridge, Coventry, GB;

– gaseous emissions of CO₂, CO, HC, O₂:

NDIR INFRALYT 4,000 four-components analyzer range of measurement:

CO 0–10% vol.

CO₂ 0–20% vol.

HC 0–5,000 ppm vol.

O₂ 0–21% vol.; manufacturer: JUNKALOR

DESSAU, BRD;

– CO control:

EEA, III C NDIR model; manufacturer: Hunstville

Electronic, Chrysler;

– NO_x emission:

URAS 2t, NDIR gas analyzer

0–5,000 ppm range; manufacturer: Hartmann & Braun AG.

All above-mentioned instruments with the exception of URAS analyzer are in accordance with appropriate EHK regulations.

ADJUSTMENT OF FUEL SYSTEM PARAMETERS

Test rooms: NC 104, NC 108, NC 50 1261 Uh; manufacturer: MOTORPAL Jihlava.

Engine

ZETOR Z-7701 Serial No.: 0101-2 25 5 88

Bore: D = 102 mm, number of cylinders i = 4

Lifting: Z = 120 mm, lift volume of engine V_M = 3.922 dm³

Fuel system

Fuel injection pump: PP 4 M 3137 S 0164

Speed controller: RV M 900 1100 3300

Jet injectors: DOP 160 S 430-1436

RESULTS OF MEASUREMENTS

Results of measurements include both analysis of fuels and results proper of engine tests with chosen fuels.

Table 4. Theoretical heat value of fuels and their blends used in measurement

Test number	Fuel	Heat value	
	composition	(MJ/kg)	(%)
1	100% NM + 0% EE	43.360	100.00
2	95% NM + 5% EE	43.074	99.34
3	70% NM + 30% EE	41.643	96.04
4	0% NM + 100% EE	37.638	86.80

Detailed fuel analysis of REE sample was treated first of all. It was the sample from semi-operating experiment delivered by manufacturer RPN Ltd, Chrudim.

REE analysis as motor fuel is given in the Table 2. Elemental analysis of both basis fuels, REE and diesel oil, is presented in Table 3.

Fuel analysis were done by J. Kovář, Ph.D from the Department of Chemistry, Czech University of Agriculture, Faculty of Agronomy in Prague.

Fuel analyses

On the basis of elemental analysis from found mass shares of individual elements, it is possible to determine theoretical heating values of fuels and their blends for formulations used at measurement (Table 4).

REE as a fuel is an absolutely new untested system, there are no corresponding fuel standards. If we proceed from the chemical and technological relations of REE and RME, we could use, for a start, values standardized for RME in ČSN 65 6507–1994 including 1-1998 amendment as operating standard. In Table 5 are given selected parameters to be emphasized.

It is necessary to say that the 1-1998 amendment leaves out some required parameters of RME to the detriment of the cause and users. These parameters are typical (main points of distillation curve) or very important for engine operation, especially such as the content of methyl alcohol residues.

Table 5. Selected parameters of RME

Density at 15°C	870–890 kg/m ³
Kinetic viscosity 40°C	3.5–5.0 mm ² /s
Ability of filtration (CFPP)	max –5°C
Flash point (PM)	min 110°C
Sulphur	max 0.02% mas.
Water	max 500 mg/kg
Mechanical impurity	max 24 mg/kg
Conradson residua of carbon	max 0.05% mas.
Acid number	max 0.5 mg KOH/g
Total content of glycerol	max 0.24% mas.
Content of alcohol (inf.)	0.30% mas.
Heat value (inf.)	37.1 MJ/kg
Distillation (inf.) – 5% point	300°C
– 95% point	360°C

If we compare the analyzed REE sample with standard values for RME, we can distinguish three groups of parameters:

a) *physical and chemical parameter characteristics of REE:*

- density – in the middle of range
- kinetic viscosity – at the top limit
- filtration ability – a little worse (about 2°C)
- sulphur content – about half worse, but small
- heating value – a little better
- distillation curve – higher by 5% point

b) *parameters characterizing purity of product and technological discipline in production:*

- flash point – significantly lower
- water content – exceeded
- mechanical impurity content – exceeded about half
- acid number – exceeded about 17-times

c) *parameters unmentioned in the standard for RME which significantly complete a point (b):*

- distillation beginning – unusually low
- REE purity – (share of esters) – gives total share of impurity and additives over 5% (!!)

On the base of parameters in (a) point we can note that REE as a new product is very close to RME with its basic physical and chemical properties. RME is usually produced in the Czech Republic, its properties have been standardized for 6 years. Shift of REE distillation curve as opposite RME in direction to higher temperatures is significant from the point of view of fuel, and so REE is more difficult for distillation.

The parameters assessment under (a) (b, c) points is unfortunately such that it does not point out the perfection bringing production technology and final product purity. It can be understood in the case of REE sample produced experimentally. Detailed analyses on alcohol and glycerol contents were not carried out in the delivered sample of REE, but the other parameters showed that both parameters were several times exceeded (unusually low flash point and beginning of distillation, as well as total impurity share over 5%). Both these components significantly affect the composition of noxious emissions as well as they are undesirable for engine operation – alcohols dilute diesel oil, glycerol, on the contrary, concentrates it and both these additives unnecessarily accelerate the degradation of diesel oil.

Fuel testing results in engines laboratory of the Department of Cars are clearly treated in tables and diagrams. The studied values have generally a logical and continuous course in relation the engine load.

ENGINE OUTPUT AND OPERATION PARAMETERS

We can follow a course of engine useful output as a loading function i.e. reduced torque. Both values are presented (with *R* index) as reduced ones, i.e. calculated for standard atmospheric conditions. The dependence is presented for mean and rated revolutions.

Table 6. Maximum value of reduced engine torque determined in mean revolutions

Test number	MTR max		PER max	
	(N/m)	(%)	(kW)	(%)
1	274.2	100.00	53.2	100.00
2	274.1	99.96	52.7	99.06
3	274.0	99.93	52.4	98.50
4	266.7	97.26	49.6	93.23

Table 7. Engine operation parameters, minimum specific fuel consumption at rated revolutions and exhaust gases maximum temperature

Test number	MPER rated min		Tv max	
	(g/kWh)	(%)	(°C)	(%)
1	244.1	100.00	660	100.00
2	247.3	101.31	650	98.48
3	257.1	105.33	600	90.91
4	273.3	111.96	600	90.91

There is a maximum value of reduced engine useful output, which was expressed in mean revolutions as well as in the rated ones in Table 6.

Other important operation parameters of engine are presented in Table 7, e.g. the minimum specific consumption of engine at rated revolutions and maximum temperature of exhaust gases.

It is possible to do the following conclusion for a growing REE share in the fuel:

- maximum torque and maximum engine output decrease, the even it negligibly, at the beginning; there is a significant decrease at 100% of REE (MTR – 3%, PER – 7%) however
- at rated output, specific fuel consumption increases according to fuel heat value drop (see Table 9)
- exhaust gases maximum temperature falls together which is favourable.

Results have suggested that the addition of REE (5% or 30%) can hardly be recognized at the maximum torque and engine maximum output by a common user (to 1.5%), it is better at 30% (+ 5%).

ENGINE EMISSION PARAMETERS

Engine smokiness is a property of incomplete combustion for compression ignition engine, which is noticeable with the naked eye at higher values. Maximum values determined at measurement are presented in Table 8.

It turns out that the maximum smokiness increases a little with the REE share growth in fuel at mean revolutions, it is decreasing at rated revolutions at not too high total level of smokiness. It has to be considered carefully that not only the maximum value is important

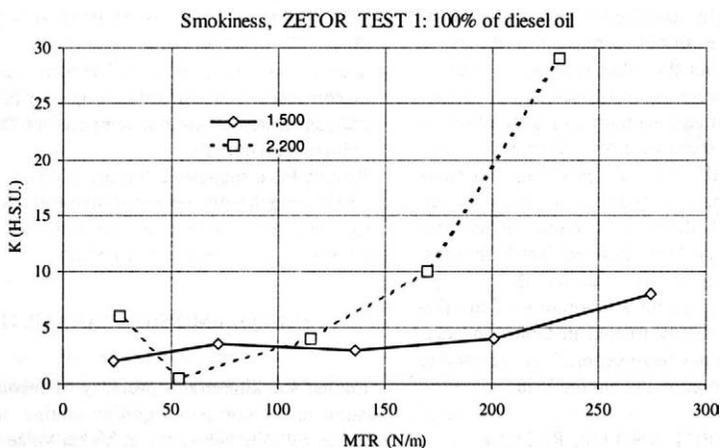
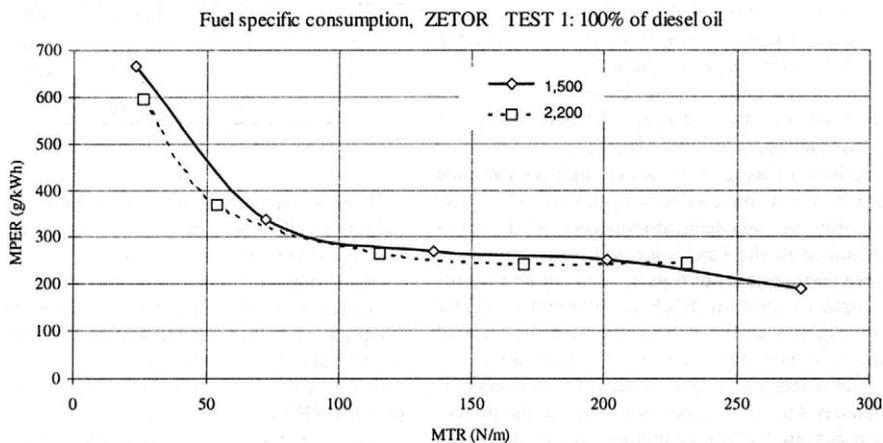
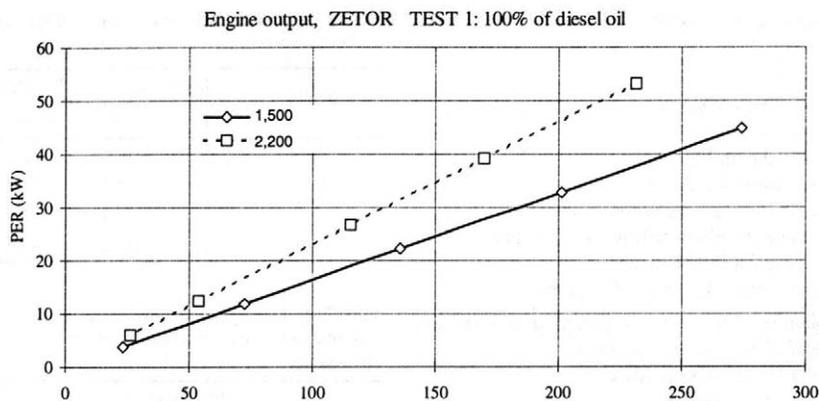


Fig. 1. Parameters of output and smokiness of Zetor engine at diesel oil drive

only but that the whole course of loading dependence is equally important.

It can be assessed with weighted average of all measured points which is the basic advantage of the 13-points test.

Three significant components are tested in emissions: CO, CM_x, No_x and C, which are calculated from the relative share on mass (g) and related to engine work unit (kWh). The mass expression is indicated by M index.

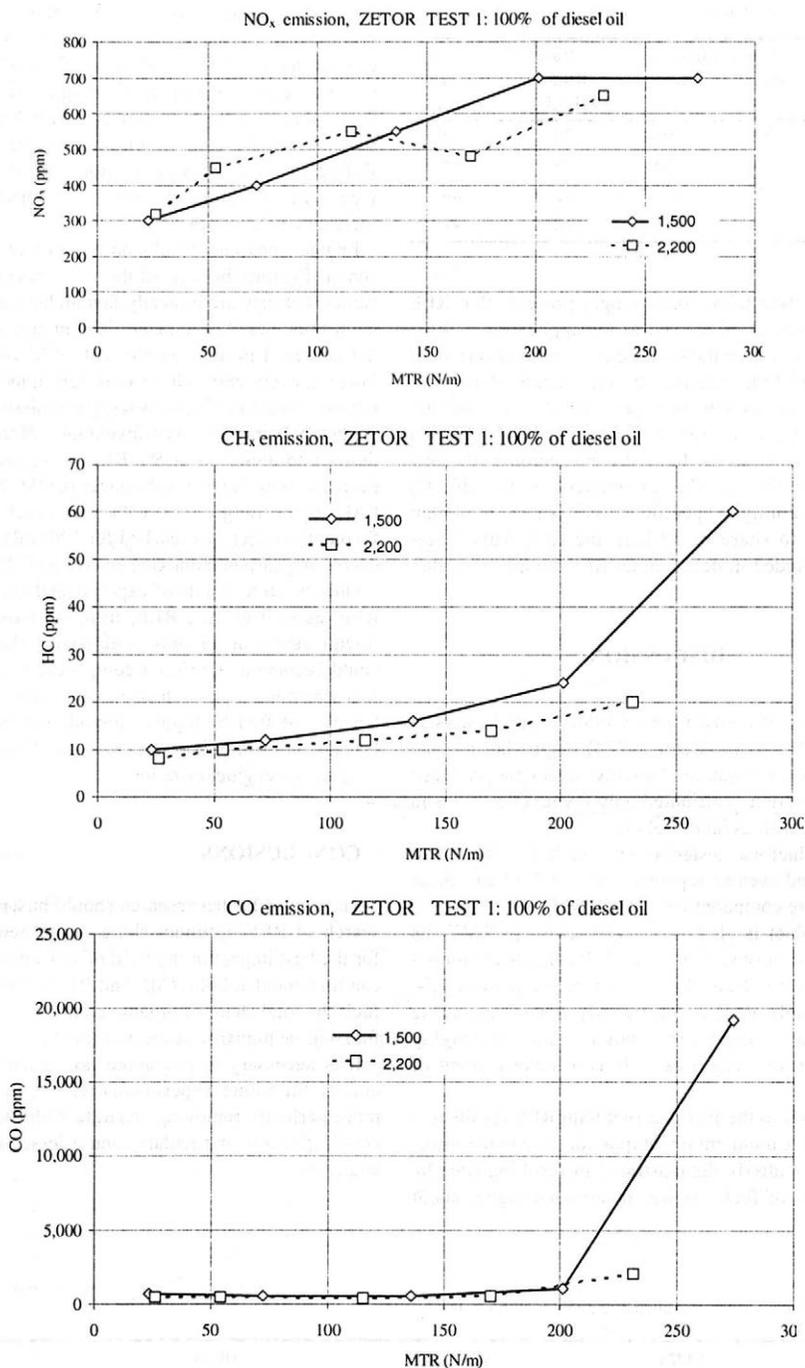


Fig. 2. Zetor engine emission parameters at diesel oil drive

Laboratory of the Department is not equipped by devices for the direct determination of solid particle masses. Corresponding values are therefore determined on the base of the smokiness quantification. Other

emission values are measured directly. Following emission values were calculated from the individual test records, they present weighted average for 13-point test (Table 9).

Table 8. Maximum values of smokiness

Test number	Mean revolutions		Rated revolutions	
	Kmax (H.S.U)	Kmax (%)	Kmax (H.S.U)	Kmax (%)
1	8	100	29	100
2	10	125	19	66
3	17	213	25	86
4	12	150	12	41

This resulting table convincingly presents that REE addition to diesel oil as well as the application of REE fuel proper decrease the specific engine emissions in all cases for all four determined components of harmful substances, no component is growing after its addition. The possibility of decreasing CO emission to less than 50% is presented as the highest contribution of the new fuel. The results of other components (NO_x, HC, C) suggest possibility of specific emissions local minimum in relation to share of REE in the fuel. This factor should be studied in detail on an REE sample of higher quality.

DISCUSSION

The testing of a totally new product – ethyl esters of rape oil – REE – in a Zetor Z-7701 engine has in spite of unsuccessful “common” quality of sample produced in semi-operation contributed only favourable results in comparison with usual diesel oil.

REE product was tested as 5% and 30% additions of diesel oil and even as separate fuel – 100% REE: these variants were compared with 100% NM.

REE product is chemically very close to RME, its production is very similar as well. Its chemical composition is obvious from the elementary sample analysis, it gives (likely RME) significantly lower heat value (approximately about 13%) which relates to roughly 10% content of oxygen as well as a lower content of carbon.

With regard to the fact that fuel with REE results in a bit lower maximum engine output and torque the lower heat value is utterly demonstrated in resulting specific consumption of fuel – it was determined higher about 12% RME.

The REE product has some properties like RME consequently it is possible to apply similar quantitative criteria as for RME – according to ČSN 65 6507 which will be gently treated. REE in spite of RME is less favourable because of higher viscosity, lower ability of filtration (under cold conditions), distillation curve is shifted to wards heavier fractions. From this point of view, REE is destined for partial compound of mixed fuels rather than as pure fuel.

Engine smokiness results do not look at first step like convincing ones because of the wider range of measured values, but they are basically favourable for REE. Maximum smokiness (29%) determined in pure diesel oil was not achieved in any sample with REE content, it was lower in every case. This fact is very important. Resulting assessment of 13-points tests by emission parameters weighted average showed favourable effect of REE addition into diesel oil at 5% REE concentration already, decrease of all harmful substances (COM, NO_xM, HCM, CM) in the range of 4–10% was reached. The best favourable effect was reached for 100% REE fuel : 50% decreasing carbon monoxide emission (COM).

Only positive results of experimental blends of NM + REE, as well as pure REE, from the point of view of tractor emission noxious components show that REE could become a significant component of engine mixed fuel which has a good chance to be ecologically friendly because of fuel biological degradation in the case of leakage into soil or harmful emission forming at internal combustion engine operation.

CONCLUSIONS

The aim of further research should be a more detailed search of REE optimum share in the new mixed fuel for the best impact in the field of noxious emission. We can imagine that both RME and REE will be in the new fuel; the total share of organic compounds in the mixed fuel will be higher in respect of this fact.

It is necessary to guarantee raw materials of better quality for future experiments with REE (and RME), more perfectly removing separate additives (water, alcohol, glycerol) particularly and a lesser share of total additives.

Table 9. Emission values, weighed average for 13-point test

Test number	COM		NO _x M		HCM		CM	
	(g/kWh)	(%)	(g/kWh)	(%)	(g/kWh)	(%)	(g/kWh)	(%)
1	44.547	100	6.374	100	0.100	100	0.219	100
2	42.782	96.0	6.083	95.4	0.090	90	0.202	92.2
3	35.016	78.6	6.275	98.4	0.095	95	0.197	89.9
4	21.943	49.3	5.860	91.9	0.087	87	0.207	94.5

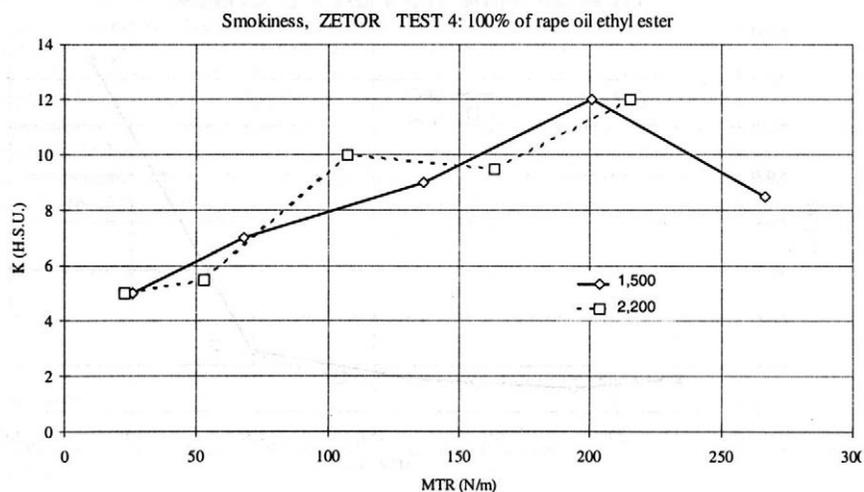
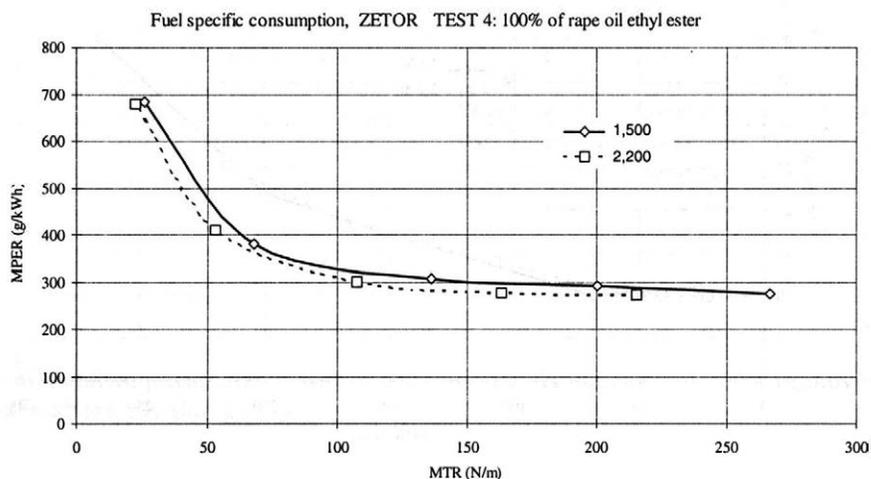
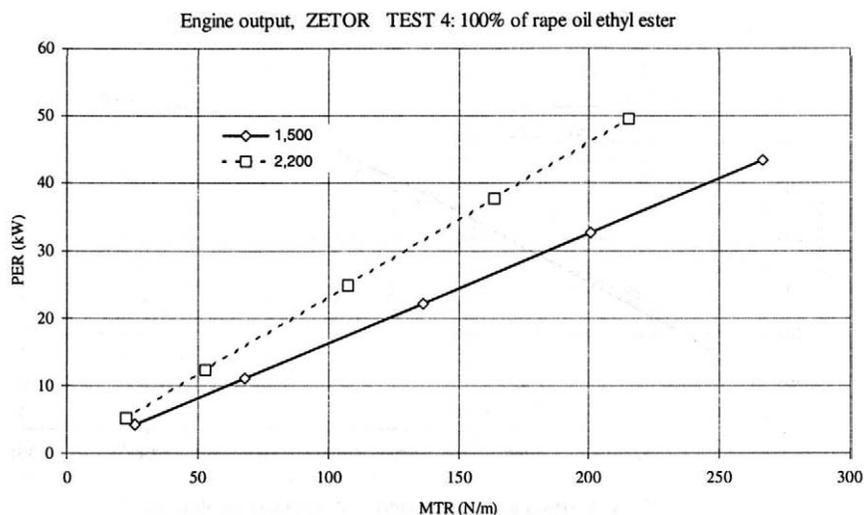


Fig. 3. Parameters of output and smokiness of Zetor engine at rape oil ethyl ester

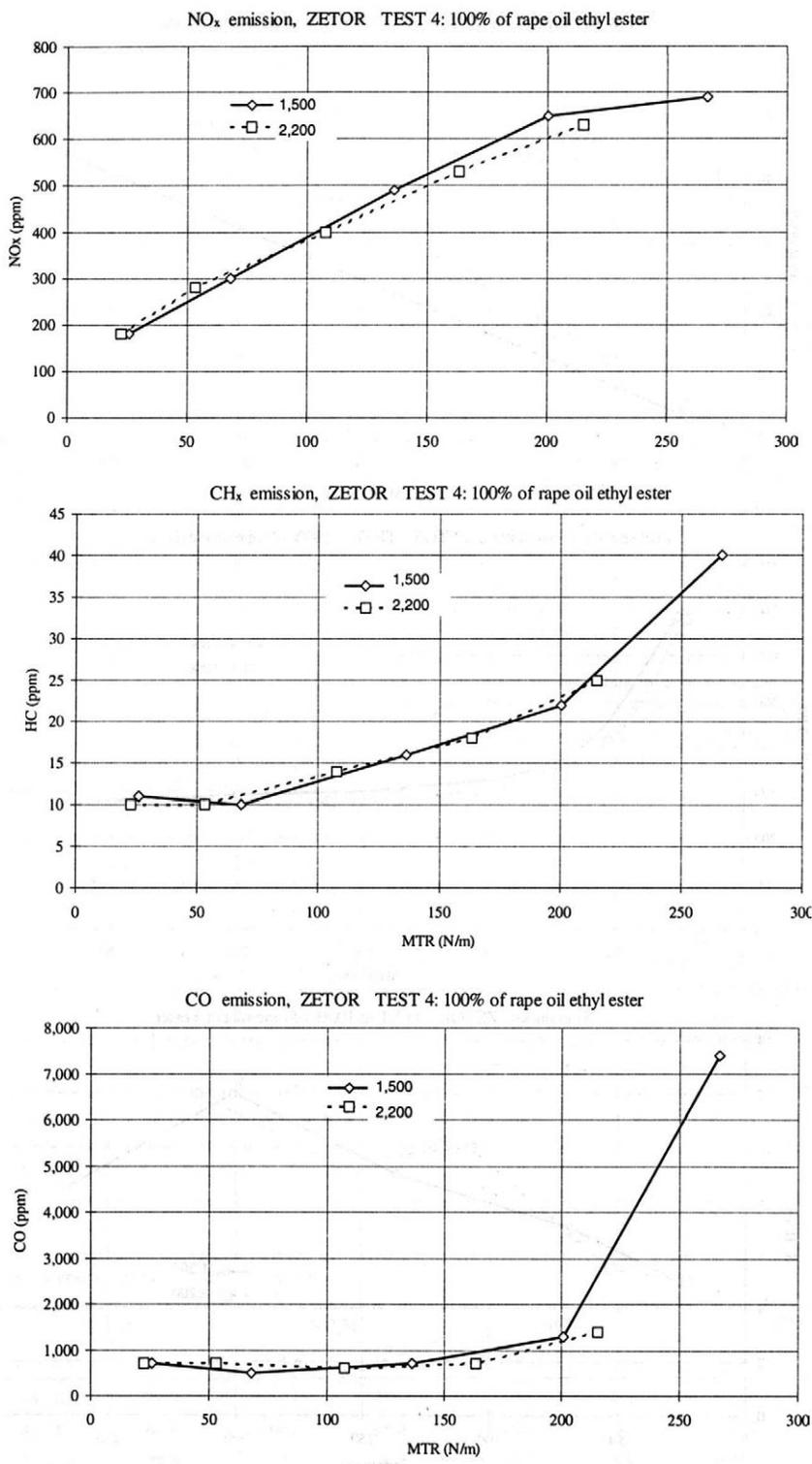


Fig. 4. Parameters of Zetor engine emission parameters at rape oil ethyl ester

LIST OF MEASURED AND CALCULATED VALUES

MEASURED VALUES PRESENTED IN TABLES			CALCULATED VALUES PRESENTED IN TABLES AND DIAGRAMS		
Symbol	Dimension	Application	Symbol	Dimension	Application
N	l/min	engine revolutions	PE	Kw	effective engine output
MT	N.m	engine torque	MP	kg/h	fuel mass consumption per hour
T	s	time of 100 g fuel consumption	MPE	g/kWh	mass specific consumption of fuel
TW	°C	cooling liquid temperature	DP	g/cycle	mass supply of fuel
TO	°C	temperature of lubrication oil in engine	DPV	mm ³ /cycle	fuel flow
BA	hPa	barometric pressure	MD	kg/h	mass real supply of air
FI	%	relative air humidity	KOEF	–	counting coefficient on descending reduction values according to ISO 2288
TA	°C	temperature of intake air	MTR	N.m	reduced torque
TV	°C	temperature of exhaust gases	PER	kW	reduced effective output
TP	°C	fuel temperature in fuel injection pump	MPER	g/kWh	reduced specific consumption of fuel
PD	mm H ₂ O	static pressure of boundary layer in veneer	DR	mm ³ /cycle	reduced flow of fuel
PS	mm H ₂ O	air pressure in suction piping	MDR	kg/h	reduced absorption capacity (actual supply of air into engine)
K	H.S.U	engine smokiness	COM	g/kWH	specific concentration CO (EHK 49R)
CO	ppm	CO concentration in exhaust gases	NOXM	g/kWH	specific concentration NO _x (EHK 49R)
CO ₂	%	CO ₂ concentration in exhaust gases	HCM	g/kWH	specific concentration HC (EHK 49R)
HC(Ch.)	ppm	HC concentration in exhaust gases	CM	g/kWH	solid particles specific concentration
O ₂	%	O ₂ concentration in exhaust gases	KV	mm ² /s	kinematic viscosity of fuel
NO _x	ppm	NO _x in exhaust gases	h	g/cm ³	fuel density

Received 11 June 2001

Provozní a emisní parametry traktorového motoru při použití etylesterů řepkového oleje jako alternativního paliva

ABSTRAKT: Práce popisuje výsledky měření kouřivosti a emisí neupraveného vznětového motoru Zetor 7701, provozovaného na alternativní palivo (etylester řepkového oleje – EEŘO) a motorovou naftu. Z porovnání emisí a kouřivosti (podle předpisů EHK 41 a EHK 21) vyplývá, že etylester řepkového oleje má příznivý vliv na snížení kouřivosti a všech složek škodlivin (COM, NO_xM, HCM, CM). Výsledné vyhodnocení třináctibodových testů váženým průměrem emisních parametrů ukázalo překvapivě vliv přídavku EEŘO do motorové nafty už v koncentraci 5 %, kdy se dosáhlo snížení všech složek škodlivin v rozmezí 4–10 %. Největšího příznivého účinku bylo dosaženo u čistého 100% EEŘO, a sice 50% snížení emise oxidu uhelnatého (COM). Kladné výsledky pokusných směsí NM + EEŘO a čistého EEŘO z hlediska škodlivých složek emisí traktorového motoru ukazují, že je jeho praktické využití možné. Nejdříve je nutné technologicky zvládnout výrobu kvalitního EEŘO (použitý vzorek z pokusné výroby neměl dobrou kvalitu) a zajistit ekonomickou rentabilitu výroby EEŘO.

Klíčová slova: traktorový motor; etylester řepkového oleje

Corresponding author:

Ing. JAROSLAV KÁRA, CSc., Výzkumný ústav zemědělské techniky, Drnovská 507, P. O. Box 54, 161 01 Praha 6-Ruzyně, Česká republika
tel.: + 420 2 33 02 22 74, fax: + 420 2 33 31 25 07, e-mail: vuzt@bohem-net.cz

Technological progress in cattle rearing in the Czech Republic after 1989 from the point of view of the accession to EU

J. VEGRIGHT¹, Z. PASTOREK¹, I. ACKERMANN², R. SCHLAUDERER²

¹Research Institute of Agricultural Engineering, Prague, Czech Republic

²Institute of Agricultural Engineering, Bornim, Germany

ABSTRACT: Considerable changes have occurred in the field of input price development in agriculture (machinery and devices, energy, fertilisers, building material...) and at product prices paid to farmers. While the input prices followed the inflation development and so increased by more than 250% in comparison with 1989, the agricultural product prices have increased only by 70%. Cost for labour also rose by about 250% in comparison to 1989 (average month wage in agriculture was in 1989 – 3,455 CZK and in 1998 – 9,143 CZK). The agriculture development was considerably affected by inflation, which increased by 270% within the observed period. Despite this fact only a slight change of the exchange rate of Czech crown occurred against important world currencies. This resulted in a higher availability of high quality foreign agricultural machinery. The labour productivity of cattle rearing was significantly increased as an effect of the changed economic conditions through introduction of modern working processes, housing systems, increase of milk yield, reduction of production unit costs of the final product and production quality increase of the enterprises. Ineffective management and ineffective rearing disappeared. It followed a considerable decrease of the number of milk cows from 1,247,000 in 1989 to 640,000 in 1999 (–49%). In the same period the annual average milk yield increased by 26% and in 1999 it exceeded the limit of 5,000 l. Nevertheless the total amount of milk produced decreased by about 30%. To reach the level of competitiveness the farmers were forced to introduce innovations in the production process. In consequence of this development the amount of housing capacities was significantly reduced. Some of the structures were partially used for other purpose, some were left and others were purposefully reconstructed and updated into free box stables with milking in the milking house. In 1989 only 108,000 cows from a total number of 1,247,000 were housed in free stables, i.e. 9%, while the rest was housed in the byre with stanchions with milking in the cow house. Up to 1999 278,000 cows, respectively 43% of total number of cows were housed in free stables. These stables are equipped by modern milking houses out of which a total amount of 730 were built after 1989. It is evident from these figures, that the introduction of innovations such as open housing systems is a precondition for economic successful milk cow rearing in the Czech Republic. It leads to important reductions of the production costs and maintenance of competitiveness. It also is combined with high labour productivity, decreased negative impacts of cattle rearing on the environment, ensured welfare of milk cows and permanent quality of the final product.

Keywords: cattle rearing; Czech Republic; transition period

The quality and technical level of technological processes in agricultural production affect significantly not only the economy of agricultural enterprises but even a lot of other factors linked with agricultural activity, e.g. landscape creation, environment protection, social conditions of countryside and settlement sustainment of rural territory.

Modern technical systems enable to decrease the labour intensity and hard manual work, to improve the staff working conditions, animal welfare and production environment the utilisation of feedstuffs and animal production potential as well as to increase the labour productivity.

Therefore, the research and development of new technical systems is in the focus all over the world and pro-

ducers of agricultural mechanisation bring every year new and more perfect machines and devices and even coherent technical systems.

The development of technological systems for cattle rearing in the Czech Republic after 1989 was significantly influenced by changes of social and economical environment in the country. Within this period new international relationships of CR with the surroundings world have been generated particularly with the EU. All these changes and relationships are dynamic and influence also the business environment of the agriculture.

The goal of this paper is to specify and quantify the most important factors and their influence on the development of technical and technological systems, labour productivity and cattle rearing economy.

The submitted article was elaborated in the frame of the project solutions supported by the National Agency for Agricultural Research – Ministry of Agriculture of the CR No. 6515, 6147 and QC 0176.

METHODOLOGICAL APPROACH

Among the most important external factors influencing cattle rearing belongs the price development of agricultural inputs (machines and devices, energy, fertilisers, construction material...) and prices paid to farmers for their products. The inflation development, labour force price and development of exchange rate of the Czech crown also are of great importance.

By utilisation of all available dates the development of these factors was specified after 1989 and possible connections regarding development of principal technical and economical indicators of cattle rearing after 1989. Particularly was analysed the development of technological systems used in cattle rearing, technical equipment of stables and farms, animal yields, human work need and labour productivity in relation to the milk production economy and its competitive ability.

RESULTS

DEVELOPMENT OF MACROECONOMICAL ENVIRONMENT INFLUENCING AGRICULTURAL PRODUCTION

After 1989 significant changes in the economical development were set in in the Czech Republic. The previous centrally planned development was abolished and substituted by the system of market economy. During a short time the systems of subsidies were removed, the taxation system was changed and Czech crown has become a convertible currency.

That led on the one hand to more realistic production costs and prices of individual products, on the other hand there occurred outstanding changes in the field of agricultural input prices (machines and devices, energy,

fertilisers, construction material...) and prices paid to farmers for their products.

It is evident from the graph in Fig. 1, that input prices in agricultural production have imitated the inflation development and have increased by more than 250% by 1998 as compared with 1989, the prices of agricultural products being increased only by 70%. This trend caused an enormous pressure on the agricultural production, which had to take into account a significant decrease of the state support. In 1998 the production support of the Czech agriculture has reached 17% (by the OECD methodics), although in the OECD countries it was in average 37% and in the EU countries 45%.

The price of labour force gradually rose, i.e. almost three times in nominal value as compared with 1989 (average month wage in agriculture was 3,455 CZK in 1989 and 9,143 CZK in 1998). At the same time also the disproportion between the average wage in CR and this in agriculture deepened, which was by 21.8% lower in 1998.

The development of agriculture was considerably influenced by inflation, which has increased by 270% during the observed period. Despite it, the exchange rate of the Czech crown changed only slightly against the main world currencies. The presented development is well evident from graph in Fig. 2. This development was relatively favourable for Czech farmers, because the prices of the high-quality foreign agricultural mechanisation have decreased and therefore this mechanisation has become more available for them. In consequence of the changes in the macroeconomical environment the agricultural enterprises have to find the ways how to survive in these conditions and to reach minimal profit necessary for renewal of agricultural mechanisation and introduction of new technological processes, which would ensure them significant competitive ability on still more exacting market.

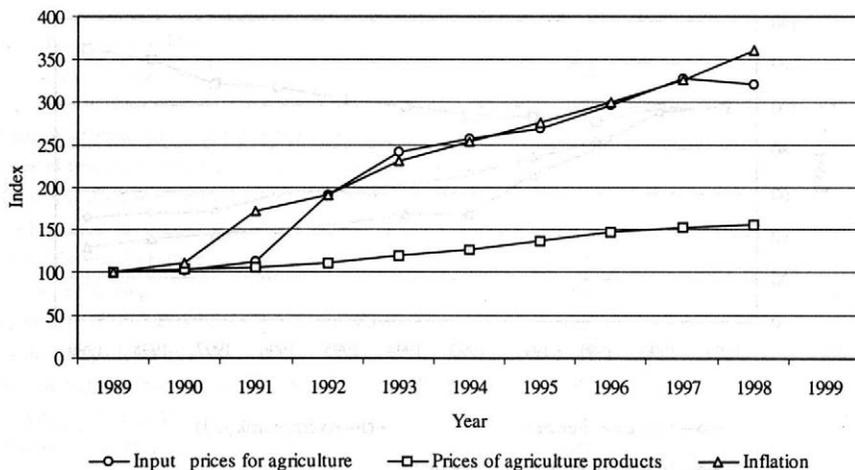


Fig. 1. Development of the input prices for agriculture, prices of agricultural products and inflation

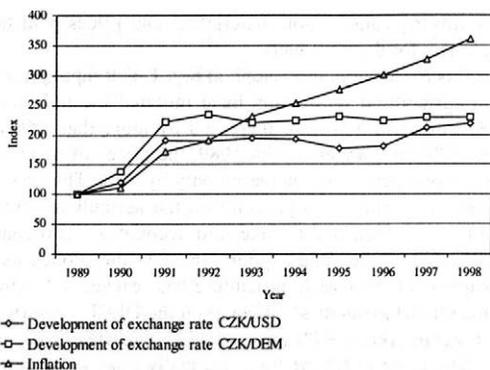


Fig. 2. The inflation and exchange rate CZK/DEM and CZK per USD development

DEVELOPMENT OF TECHNOLOGICAL SYSTEMS IN CATTLE REARING

All previously presented effects worked (and still work) in the field of cattle rearing in significantly increasing the labour productivity through introduction of modern working processes and housing systems, milk yield increase, decrease of production costs per unit of final product and increase of production quality of the enterprises, which are able to be successful in that economical environment and to be profitable. Nevertheless, these effects lead simultaneously to the production suppression and liquidation of unprofitable enterprises.

In Fig. 3 is presented the development of total amount of milk cows kept in CR, their average milk yield and total workers in agriculture.

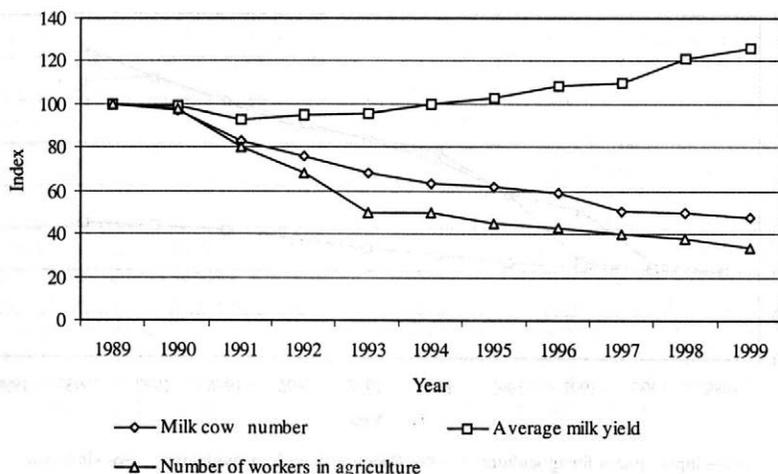


Fig. 3. Milk cow number development, average milk yield and number of workers in agriculture within period 1989–1990

In 1989 1,218.10³ milk cows were reared in CR. This number decreased to 589.10³ cows, i.e. by 51% in 1999. This decrease was in fact continuous and had negative impact particularly onto enterprises with low husbandry profitability. Mainly in the starting period some enterprises have disposed of all milk cows and have focused merely to the crop production.

In the same period the average annual milk yield increased by 26% and has exceeded the limit 5,000 l in 1999. In the starting period the average milk yield decreased under the level of 1989 and finally has exceeded that level in 1995 and now is still rising. At the end of 1999 the average annual milk yield was 5,022 l. It is evident from the milk yield decrease after 1989, that many agricultural enterprises have paid effort to keep the milk cow rearing despite the low milk yield and without any significant investment for the herd renovation and new technologies. Only in a half of the observed period the total average milk yield of cows reared in CR is significantly affected by the enterprises, which invested in to the purchase of the high-yield milk cows, improved the feedstuffs quality, modernised stables and technical systems.

Housing

In the past years many stables and farms for milk cows were built. These housing and storage capacities were partially left and partially utilised for other purposes, most of them are in operation up to now either in original state or were purposefully modernised and now are used not only for milk cows rearing, but even for pigs and their fattening and for housing of other animals.

It concerns mainly two-row tied and bedded stables K-96 for milk cows in total amount more than 6,000 objects and the four-row tied and bedded stables K-174 for milk cows in total amount about 2,000 objects. These

stables are at present the basis of the housing capacities for milk cows. The successful modernisation of these stables is possible only with respect to many new knowledge and changes, which occurred in milk cows rearing within that period.

With growing milk yield also grows the body dimensional frame and weight of milk cows, which could reach up to 700 kg. The stables of types K-96 and K-174 were built with the supporting columns with the lengthways module 4,500 mm and stands width 1,125 mm. This width of the stand does not correspond with the big milk cows and therefore it is necessary to extend it to at least 1,200 mm. Nevertheless this extension is not possible due to the columns lengthways module. For these milk cows the modernisation of these stables is problematic. It is a reason, why still more farmers in recent time consider the new stable construction.

The development in the field of feedstuffs production, milk yield, herd breeding composition, economical pressure onto cost reduction per production unit and also availability of modern technical systems has created conditions for successful introduction of milk cows housing free systems. Now there are no doubts about their advantages. The free stable extension is at present limited mainly by the availability of investment needed for modernisation or new construction.

From the total amount of $1,247.10^3$ cows in 1989 only 108.10^3 , i.e. 9% were housed in the free stables and the rest in the tied with the stand milking. The number of the free stables rose rapidly after 1989 and in 1999 the free stables for milk cows reached 35% of the total number of housing stands for milk cows.

The average size of stables for milk cows, reconstructed after 1989 has significantly decreased. This was caused by the considerable growth of small-size farms with low numbers of milk cows using particularly the tied system of housing. It is also evident from the fact, that average size of the reconstructed free stable for the milk cows is 177 housing stands.

For the free housing the most extended type is the free, bedded box stable. These stables are designed, as light, not insulated facilities with accent on good ventilation and welfare. In the past period there was a tendency to use even the not bedded stables with production of slurry, mainly in consequence of the cost and human work savings and sometimes also of the lack of suitable bedding. The share of free, not bedded stables built-up or reconstructed after 1990 is 7.3% of the total amount of housing stands in reconstructed or newly built-up stables for milk cows.

Feeding

After 1989 the approach to the milk cow nutrition has significantly changed. There exists a distant deflection from summer and winter feeding portions and still more is used the whole-year feeding portion on the base of concentrates without green feeding. Although in the previous time period many ballast and poor-quality feedstuffs were fed with a low content of nutrients and the amount of concentrates was limited (0.25 kg/l of milk), after 1989 have asserted modern methods of nutrition based on feeding of quality bulky feedstuffs with high content of nutrients and energy and the availability of concentrates is not limited. Some feedstuffs

Table 1. Stables and technological equipment for animal production to 1. 2. 1999

Stable, equipment	Total number of stables, average size	Stables and equipment reconstructed after 1. 1. 1991
Stables for milk cows (total)	10,311	1,902
Including: – free bedded stables	1,436	924
– free not bedded stables	146	63
– free stables (total)	1,609	987
Average size of stable for milk cows (number of milk cows)	78	27
Average size of free stable for milk cows (number of milk cows)	173	177
Average size of tied stable for milk cows (number of milk cows)	60	27
Stables for heifers	3,811	455
Average size of stable for heifers (number of heifers)	109	78
Stables for cattle fattening	5,815	757
Average size of stable for cattle fattening (number of animals)	67	41
Stationary milking parlours (pcs)	1,094	726
Including: – herringbone milking parlours (pcs)	502	346
Rotary milking parlours (pcs)	196	29
Milking parlours (total pcs)	1,290	755
Stand milking apparatus (pcs)	6,157	698

Resource: Czech Statistics Agency

were quite excluded from the feeding ration (beet cuts, straw, beet pulps...). The content of dry matter, which can be accepted by the milk cow in the feeding ration the limiting factor. This amount of dry matter has to contain a calculated amount of nutrients and energy. The dry matter reception by the milk cows has increased from previous 10–12 kg/day up to 18–22 kg/day. For the bulk feedstuffs utilisation is asserted their mixing and TMR (Total Mix Ration) feeding containing balanced content of nutrients, dry matter and crude fibre corresponding with the animal type, weight and milk yield.

For the TMR preparation and application the mixing feeding wagons utilisation has proved competent. These wagons are equipped by equipment for unloading and loading of feedstuffs stored in the silo clamps. This feeding technology has substituted other technical systems in modernised and new stables and has become dominant. From point of view of construction in CR are enforced the mixing feeding wagons equipped by mixing shaft, mixing wagons with horizontal and vertical mixing auger. All these types can be performed as semi-trailers, trailers or self-propelled and can be equipped by cutter. All these adaptations are able to prepare high-quality TMR.

It can be estimated, that after 1989 the Czech agriculture has been equipped by about 1,300 mixing feeding wagons (according to the Czech Statistical Agency).

Besides these modern technologies also classical feeding wagons are being used in older stables. The bottom conveyor equips these wagons and good labour organisation enables them to create the mixed feeding ration. These wagons are often used for bedding. Only in limited rate are in using the stationary feeding systems permanently built-in in the stables and in the modernised stables are used not at all.

The present situation in the field of the cattle rearing stables in CR and utilised technological systems is presented in Table 1.

Milking and milk treatment

Also in the field of milking and milk treatment many changes influencing demands for milking device have occurred after 1989.

Above all, the milk cows properties have changed from the point of view of machine milking. Although the maximum milking intensity was in the past about 2–4 kg/min, the present high-yield milk cows reach normally the milking intensity 4–6 kg/min and peak up to 12 kg/min. It has requested a new construction of the milking devices to ensure demanded speed and quality of milking process without negative effects onto lacteal gland state of health and overall milk cow health. The milking set had to be newly solved (extended claw, new teat cups, extended pipe diameters, higher performance of vacuum pumps...).

The demands for environment protection led to application of ecological vacuum pumps (vacuum pumps with rotary pistons) and oil re-circulation in rotary paddle vacuum pumps and their noisiness reduction.

The demands for the milk qualitative parameters still increase. For example CPM, SB, CB maximum amount valve has decreased as well as limit of milk freezing point. The basic qualitative demands for raw cow milk valid in CR and EU are presented in Table 2.

The farmer producing milk is now being found in strongly competitive environment, where the dairy plants dictate still more strict demands and motivate their achieving by the purchase milk price.

With respect to the large number of tied stables milking into milk pipelines is utilised. Milking into cans is still in use for the smaller herds.

In the modernised or newly built stables significantly dominates the milking in the parlours, which ensure the best conditions for hygienic acquisition of milk. The milking equipment in the modern milking parlours creates optimal conditions for physiologically correct milking, milking process automation and high performance of the service. In connection with automated identification of milk cows and automated data collection regarding the milk yield level, milk cow state of health and reproduction, the milking parlour turns into the centre for dairy farm controlling with computers utilisation. The computer with necessary software equipment has become apparent and normal part of the dairy farms.

The most utilised are the stationary milking parlours including well-ried herringbone parlours, which repre-

Table 2. Qualitative demands for raw cow milk

Index	Values valid in		Average values reached in CR in 1999
	CR	EU	
Max. total number of micro-organism (1 ml of milk $\times 10^3$)	100	100	65
Max. number of somatic cells (1 ml of milk $\times 10^3$)	400	400	248
Freezing point ($^{\circ}\text{C}$)	-0.515	-0.515	-0.523
Minimum protein content (g/l)	28.0		33.4
Minimum fat content (g/l)	33.0		42.4
Max. number of coliform bacteria (1 ml)	1,000		191
Max. number of thermoresistant micro-organism (1 ml)	2,000		1,192
Max. number of psychotrophic bacteria (1 ml $\times 10^3$)	50		10.9

sent almost one half of all stationary milking parlours being in operation. Installation of new auto-tandem milking parlours is gradually suppressed. A certain extension is evident at the parallel milking parlours (side by side) as an alternative to the herringbone parlours. Particularly at the present time some investors prefer the group departure milking parlours (both herringbone and parallel), despite they are more expensive and their advantages are questionable (low time save, larger built-up area, complicated stand construction, large area polluted by excrements...).

The rotary milking parlours with newly constructed chassis significantly increasing the operational reliability are again popular.

The milking devices utilised in individual types of milking parlours are in fact similar and are characterised by the sectional solution, so that the user can choose technical level according to his/her needs. The simplest systems control automatically the milking and sanitary process, the most complicated systems are equipped by the system of automated identification, milk amount measuring, moving activity evaluation, measuring of lacteal gland state of health parameters (specific electrical conductivity, temperature...) and communicate with the controlling computer. The automated milking systems (AMS) often called the milking robots are in CR not used so far and there are not even particularly economical presumptions for their application.

For milk treatment and storage are almost exclusively used cooling tanks or containers with indirect cooling (cold accumulation in ice water in time of cheap rate of electricity). The cooling tanks with direct evaporation are being used exceptionally on the Czech farms.

Manure removal and bedding

In the tied stables prevails manure removal by scraper conveyer and bedding is performed manually from the truck.

In the free-bedded stables dominates the manure removal by means of tractor scraper with unloading onto yard's manure heap or by loading onto mobile vehicle (trailer, container). The scraping paddles are being used seldom in the bedded stables (high price, complications during bedding operation...). For the bedding purpose are utilised adapted feeding wagons with bottom conveyer or bales separators with side discharging, semi-trailed on tractor.

In the free not-bedded stables prevails so far manure removal by tractor scraper. Still more farmers prefer the scraping paddles characterised by high technical reliability, safety operation and universal application even for wide manure corridors. The scraping paddles have some advantages when being used in the not-bedded stables (automated operation and manure removal sometimes daily, cleaner manure corridor and feeding place with favourable effect on hoofs, reduced resting in the corridors and higher animal cleanness...).

The deep bedding is used particularly for bull housing and partially also for heifers in enterprises with sufficient inventory of straw and significant need of organic fertilisation. For the milk cow the deep bedding is being used only exceptionally. The deep bedding stands housing systems, popular mainly in Germany are not used in CR at all.

LABOUR PRODUCTIVITY AND MILK PRODUCTION ECONOMY

In the new and modernised stables for the milk cows there is reached a low need of human labour calculated for 1 litre milk, ranging between 35–60 hours per 1 litre milk. This is fully comparable with the values reached on the best European farms.

The total level of labour productivity is influenced besides the human labour need also by the reached milk yield. The development of the average milk yield was mentioned above. Nevertheless, it is important to

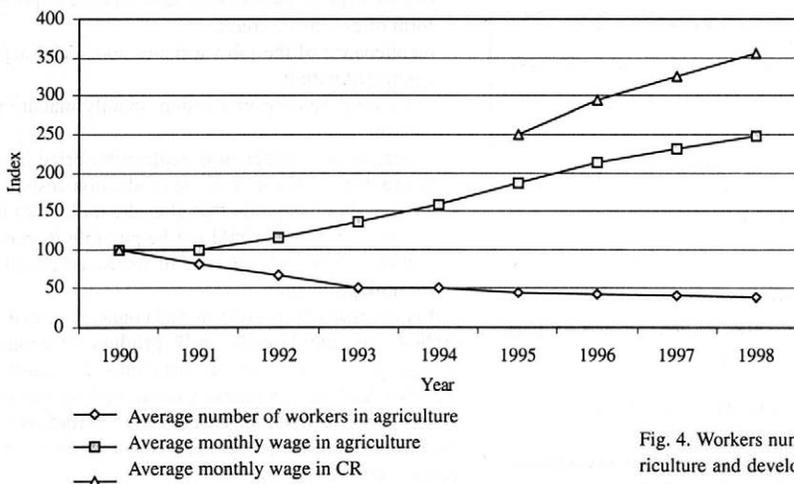


Fig. 4. Workers number development in agriculture and development of average gross monthly wages within period 1990–1998

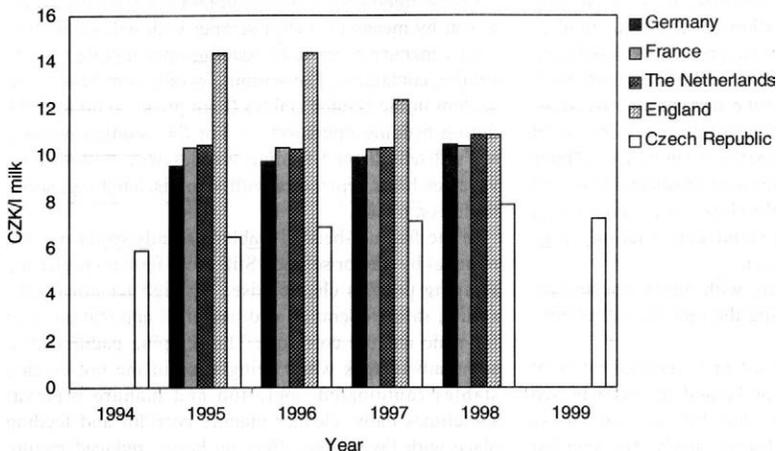


Fig. 5. Average milk prices

present, that the average milk yield of cows reared on modernised farms is considerably higher than the average milk yield in CR and normally is about 8,000 l/cow per year.

The old tied stables reached – by type and equipment – the human work need 95–130 hours/cow at significantly lower annual milk yield (3,500–4,500 l/cow). In such conditions one worker produced 54–95 thousand litres of milk.

It is evident from Fig. 4 that the worth of human labour rapidly grows and therefore reduction of the human labour need is a very important condition for survival.

The expressive growth of the labour productivity on the new and modernised farms is also reflected in the total decrease of workers in agriculture and total growth of labour productivity within the milk cow rear-

ing. By utilisation of the statistical data about human labour consumption it can be proved, that in 1989 worked in the milk cow rearing in total 64.2 thousand of direct workers and only 22.5 thousand workers in 1999, i.e. less by 65%. In 1989 produced one worker in milk cow rearing in average 75,500 litre of milk and in 1999 even 132,000 litre, i.e. by 74.8% more.

Although the agricultural input costs increase, the average milk realisation price is changing slowly and at present even decreases and by far does not reach the EU values as evident from Fig. 5.

The milk production profitability is a problem of most of the Czech milk producers. On average the production costs per 1 litre of milk exceed its realisation price. Despite this situation the farmers do not give up the milk production. There are many reasons for this situation. In discussions with individual producers following aspects were presented:

- utilisation of bulk feedstuffs produced on the farm,
- continual survey of financial means (i.e. payment for milk) necessary during the year for normal operation of enterprise, which should be otherwise acquired in form of expensive credit,
- maintenance of the job vacancies and social aspects connected with it,
- linkage to the crop production, mainly manure production,
- expectation of better milk realisation price in near future in comparison with the production costs,
- anxiety about situation that after the milk cows rearing abolishment it would not be possible its renovation (too high costs) in case of improved conditions for milk production.

It is necessary to present in this connection, that it is difficult to calculate the milk production economy without precise and uniform methods. It regards e.g. the own feedstuff evaluation consumed on the farm, service price in frame of enterprise, overhead cost etc. Therefore for many farmers the enterprise profitability is most important as a whole.

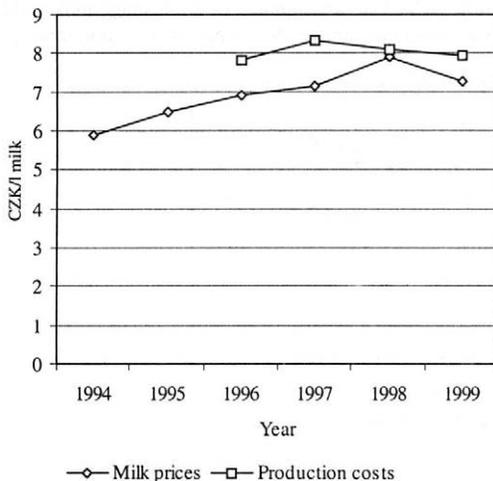


Fig. 6. Milk production costs and milk prices development in the Czech Republic

SUMMARY

The development of technological systems for cattle rearing after 1989 was significantly influenced by dynamical changes of economical environment in CR. The main changes, which had, or up to now have direct effect onto agriculture development in the field of the milk cows breeding can be characterised by following aspects:

- changes in the field of input prices development into agriculture (machines and devices, energy, fertilisers, construction material...) and prices paid to farmers for their products. Although the input prices followed the inflation development and have risen by more than 250% in comparison with 1989, the prices of agricultural products have risen only by 70%.
- labour force price has risen almost three times in nominal value in comparison with 1989 (average month's wage in agriculture was 3,455 CZK in 1989 and even 9,143 CZK in 1998). The agriculture development was considerably affected by inflation, which has increased by 270% within the observed period. Nevertheless the only little change of exchange rate of Czech crown against the main world currencies, making the high-quality foreign agricultural mechanisation more available for Czech farmers.

All the above presented factors in their consequence effected (and still effect) in the field of cattle rearing the significant increase of labour productivity through introduction of modern working methods and housing systems, milk yield increase, production costs reduction per unit of final product and production quality increase in the enterprises which want to be successful and profitable in a demanding economical environment. Nevertheless these factors lead simultaneously to the production suppression and liquidation of unprofitable plants.

It has resulted in outstanding reduction of milk cows number to 640 thousand in 1999; i.e. by 49% less compared with 1989.

On 1989 from the total amount 1,247 thousand of cows only 108 thousand, i.e. 9%, were housed in free stables and the rest in the tied stables with the stand milking. In 1999 even 278 thousands cows, i.e. 43% from total amount of breded cows were housed in free stables. In consequence of that development considerable housing capacities were released and partially used for other purposes, some of them were quite left and certain part was reconstructed and modernised for

free box stables with milking in the parlour. The milk cows are being housed at present in the light, not-insulated and well-ventilated stables, which meet requirements for welfare and environment protection. Almost exclusively the complex feeding ration (TMR) is fed being prepared and applicated by mixing feeding wagons. In consequence of these facts:

- the number of animals cared for by one worker has increased and this situation caused total reduction of the workers in the milk cows breeding by 53 thousand in comparison with 1989,
- average labour productivity measured by the milk amount produced by one worker has increased by almost 75% in comparison with 1989,
- annual milk yield has increased by 26% and has exceeded the limit of 5,000 litres in 1999.

From the above mentioned is evident, that the future of the milk cow rearing in CR is not possible to be considered without transfer to the free systems of housing, both bedded and not bedded. These stables have to be equipped by modern technological systems with application of automated data collection and their evaluation by computer for the purpose of the breeding control. Only under these conditions it is possible to ensure a high labour productivity, reduction of negative impacts onto environment, ensure welfare for animals and high quality of the final product. Technical and technological systems used in current modern stables for milk cows in CR do not differ from similar stables built in the EU member states and meet requirements for welfare and environment protection applied in EU.

These stables and farms are as well necessary condition for the production costs reduction and maintenance of the Czech farmer's ability to compete within the challenging environment of EU.

References

- Mechanizační prostředky a vybavení v zemědělství k 1. 2. 1999, 1999. Český statistický úřad, 1224-99: 48.
- Technika a technologické systémy v zemědělství České republiky, 1999. Praha, MZe ČR: 81.
- Zpráva o stavu zemědělství ČR za rok 1998 „Zelená zpráva“, 1999. Praha, MZe ČR: 105.
- Zpráva o stavu zemědělství ČR za rok 1999 „Zelená zpráva“, 2000. Praha, MZe ČR: 124.

Received 11 June 2001

Technologické procesy chovu skotu v ČR po roce 1989 z hlediska přibližování k EU

ABSTRAKT: K výrazným změnám došlo v oblasti vývoje cen vstupů do zemědělství (stroje a zařízení, energie, hnojiva, stavební materiál...) a cen placených zemědělcům za jejich výrobky. Zatímco ceny vstupů kopírovaly vývoj inflace a vzrostly ve srovnání s rokem 1989 o více než 250 %, vzrostly ceny zemědělských výrobků pouze o 70 %. Postupně rostla cena pracovní síly, která ve srovnání s rokem 1989 vzrostla v nominální hodnotě téměř trojnásobně (průměrná měsíční mzda

v zemědělství byla v roce 1989 3 455 Kč a v roce 1998 již 9 143 Kč). Do vývoje v zemědělství výrazně zasáhla i inflace, která se za sledované období zvýšila o 270 %. Přitom však došlo jen k malé změně směnného kursu Kč vůči hlavním světovým měnám, tzn., že se pro české zemědělce stala cenově dostupnější kvalitní zahraniční zemědělská technika. Dochází k výraznému zvyšování produktivity práce zaváděním moderních pracovních postupů a systémů ustájení, ke zvyšování užitkovosti, snižování výrobních nákladů na jednotku finálního výrobku a ke zvyšování kvality produkce u podniků, které chtějí v tomto náročném ekonomickém prostředí obstát a prosperovat. Současně však vedou k útlumu výroby a zániku neekonomických chovů. To se projevilo výrazným poklesem počtu dojnic na 640 tisíc v roce 1999, což je o 49 % méně než v roce 1989. Ve stejném období však vzrostla roční průměrná užitkovost o 26 % a v roce 1999 překročila hranici 5 000 l. Přesto došlo k celkovému snížení výroby mléka asi o 30 %. V důsledku tohoto vývoje se uvolnily značné ustájecí kapacity, které byly zčásti využity pro jiné účely, některé byly zcela opuštěny a další účelně rekonstruovány a modernizovány na volné boxové stáje s dojením v dojrně. Z celkového počtu 1 247 tisíc krav bylo v roce 1989 ustájeno ve volných stájích jen 108 tisíc zvířat, tj. 9 %, a zbytek byl ustájen ve vazných stájích s dojením na stáni. V roce 1999 bylo ve volných stájích ustájeno již 278 tisíc krav, tj. 43 % z celkového počtu chovaných krav. Tyto stáje jsou vybaveny moderními dojrnami, kterých bylo po roce 1989 postaveno více než 730. Je tedy zřejmé, že nezbytnou podmínkou pro ekonomicky úspěšný chov dojnic je zavádění inovací, např. volného systému ustájení vybaveného moderními technickými systémy. Tak bude zajištěno výrazné snížení výrobních nákladů a konkurenceschopnost. Současně to povede ke zvýšení produktivity práce, snížení negativních vlivů na životní prostředí, zajištění welfare pro dojnice a ke stále kvalitě finálního produktu.

Corresponding author:

Ing. JIŘÍ VEGRICHT, CSc., Výzkumný ústav zemědělské techniky, Drnovská 507, P. O. Box 54, 161 01 Praha 6-Ruzyně,
Česká republika
tel.: + 420 2 330 22 22 81, fax: + 420 2 33 31 25 07, e-mail: vuzt1.05@bon.cz

INSTRUCTIONS FOR AUTHORS

The responsibility for the contents of a manuscript rests with the authors. The Editorial Board will decide on suitability for publication, after considering the scientific importance and overall technical quality of the manuscript and the comments of the referees.

The manuscript should be typed on standard A4 paper. A PC diskette with the complete text and including references, tables and figure legends of graphical documentation should be provided with each manuscript, indicating the used editor program.

Manuscript should consist of the following sections: Title page, Abstract, Keywords, Introduction, Materials and Methods, Results, Discussion, References, Address of corresponding author, Tables, Legends to figures.

The Title page must contain an informative title, complete name(s) of the author(s), the name(s) and address(es) of the institution(s) where the work was done.

The **Abstract** should state in a short and concise form what was done and how, and should contain basic numerical and statistical data representative of the results. It should be submitted in English and, if possible, also in Czech.

Keywords follow the abstract; they are ranked from general to specific terms, and are written in lower case letters and separated by semicolons.

The **Introduction** (without a subtitle) should consist of a short review of literature relevant to and important for the study. The reason(s) for carrying out the work may be included.

In **Materials and Methods**, the description of experimental procedures should be sufficient to allow replication. Abbreviations can be used if necessary; first use of an abbreviation should be just after its complete name or description. The International System of Units (SI) and their abbreviations should be used.

Results should be presented clearly and concisely. In this section figures and graphs should be used rather than tables for presentation of quantitative values. A statistical analysis of recorded values should be summarized in tables.

The **Discussion** should interpret the results, without unnecessary repetition. Sometimes it is possible or advantageous to combine Results and Discussion in one section.

If **Acknowledgments** are needed, they come next.

References used in the text consist of author's name and year of publication. The list of references should include only publications quoted in the text. These should be in alphabetical order under the first author's name, citing all authors, year (in brackets), full title of the article, abbreviation of the periodical, volume number, first and last page numbers.

Contact address should include the postal address, telephone, fax and e-mail numbers of the corresponding author.

Tables and Figures shall be enclosed separately. Each of them must be referred to in the text. Figures should be restricted to material essential for documentation and understanding of the text. Duplicate presentation of data in both tables and figures is not acceptable. All illustrative material must be of publishable quality. Both line drawings and photographs are referred to as figures. Photographs should have high contrast. Each figure should be accompanied by a concise, descriptive legend.

Reprint: Ten (10) reprints of each published paper are supplied free of charge.

POKYNY PRO AUTORY

Autor je plně odpovědný za původnost práce a za její věcnou i formální správnost. O uveřejnění práce rozhoduje redakční rada se zřetelem k lektorským posudkům, vědeckému významu a přínosu i kvalitě práce.

Rukopis musí být zaslán vtištěný na papíru formátu A4. K rukopisu je vhodné přiložit disketu s textem práce, popř. grafickou dokumentaci pořízenou na PC (uvést použitý program).

Vědecká práce musí mít toto členění: titulní strana, abstrakt a klíčová slova, úvod, materiál a metody, výsledky, diskuse, literatura, kontaktní adresa, tabulky a obrázky včetně popisů.

Titulní strana musí obsahovat název práce, plné jméno autorů, název a adresu instituce, kde byla práce dělána.

Souhrn musí vyjádřit všechno podstatné, co je obsaženo ve vědecké práci, má obsahovat základní číselné údaje včetně statistických hodnot. Je uveřejňován a měl by být autory dodán v angličtině a češtině.

Klíčová slova (keywords, index terms) se připojují po vyečarání řádku pod souhrn. Řadí se směrem od obecných výrazů ke speciálním; začínají malým písmenem a oddělují se středníkem.

Úvod (bez nadpisu) by měl obsahovat krátký přehled důležité literatury vztahující se k tématu a cíl práce.

Materiál a metody: Model pokusu musí být popsán podrobně a výstižně. Popis metod by měl umožnit, aby kdokoli z odborníků mohl práci opakovat. Zkratky jsou používány jen pokud je to nutné; první použití zkratky musí být uvedeno úplným popisem nebo vysvětlením. Používané měrové jednotky musí odpovídat soustavě měrových jednotek SI.

Výsledky: Doporučuje se nepoužívat k vyjádření kvantitativních hodnot tabulek, ale dát přednost grafům anebo tabulky shrnout v statistickém hodnocení naměřených hodnot. Tato část práce by neměla obsahovat teoretické závěry ani dedukce, ale pouze faktické nálezy.

Diskuse obsahuje zhodnocení práce. Je přípustné spojení s předchozí kapitolou (Výsledky a diskuse).

Poděkování se uvádí před přehled použité literatury.

Literatura: Měly by být citovány práce uveřejněné v lektorovaných periodikách. Odkazy na literaturu v textu se provádějí uvedením jména autora a roku vydání publikace. V části Literatura se uvádějí jen práce citované v textu. Citace se řadí abecedně podle jména prvního autora: příjmení, zkratka jména, rok vydání (v závorce), plný název práce, úřední zkratka časopisu, ročník, první-poslední stránka; u knih je uvedeno místo vydání a vydavatel.

Kontaktní adresa obsahuje vedle poštovní adresy také čísla telefonu, faxu a e-mail adresu autora pověřeného korespondencí.

Tabulky a obrázky: Tabulky, obrázky a fotografie se dodávají zvlášť a všechny musí být citovány v práci. Akceptovány budou pouze obrázky, které jsou nezbytné pro dokumentaci výsledků a umožňují pochopení textu. Není přípustné dokumentovat výsledky jak v tabulkách, tak pomocí grafů. Všechny ilustrativní materiály musí mít kvalitu vhodnou pro tisk. Fotografie i grafy jsou v textu uváděny jako obrázky a musí být průběžně číslovány. Každý obrázek musí mít stručný a výstižný popis.

Separáty: Autor obdrží 10 separátních výtisků publikované práce.

RESEARCH IN AGRICULTURAL ENGINEERING

Volume 47, No. 3

2001

CONTENTS

PASTOREK Z.: The 50 th anniversary of the Research Institute of Agricultural Engineering in Prague	81
JELÍNEK A., ČEŠPIVA M., PLÍVA P., HÖRNIG G., STOLLBERG U.: Composting as possibility of toxic gases emissions reduction, mainly ammonia, generated during manure storage	82
PAWLICA R., KOVAŘÍČEK P.: The batch process of maize drying by mobile drier	92
KROUPA P., SKALICKÝ J.: Storage of wet maize in sealed containers in CO ₂ protective atmosphere	99
HUTLA P., SLADKÝ V.: Optimal drying of energetical wooden chips	104
BOUČEK J., KÁRA J.: Operation and emission parameters of tractor engine at rape oil ethyl esters application as alternative fuel	110
VEGRICHT J., PASTOREK Z., ACKERMANN I., SCHLAUDERER R.: Technological progress in cattle rearing in the Czech Republic after 1989 from the point of view of the accession to EU	120

OBSAH

PASTOREK Z.: Padesát let Výzkumného ústavu zemědělské techniky v Praze	81
JELÍNEK A., ČEŠPIVA M., PLÍVA P., HÖRNIG G., STOLLBERG U.: Kompostování jako možnost snižování emisí toxických plynů, zejména amoniaku, vznikajících při skládování hnoje	82
PAWLICA R., KOVAŘÍČEK P.: Dávkovací proces sušení kukuřice mobilní sušičkou	92
KROUPA P., SKALICKÝ J.: Skladování vlhkého kukuřičného zrna v hermeticky uzavřených zásobnících v ochranné atmosféře CO ₂	99
HUTLA P., SLADKÝ V.: Optimalizace sušení energetické dřevní štěpky	104
BOUČEK J., KÁRA J.: Provozní a emisní parametry traktorového motoru při použití etylesterů řepkového oleje jako alternativního paliva	110
VEGRICHT J., PASTOREK Z., ACKERMANN I., SCHLAUDERER R.: Technologické procesy chovu skotu v ČR po roce 1989 z hlediska přibližování k EU	120

Vědecký časopis RESEARCH IN AGRICULTURAL ENGINEERING (Zemědělská technika) ● Vydává Česká akademie zemědělských věd – Ústav zemědělských a potravinářských informací ● Redakce: Slezská 7, 120 56 Praha 2, tel.: + 420 2 27 01 03 55, fax: + 420 2 27 01 01 16, e-mail: forest@uzpi.cz ● Sazba a tisk: ÚZPI Praha ● © Ústav zemědělských a potravinářských informací, Praha 2001

Rozšiřuje Ústav zemědělských a potravinářských informací, referát odbytu, Slezská 7, 120 56 Praha 2, tel.: + 420 2 27 01 03 85, e-mail: finance@uzpi.cz