CZECH ACADEMY OF AGRICULTURAL SCIENCES

Research in AGRICULTURAL ENGINEERING

ZEMĚDĚLSKÁ TECHNIKA

INSTITUTE OF AGRICULTURAL AND FOOD INFORMATION

1

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 gescí České akademie zemědělských věd

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, ergonomy 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 24 25 51 06, fax: + 420 2 22 51 40 03, e-mail: braun@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.

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 24 25 51 06, fax: + 420 2 22 51 40 03, e-mail: braun@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.

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

MK ČR 6698

The effect of harvest time on the moisture content and heating value of biofuels

J. ŠTENCL[1], V. SLADKÝ[2]

[1]*Mendel University of Agriculture and Forestry, Faculty of Agronomy, Brno, Czech Republic*
[2]*Research Institute of Agricultural Engineering, Prague, Czech Republic*

ABSTRACT: The paper presents results of tests of moisture content and heating value changes of 9 samples of biofuels in relation to harvest time: Jerusalem artichoke (stems), *Miscanthus*, triticale, hemp (male and female stems), flax (stems), saflor (stems), grass, hyso I and II (stems). Samples were collected on fields in the period October – April in two-week and/or month intervals 1997–1999. Values measured were processed graphically. The moisture content and heating values created a mirror image in these diagrams. Stems of flax showed the highest heating value (17.2 MJ/kg), *Miscanthus* and stems of Jerusalem artichoke showed 15.5 MJ/kg. The lower heating value was about 12.5 MJ/kg (triticale, male stems of hemp and grass) and female stems of hemp showed the lowest heating value 8.1 MJ/kg. The final moisture content of the biofuels was reached mostly in the spring period or at the end of winter, exceptionally during December or January (triticale, hemp and stems of flax).

Keywords: biofuel; harvest; moisture content; heating value

Physical properties of solid biofuels are influenced particularly by their moisture content. The moisture content in the period of the vegetation development of energy crops ranges from 60% (woody species) to 85% (grasses) essentially affecting the method of harvest, primary drying and particularly the method and costs of handling and transport. With the increasing moisture content the combustion heat and heating value decrease and, therefore, an effort exists to obtain the highest percentage of dry matter (DM) in the burnt biomass. In wood briquettes, the value can reach even more than 90%. Common fuels are evaluated as good if they have more than 70% DM e.g. wood chips or 80% in stalk crops (SLADKÝ 1995). The effect of the change in biomass moisture content on the heating value is given in Tables 1 and 2 (NOSSEK 1986).

The process of wet biomass dehydration, particularly of wood has been the subject of many research and development papers. In general, the technological process is always expensive both from the viewpoint of costs necessary for storage under conditions of natural drying by non-conditioned ambient air and costs for ventilation or possible tempering of the drying environment. The amount of water, which is necessary to be evaporated, is usually very high. For example, to obtain one tonne of stalk

Table 1. Effect of the decreased biomass moisture content on increased heating values (expressed in MJ/kg)

Moisture content	Heating value	Increase in the biomass heating value by the value of Q_v (MJ/kg) decreasing the original moisture content to w (%)									
w (%)	Q_v (MJ/kg)	60	55	50	45	40	35	30	25	20	15
65	5.1	3.1	5.5	7.4	9.3	10.3	11.5	12.4	13.2	14.0	14.6
60	6.2	–	2.8	5.0	6.8	8.3	9.6	10.6	11.6	12.4	13.1
55	7.3	–	–	2.5	4.5	6.2	7.6	8.9	10.0	10.9	11.7
50	8.4	–	–	–	2.3	4.1	5.7	7.1	8.3	9.3	10.2
45	9.5	–	–	–	–	2.1	3.8	5.3	6.6	7.8	8.8
40	10.5	–	–	–	–	–	1.9	3.6	5.0	6.2	7.3
35	11.6	–	–	–	–	–	–	1.8	3.3	4.7	5.8
30	12.7	–	–	–	–	–	–	–	1.7	3.1	4.4
25	13.8	–	–	–	–	–	–	–	–	1.6	2.9
20	14.9	–	–	–	–	–	–	–	–	–	1.5

The study is a part of the Grant project of National Agency for Agricultural Research (NAZV) 7MZ7315 supported by the Ministry of Agriculture of the Czech Republic and by the Grant MSM 432100001.

Table 2. Effect of the decreased biomass moisture content on increased heating values (expressed in %)

Moisture content in fuel	Increase in the biomass heating value by (%) decreasing the original moisture content to w (%)									
w (%)	60	55	50	45	40	35	30	25	20	15
65	61	108	146	177	202	224	243	259	273	286
60	–	45	80	109	134	154	172	187	200	212
55	–	–	34	62	85	105	122	136	149	160
50	–	–	–	27	49	68	85	99	111	122
45	–	–	–	–	22	40	56	70	82	93
40	–	–	–	–	–	18	34	47	59	69
35	–	–	–	–	–	–	15	28	40	50
30	–	–	–	–	–	–	–	13	24	34
25	–	–	–	–	–	–	–	–	11	21
20	–	–	–	–	–	–	–	–	–	10

crop of 16% moisture content it is necessary to remove 3,200 kg water from about 4,200 kg freshly mowed biomass of initial 80% moisture content. Therefore, recent papers are orientated to searching the most favourable harvest time particularly with respect to maturity, moisture content and related heating value of energy crops. Dead plants in nature lose the water content gradually during several days (stalk crops), several months (thick-stalk plants) up to several years (woody plants). Intensification and increased effectiveness of the drying process and optimization of the harvest time of energy crops are, therefore, of fundamental importance for their application in thermal energetics. The first step in the process is to obtain knowledge on water release from biofuels and on changes in heating values.

The aim of the study is to determine and analyse the relationship between the heating value and moisture content of selected energy plants and the harvest time and in this way to present results of long-term measurements carried out within the Grant project *Energy properties of stalk crops*.

MATERIAL AND METHODS

Measurements of the moisture content and heating values or combustion heat were carried out in the laboratory in nine energy plants: Jerusalem artichoke (stem), *Miscanthus*, triticale, hemp (male and female stems), flax (stems), saflor (stems), grass, hyso I and II (stems). Samples were taken in a stand from the beginning of October to the end of April in the usual interval of two weeks, rarely due to unfavourable weather or under steady changes in some plants up to a month. The altitude of localities with the crops was 250–500 m. Sampling was finished when the moisture content of samples reached the determined degree of stability: its change was smaller than 10% as compared with the previous measured value. Sampling was never carried out due to objectivity in the course of precipitation or closely after it.

The moisture content of samples was determined in accordance with standards used both in our country, e.g. ČSN 46 7092 (Metody zkoušení krmiv, část 3: Stanovení vlhkosti – Methods of feed testing, part 3: Moisture content determination) and abroad (DISSEMOND, ZAUSSINGER 1995; HALL 1979). Samples of about 100 g in weight weighted with 0.01g accuracy were dried in an electric dryer at 105°C temperature for 24 hours. On the basis of dry matter (DM) obtained the percentage moisture content in the material was calculated. Heating values were determined in accordance with the ČSN 44 1310 (Tuhá paliva – označování analytických ukazatelů a vzorce přepočtu výsledku rozboru na různé stavy paliva – Solid fuels – marking analytical indices and formulae for the conversion of analysis results to various states of the fuel) by calorimetry using adiabatic combustion of 1 g biomass at 100% DM in a closed vessel with oxygen atmosphere under 0.2–0.3 MPa pressure. A semi-automatic calorimeter HAAKE HC 10 was used.

The heating value calculation of a fuel is derived from the value of combustion heat determined from DM and the amount of water in a sample with respect to the hydrogen content. Hydrogen is a 'water-forming' element and its content in biofuel DM ranges from 4 to 6%.

The calculation procedure is as follows:

- to determine DM in the fuel sample by drying (%),
- to determine the combustion heat of the sample DM (kJ/g),
- to determine the combustion heat for the DM proportion in a sample (kJ/g),
- subtraction of the sample water evaporation heat from the sample DM proportion heat (1g water requires 2.44 kJ for evaporation),
- determination of the amount of water produced by hydrogen combustion from the sample DM,
- heat subtraction for evaporation of the water proportion from a sample and water from combusted hydrogen from the amount of heat from the sample DM proportion (kJ/g).

According to the ČSN 44 1310 standard the heating value (kJ/kg, MJ/kg) of the fuel sample is calculated from the following relation:

$$Q_v = Q_s - 2.44.\ (w + 8.94.H) \qquad (1)$$

Measurements of the moisture content and the heating value of biofuels are methods interdependent from the physical point of view. The general definition of heating value (ČERNOCH 1977) can be expressed as follows:

$$Q_v = Q_s \frac{m_s}{m_v + m_s} - L \frac{m_v}{m_v + m_s} \qquad (2)$$

where: L – the water evaporation heat,

Q_s – the content of heat in the sample DM proportion – DM combustion heat.

If we substitute into the equation (2) for m_s an expression resulting from the definition of the moisture content in a fuel:

$$w = \frac{m_v}{m_v + m_s} \qquad (3)$$

we obtain an equation:

$$Q_v = Q_s(1 - w) - Lw \qquad (4)$$

where: Q_s – heat content in the sample DM proportion, DM combustion heat (MJ/kg),

2.44 – heat for the evaporation of 1 kg water (MJ/kg),

w – amount of water (kg) in a sample,

m_s – sample DM weight (kg),

m_v – sample water weight (kg),

8.94 – coefficient for the conversion of hydrogen weight to the amount of water,

H – amount of hydrogen in the sample DM (kg/kg).

If we consider that Lw is very small in comparison with Q_s then the relationship between heating value and biofuel moisture content expressed by equation (4) can be considered to be linear with a negative coefficient. It follows that the relation between moisture content and the biofuel heating value is indirect forming a mirror image in a diagram at a suitable scale.

RESULTS

The measured changes in heating values and moisture content of analysed biofuels during the period under investigation are presented in diagrams (for the purpose of illustration and lucidity): Fig. 1 Jerusalem artichoke (stem), Fig. 2 *Miscanthus*, Fig. 3 triticale, Fig. 4 hemp (male and female stems), Fig. 5 flax (stems), Fig. 6 saflor (stems), Fig. 7 grass, Figs. 8 and 9 hyso I and II (stems).

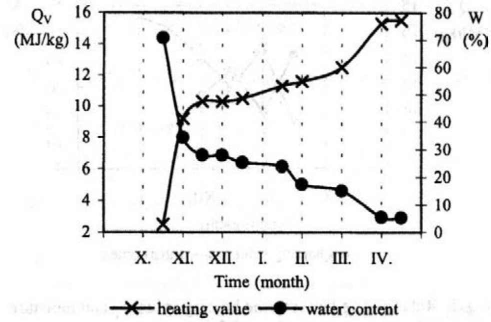


Fig. 1. Relationship between the heating value Q_V and moisture content W and the harvest time of Jerusalem artichoke (stems)

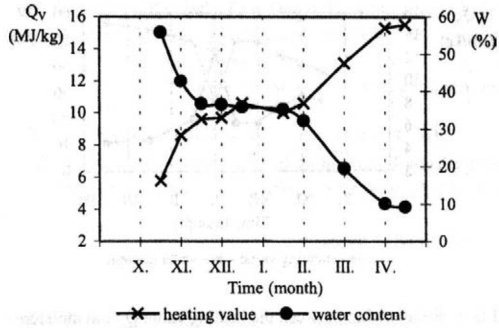


Fig. 2. Relationship between the heating value Q_V and moisture content W and the harvest time of *Miscanthus*

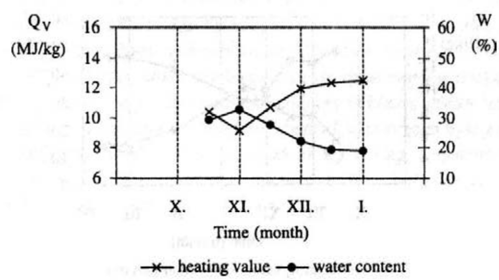


Fig. 3. Relationship between the heating value Q_V and moisture content W and the harvest time of triticale

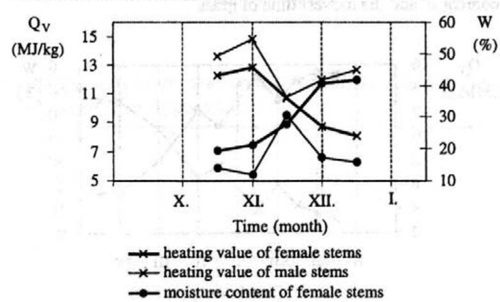


Fig. 4. Relationship between the heating value Q_V and moisture content W and the harvest time of hemp (stems)

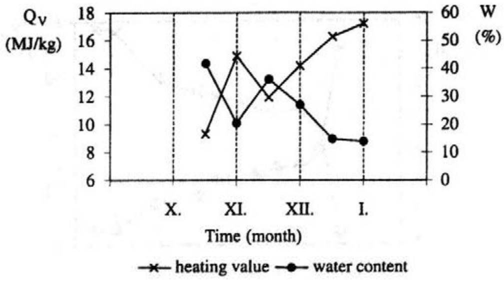


Fig. 5. Relationship between the heating value Q_v and moisture content W and the harvest time of flax (stems)

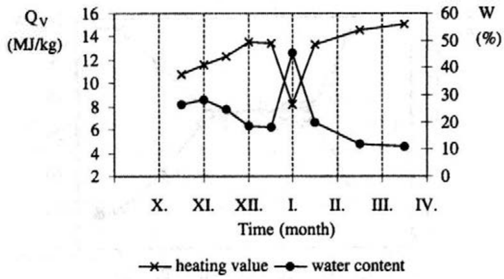


Fig. 6. Relationship between the heating value Q_v and moisture content W and the harvest time of saflor (stems)

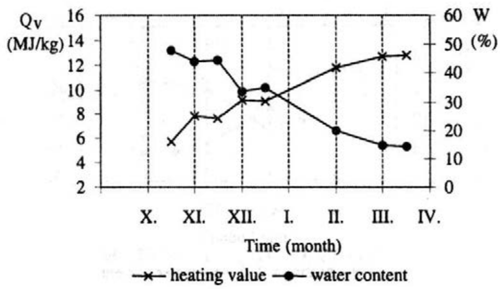


Fig. 7. Relationship between the heating value Q_v and moisture content W and the harvest time of grass

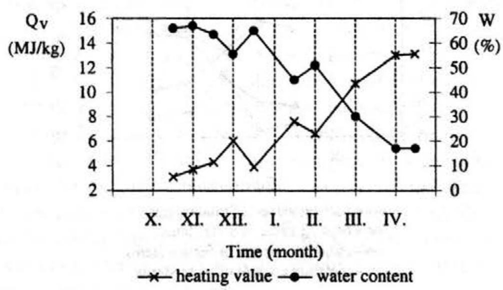


Fig. 8. Relationship between the heating value Q_v and moisture content W and the harvest time of hyso I

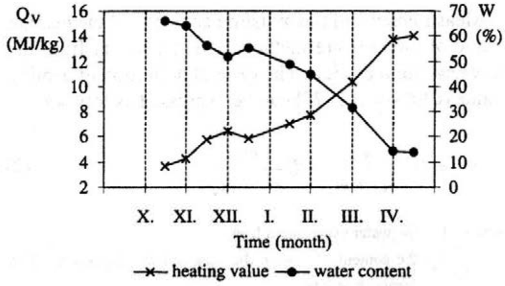


Fig. 9. Relationship between the heating value Q_v and moisture content W and the harvest time of hyso II (stems)

DISCUSSION

The course of biomass moisture content and heating values in relation to the harvest time – taking of samples shows that the highest energy values were exhibited for stems of flax (17.2 MJ/kg), *Miscanthus* and Jerusalem artichoke stems (identically 15.5 MJ/kg). The lower limit of the final heating value was about 12.5 MJ/kg (triticale, male stems of hemp, grass) and only in female stems of hemp the value decreased to 8.1 MJ/kg. Figs. 1–9 correspond to the calculated relation for heating value, equation (4), and show that changes in moisture content and heating value in relation to harvest time represent a mutual mirror image. From the viewpoint of practice, it is possible to use the fact for the prediction of a relatively hardly determinable heating value directly from the moisture content of the energy plant.

The determined heating values of the tested biofuels in relation to their water content set down within the project during last three years show that they have comparable heating values with the most used fossil fuel in our country, i.e. brown coal, viz. 15–17 MJ/kg (ŠPETL 1986) providing that their moisture content is kept lower than 14%. At the same time, however, it is necessary to say that other important comparative parameters as bulk weight (kg/m^3) and energy density (usually GJ/m^3) are even many times more favourable in brown coal (OBERNBERGER 1996).

Data from the long-term monitoring of the development of water content in a number of energy plants, particularly of thick-stalk crops show that after physiological death of organisms the water content gradually spontaneously decreases down to the value of equilibrium moisture content (Figs. 1–9) which usually corresponds to the water activity lower than 0.6 (ŠTENCL 1999). Microbial deterioration of the biomass does not, therefore, occur. Under conditions of the equilibrium moisture content the biofuels show the highest heating value. The final state is, however, reached usually in spring or at the end of winter, exceptionally in December or January (triticale, hemp, flax stems). If it is not possible to harvest the crop in the period of optimum moisture content then it is necessary to dry it. The harvest of energy plants can be carried out by ordinary agricultural means of mechanization. During the long period of drying matter losses occur. In annual plants, gradual 'leaching' of nutrients into the soil is favourable and welcome. The leaching occurs both during the harvest of plants and particularly when the straw is exposed to weather conditions (rain).

Energy plants and cumbustible secondary products of agricultural and forest production can represent particularly a local important source of energy capable to replace up to 10 mil. tonne brown coal per year in the Czech Republic (CHMELÍK 1997). If the biofuels were market fuels in full scale they would have to undergo the process of standardization. A basic condition is to determine the admissible moisture content because the value effects not only heating values but also methods of handling, transport and storage as well as possibilities of further processing, e.g. pressing, briquetting, pelleting etc. Increasing the proportion of biofuels in the national energy budget would make possible to utilize local sources of energy, to create new job opportunities, to decrease fossil fuel mining and their import and to contribute to the improvement of the environment.

References

ČERNOCH S., 1977. Strojně technická příručka. Praha, SNTL: 433.

DISSEMOND H., ZAUSSINGER A., 1995. Stroh – ein nachwachsender Rohstoff für die energetische Nutzung. Bodenkultur, *46*: 63–81.

HALL C. W., 1979. Dictionary of drying. Marcel Dekker, Inc. NY: 208–210.

CHMELÍK K., 1997. Energetické a průmyslové využití plodin z marginálních oblastí. [Závěrečná zpráva.] Praha, VÚZT: 58.

NOSSEK E., 1986. Holzheizen, ein Energieschwerpunkt des Landes Niederösterreich. Wien, Amt der Niederösterreichischen Landesregierung: 27–32.

OBERNBERGER I., 1996. Erforderliche Brennstoffeigenschaften Holz und halmgutartiger Biomasse für den Einsatz in Grossanlagen. Hamburg, Springer Verlag: 53–59.

SLADKÝ V., 1995. Stébelniny jako energetický zdroj pro venkov. EKO, *6*: 15–19.

ŠPETL F., 1986. Fosilní paliva. Praha, SNTL: 85–93.

ŠTENCL J., 1999. Water activity of skimmed milk powder in the temperature range of 20–45°C. Brno, Acta Veter., *68*: 209–215.

Received 18 November 1999

Vliv doby sklizně na vlhkost a výhřevnost biopaliv

ABSTRAKT: V článku jsou uvedeny výsledky uskutečněných měření vlhkosti a výhřevnosti devíti vzorků energetických rostlin v závislosti na době sklizně: topinambur (stonky), *Miscanthus*, triticale, konopí (stonky samčí a samičí), len (stonky), saflor (stonky), travina, hyso I a II (stonky). Vzorky byly odebírány na porostu v období od začátku října do konce dubna ve čtrnáctidenních až měsíčních intervalech v období let 1997–1999. Průběhy naměřených hodnot byly zpracovány graficky. Vlhkost a výhřevnost vytváří v těchto grafech vzájemný zrcadlový obraz. Nejvyšší energetické hodnoty vykázaly stonky lnu (17,2 MJ/kg), *Miscanthus* a stonky topinamburu (shodně 15,5 MJ/kg). Dolní hranice dosažené konečné výhřevnosti byla asi 12,5 MJ/kg (triticale, samčí stonky konopí, travina), pouze u samičích stonků konopí klesla až na 8,1 MJ/kg. Konečného stavu vlhkosti u sledovaných biopaliv, definovaného změnou vlhkosti v měřeném intervalu méně než 10 %, bylo dosaženo převážně na jaře nebo na konci zimy, výjimečně v prosinci nebo v lednu (triticale, konopí, stonky lnu).

Klíčová slova: biopalivo; sklizeň; vlhkost; výhřevnost

Corresponding author:

Doc. Ing. JIŘÍ ŠTENCL, CSc., Mendelova zemědělská a lesnická univerzita, Agronomická fakulta, Zemědělská 1, 613 00 Brno, Česká republika, tel.: + 420 5 45 13 21 16, fax: +420 5 45 21 20 44, e-mail: stencl@mendelu.cz

Affecting the malting barley quality by long-term storage

J. Mareček, L. Sychra, H. Najmanová

Mendel University of Agriculture and Forestry, Faculty of Agronomy, Brno, Czech Republic

ABSTRACT: Long-term storage of high quality lots of malting barley for gradual consumption is one of the possibilities how to ensure the uniform grain quality for storage. Changes in the samples of long-term stored malting barley of the varieties *Akcent*, *Kompakt*, *Krona*, *Olbram* and *Rubín* were monitored in regular intervals for two years using the germination parameters. At the beginning of the storage, the malting barley was treated by controlled ventilation. The analysis shows that the long-term storage does not result in a marked decrease of the malting barley grain quality in terms of the observed parameters. The significant parameter of malting barley quality was germination energy. It reached following values for the beginning and for the end of storage by variety *Akcent* 99.2% and 94.0%, by variety *Kompakt* 98.2% and 99.8%, by variety *Krona* 97.2% and 94.3%, and by variety *Olbram* 97.7% and 94.3%, respectively.

Keywords: malting barley; germination energy; germination index; protein content

Supplying malting barley of uniform quality for malting throughout the whole year until the next harvest has been so far problematic. Differences in the malting barley technological quality in individual years affect also the quality of the produced malt, especially in years with unfavourable climatic conditions during ripening and harvest. Growers face a problem of obtaining the required quality, which is reflected in a market price. A consequent problem is the quality maintenance at handling and storage until the proper malt production.

One of the possibilities how to ensure the malting barley supplies of uniform quality for malting is a long-term storage of the malting barley high quality lots.

This problem is being approached in co-operation with the Mendel University of Agriculture and Forestry in Brno and Research Institute of Brewing and Malting – Malting Institute in Brno. The results obtained so far suggest the suitability of the chosen method.

With regard to the known results of the use of the controlled ventilation in the course of grain storage and results of analyses into the storage type effect on the quality of the grain crops, storage without the active ventilation of the grain in the silo was chosen (Sychra, Hubík 1998). In connection with the previous results (Briggset et al. 1994; Mareček, Sychra 1999) we can assume that under the optimum storage conditions, the same or slightly lower quality of malting barley can be maintained during a long-term (2 years) storage.

MATERIAL AND METHODS

For monitoring of the effect of a long-term storage of malting barley from the 1996 harvest on the grain quality, varieties *Akcent*, *Kompakt*, *Krona*, *Olbram* and *Rubín* were used, i.e. the varieties that were commonly used at that time.

Grain samples of 1.5 kg of the above varieties were put into sacs made of non-woven plastic textile, permeable to air, and placed into a grain layer in a silo. All samples of the varieties were stored in identical conditions. The samples were laboratory analysed at regular intervals for two years.

The silo storage-room had a storage capacity of 1,000 tons. In this storage-room where the samples were placed in the first phase (three months), the system of active ventilation was used. In the second phase (until termination of storage) the grain was not actively ventilated. Throughout the whole storage period the relative grain water content ranged between 13.5% and 15%.

In the regularly collected samples the following grain parameters were determined in the laboratories of the Malting Institute in Brno: protein content in grain, germination energy and germination index (EBC 1998).

An essential quality parameter of malting barley is its ability of uniform and rapid germination. Therefore several methods have been developed for the determination of this parameter. Three of these methods were used in our study.

The dependence of the monitored qualitative parameters on the storage time was analysed in the obtained results using the statistical analysis and determination of Pearson's correlation coefficients. The significance level of the analyses was 95%.

The method of least squares was used for the regression analysis of time dependence of the mentioned qualitative parameters. The coefficients of regression equations were determined in the form $y = a + bx$, where x means storage period in days; further the standard errors, t-statistics and significance of the coefficients were determined. Then the standard deviations, correlation coefficient squares (r^2), significance, Durbin-Watson statistics and

The problem was studied by the Project MSM 432100001.

the logarithmic function of likelihood were determined for the final equation.

For the analytical evaluation of the effect of the monitored malting barley varieties on the changes in the observed parameters during the long-term storage the testing of coincidence of regression lines was performed in all monitored grain parameters in individual varieties. At this evaluation, the data sets for individual varieties passed through the test of null hypothesis of the agreement of absolute terms, slopes and identity of regressions. Consequently, multiple comparisons for slopes and absolute terms of the regression equations were performed by the method of the 95% Tukey – HSD (honestly significant difference) interval. The result of the assays was either rejection or acceptance of the hypothesis, determination of dextral probability and statistical significance of differences, and creation of homogeneous groups of varieties for the individual quality parameters. The storage time of the monitored malting barley varieties was determined by *x*-axis.

RESULTS AND DISCUSSION

The experiment included varieties of high malting quality with optimum protein content in grain. The only exception was the sample of the variety *Krona*, whose content of N-substances ranged between 12% and 12.5%. It means that at the beginning of the experiment, the samples met the requirements for high quality malting barley.

GERMINATION

One of the methods to assess malting barley germination is based on the germination energy. Germination was most affected by storage in the variety *Akcent* (Fig. 1), when the drop of the initial value from 99.2% to 94.0% was observed at the end of the experiment. Table 1 shows that the drop of the germination energy in the course of the storage time is highly significant.

The *Krona* variety showed a different character of the effect of the long-term storage on the germination energy, which increased during two-years from the initial 97.2% to 99.3%, the difference was significant.

The changes in the germination energy in the varieties *Kompakt*, *Olbram* and *Rubín* in the course of time were not significant. However, the variety *Rubín* showed a tendency towards the increasing index. Variety *Olbram* (decreasing from the initial value of 97.7% to 94.3%) showed an opposite tendency. The least change of the germination energy during the long-term storage was observed in variety *Kompakt* (from the initial value 98.2% to 99.8%).

The value of the germination index (Fig. 2), which represents the sample vitality and uniformity of germination, increased in all observed varieties during the period of storage. Variety *Akcent* reached the highest values and at the same time the least change of this index. Therefore the changes of the germination index during the study were not significant in this variety.

Varieties *Kompakt*, *Krona* and *Olbram* reached nearly the same values of the above index and also their changes throughout the observation period were similar. In all these varieties the value of the germination index exhibited a highly significant increase. The initial values increased from 6.7 to 7.7; from 6.4 to 7.7 and from 7.9 to 8.0 in the varieties *Kompakt*, *Krona* and *Olbram*, respectively.

The lowest values of the germination index were observed in variety *Rubín*, though even in this variety a significant increase of the germination index was observed.

The *Akcent* variety is characterized by a short period of post-harvest maturation and a rapid reaching the germination energy and germination index necessary for starting the malt production (PSOTA, PROCHÁZKA 1998). However, during the storage a gradual deterioration of these indices occurs. In contrast, the varieties *Rubín* (PSOTA, PROCHÁZKA 1998) and *Krona* (PSOTA 2000) exhibit a longer post-harvest maturation. During the long-term storage the values of germination energy and uniformity of germination are increasing. In terms of the post-harvest maturation, the varieties *Kompakt* and *Olbram* were between the varieties *Akcent* and *Krona*. The obtained results do not allow to assess whether there is a relationship between the length of the post-harvest maturation and suitability of the variety for the long-term storage.

PROTEIN CONTENT

The long-term storage had no effect on the protein content as we assumed (Fig. 3). This confirms the suitability of the storage conditions used. In the case of unsuitable conditions and higher grain water content, the respiration activity of the grain would have been increased, resulting in a decrease of the sugar content and a simultaneous increase of the protein content. The grain water content and storage temperature have a great impact on the storage

Table 1. The Pearson's correlation coefficients and probability (correlation of quality parameters to storage time)

Variety	Grain proteins		Germination energy		Germination index	
	correlation	probability	correlation	probability	correlation	probability
Akcent	0.1470	0.3081	–0.8599	0.0000	0.4580	0.0498
Kompakt	0.3095	0.1408	0.1509	0.3033	0.7247	0.0017
Krona	–0.2245	0.2201	0.7058	0.0024	0.8071	0.0002
Olbram	0.4282	0.0633	–0.5410	0.0229	0.7013	0.0026
Rubín	–0.1091	0.3553	0.2594	0.1852	0.5665	0.0173

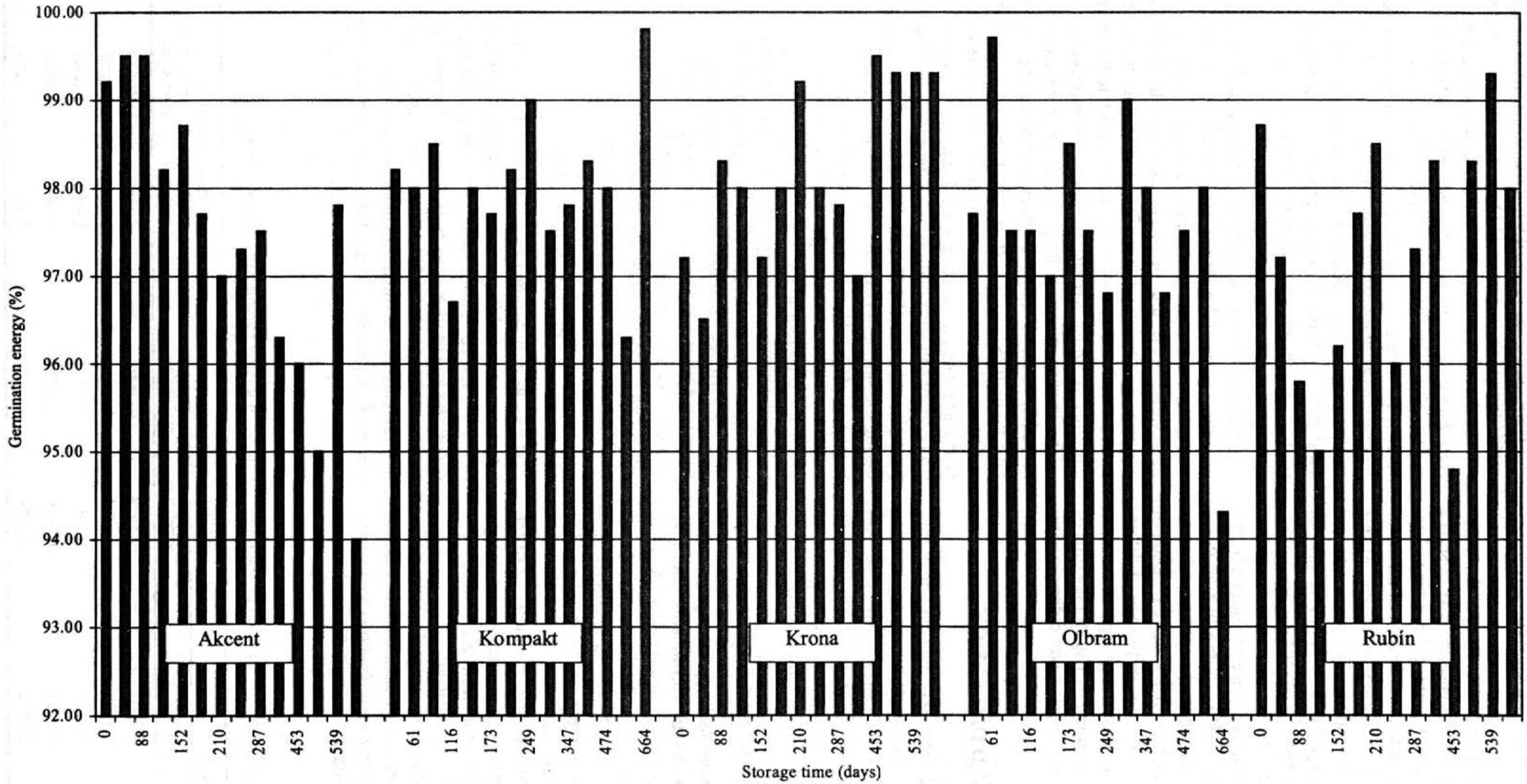


Fig. 1. Effect of storage time on germination energy

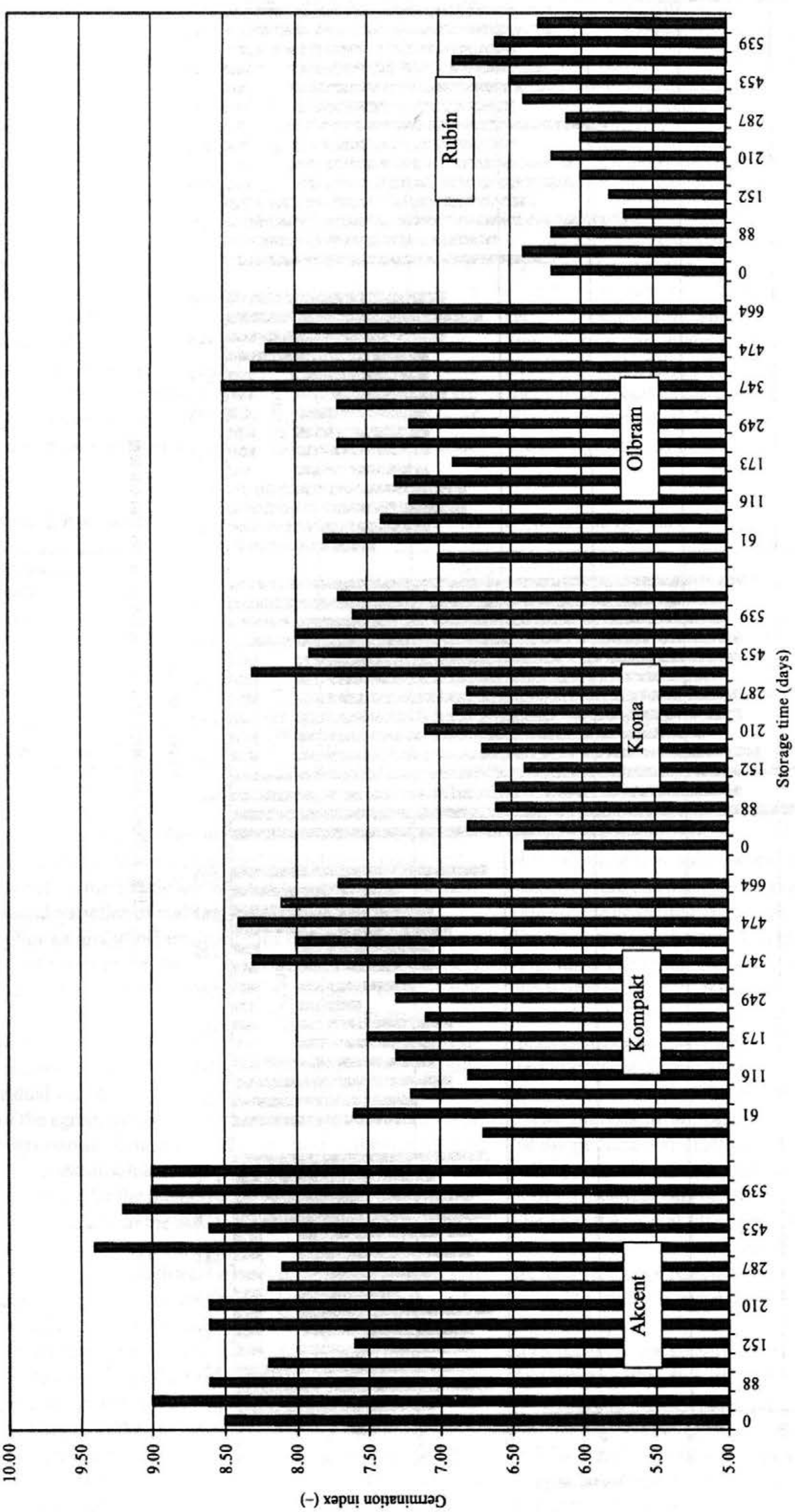


Fig. 2. Effect of storage time on germination index

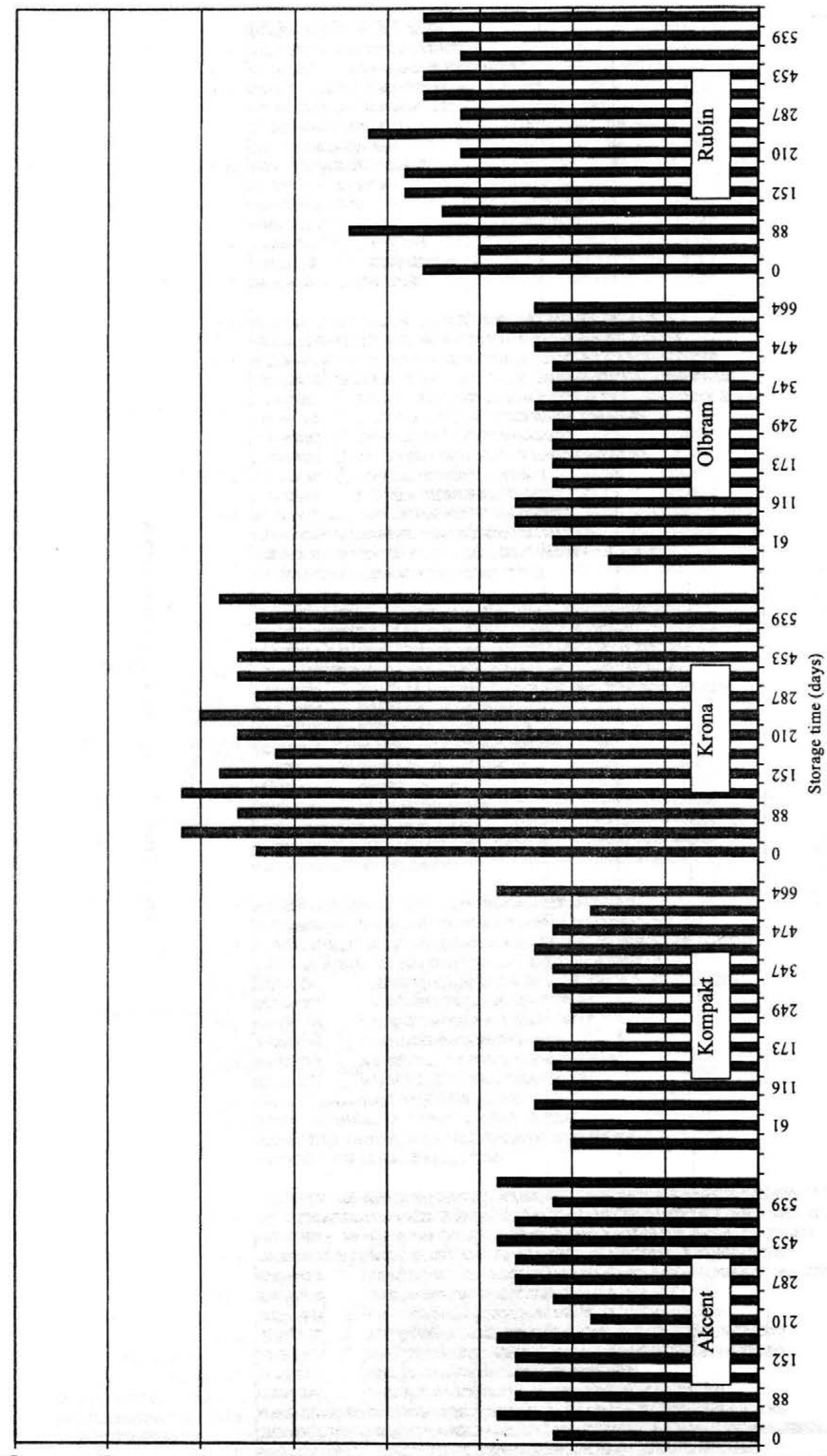


Fig. 3. Effect of storage time on barley grain protein content

time (EBC 1999). Changes in the protein content during the storage were minimum, and therefore the results of the storage time effect on the protein content were not significant (Table 1).

PREDICTION

Based on the obtained results it is possible to determine, with a certain probability, the course of individual parameters monitored during the storage. For this purposes the analysis of regression data adjustment was performed, i.e. the analysis of the above parameters in dependence on the storage times (Table 2). The method of the least squares was used for the determination of the regression adjustment based on the character of the obtained data (time series data). The results of the regression analysis are complementary to those obtained from the analysis of correlation coefficients. They confirm that the significance of the dependence of grain parameters on the malting barley storage time is not equal for all parameters under study. Similarly, marked differences were found among the individual varieties of malting barley.

For an analytical evaluation of the effect of the monitored varieties on the changes of qualitative parameters during the long-term storage, the testing of coincidence of the regression lines was performed in all observed grain parameters (protein content, germination energy, germination index). At this evaluation, the data sets for the individual varieties passed through the test of null hypothesis of the agreement of absolute terms, slopes and identity of regressions. Consequently, multiple comparisons for slopes and absolute terms of the regression equations were performed by the method of the 95% Tukey – HSD interval. The result of the assays was either rejection or acceptance of the hypothesis, determination of dextral probability and statistical significance of differences, and creation of homogeneous groups of varieties for the individual quality parameters. The storage time of the studied malting barley varieties was determined by the *x*-axis.

The analysis of the regression line coincidence for the protein content in the grain of malting barley showed that the chosen null hypothesis on the agreement of all-absolute terms and regressions was rejected regarding highly significant differences. On the other hand, the hypothesis that all slopes are of the same value was accepted due to an insignificant difference. A multiple comparison revealed the existence of two homogeneous groups in which the hypothesis is not rejected, and in the equation of the regression line the same value of the absolute term can be used. It is the case of the groups *Kompakt – Olbram* (common value of the absolute term is 10.5932), and the group *Olbram – Akcent* (common value of the absolute term is 10.6825). The comparison of the regressions showed that the hypothesis of coincidence of all slopes is not rejected, and for all varieties the same slope can be used in the equation of regression line in the form of $y = a + 0.0001x$.

In the comparison with the analyses of other parameters, the results of the analysis of coincidence of regression lines for germination energy are markedly different. In this case, the null hypothesis is not rejected for the agreement of all values of the absolute term regarding the non-significant difference. However, the hypothesis is rejected for the agreements of all slopes and regressions due to a highly significant difference. The multiple comparison of the absolute term values showed that all varieties can be classified into one homogeneous group, and that the same value of the absolute term can be used for all regressions. Then the equation of the regression line is $y = 97.9174 + bx$. A multiple comparison of slopes revealed three homogeneous groups in which the hypothesis on agreement is not rejected. The groups are as follows: *Akcent – Olbram* (regression coefficient –0.0053), *Olbram – Kompakt – Rubín* (regression coefficient –0.0003), and *Kompakt – Rubín – Krona* (regression coefficient 0.0020).

The analysis of the agreement of the regression lines for the germination index resulted in the rejection of the null hypothesis claiming that all values of the absolute term are identical, due to the highly significant difference. The hypothesis that all regressions are identical is also rejected. On the contrary, the hypothesis that all slopes are identical is not rejected due to the insignificant difference. The multiple comparison found one homogeneous group *Kompakt – Olbram*, where the hypothesis on the agreement of the absolute term values is not rejected. An identical value of the absolute term 7.1342 can be used for this group. The multiple comparison of slopes showed that the null hypothesis is not rejected in any of the pairs and that for all regression equations in all varieties an identical slope can be used. The equation of the regression line is $y = a + 0.0017x$.

Table 2. Regression results – ordinary least squares regression $y = a + bx$ (x = storage time)

Dependence variable	Grain proteins				Germination energy				Germination index			
	a	b	R^2	significance	a	b	R^2	significance	a	b	R^2	significance
Akcent	10.7267	0.0001	0.0216	0.6161	99.3565	–0.0072	0.7394	0.0001	8.3088	0.0011	0.2097	0.0996
Kompakt	10.5094	0.0003	0.0958	0.2816	97.8214	0.0007	0.0228	0.6065	6.9966	0.0019	0.5252	0.0034
Krona	12.3762	–0.0002	0.0504	0.4403	97.2172	0.0036	0.4982	0.0048	6.4164	0.0026	0.6514	0.0005
Olbram	10.5675	0.0003	0.1833	0.1267	98.4814	–0.0034	0.2926	0.0458	7.1715	0.0018	0.4918	0.0052
Rubín	11.3220	–0.0001	0.0119	0.7105	96.7104	0.0019	0.0673	0.3704	5.9882	0.0009	0.3209	0.0347

CONCLUSION

We can assume, based on the monitoring and the obtained results, that the maintenance of suitable parameters during the long-term storage of malting barley allows to keep the grain quality on a suitable level for the subsequent processing in the malt production. In the monitored technological parameters characteristic for malting barley, only a minimum quality changes were recorded, and in some cases the values of the qualitative technological indices were even improved (N-substances in grain, germination energy, germination index) during the two-year storage.

We can therefore assume a continuation of the development of the monitored indices, i.e. of the energy and index of germination. It was found that the differences in grain quality during the storage can be mainly ascribed to the variety, which was confirmed by the results of testing the regression adjustment coincidence.

It further follows out of the obtained results that the first period of the grain storage is most important for the grain stabilization and condition. In this period, the use of active ventilation in grain silos and storehouses is desirable. After this stabilization phase, the use of active ventilation is not necessary provided that a sufficient heat and water content stabilization of the grain can be ensured.

References

BRIGGS D.E., WOODS J.L., FAVIER J., 1994. Drying and storage treatments for overcoming dormancy in malting barley. J. Inst. Brew., *100*: 271–278.

EBC, 1998. Analytica-EBC. Carl, Getränke-Fachverlag, Nürnberg.

EBC, 1999. Results Field Trials Harvest 1998. Zoeterwoude, April.

MAREČEK J., SYCHRA L., 1999. The Changes of Wheat Quality by Long-Term Storage. In: Technology for Competitive Agriculture and Food Industry. Brno:16.

PSOTA V., 2000. Ječmen jako sladovnická a pivovarnická surovina. In: Jačmeň, výroba a zhodnotenie. Nitra: 85–98.

PSOTA V., PROCHÁZKA S., 1998. IAA. ABA, and germination of spring barley caryopses during post-harvest maturation. J. Inst. Brew., *104*: 105–107.

SYCHRA L., HUBÍK K., 1998. Vliv skladování na technologickou jakost zrna pšenice a sladovnického ječmene. In: Problematika N-látek v rostlinných produktech. Kroměříž: 66–68.

Received 12 July 2000

Ovlivnění kvality sladovnického ječmene při dlouhodobém skladování

ABSTRAKT: Víceleté uskladnění kvalitních partií sladovnického ječmene k postupné spotřebě je jednou z možností zajištění vyrovnané kvality zrna ke sladování. Pomocí parametrů klíčení byly v pravidelných časových intervalech po dobu dvou let sledovány změny u vzorků dlouhodobě skladovaného sladovnického ječmene odrůd *Akcent*, *Kompakt*, *Krona*, *Olbram* a *Rubín*. Na počátku skladovacího období byl sladovnický ječmen ošetřen aktivní ventilací. Z analýzy vyplývá, že při dlouhodobém skladování nedochází k výraznému poklesu sledovaných parametrů kvality zrna sladovnického ječmene, u některých parametrů dochází dokonce ke zlepšování počátečních hodnot. Nejvýznamnějším ukazatelem sladovnického ječmene je energie klíčení, která dosahovala na počátku a na konci skladování u odrůdy *Akcent* hodnot 99,2 % a 94,0 %, u odrůdy *Krona* 97,2 % a 94,3 %, u odrůdy *Olbram* 97,7 % a 94,3 %, u odrůdy *Kompakt* 98,2 % a 99,8 %. Pomocí regresních rovnic je na základě znalosti počáteční kvality zrna sladovnického ječmene možné předpokládat vývoj kvality v průběhu skladování, a to pomocí lineární regrese ve tvaru $y = a + bx$.

Klíčová slova: sladovnický ječmen; energie klíčení; index klíčení; obsah bílkovin

Corresponding author:

Doc. Ing. JAN MAREČEK, CSc., Mendelova zemědělská a lesnická univerzita, Agronomická fakulta, Zemědělská 1, 613 00 Brno, Česká republika, tel.: + 420 5 45 13 21 01, fax: + 420 5 45 13 29 14, e-mail: marecekj@mendelu.cz

Effects of a mower-conditioner on herbage at forage harvesting

Ľ. Gonda, M. Kunský, N. Gáborčík

Grassland and Mountain Agriculture Research Institute, Banská Bystrica, Slovak Republic

ABSTRACT: The physiological processes in plants do not cease to exist after cutting but are continuing during a certain period of time. The nutrient and water intake is getting weaker and plants are dehydrated. The dehydration period should be as short as possible to prevent nutrient losses in swaths. The initial water content in the harvested herbage (about 200 g/kg) should be reduced to 350–550 g/kg as soon as possible. The required acceleration of drying by conditioning complies with biological processes in mown crop. The results of field and laboratory trials testing a prototype (MD 5-K) swath conditioner integrated into a disc mower are presented. The conditioner markedly destructed the plants and their leaf area at a range of 86.8–85.6% of the treated swath and the destruction was sufficient for the required acceleration in the swath drying. A significant impact of the active working rotor parts was found in the conditioned swath in permanent grassland. A comparison under identical conditions showed that the swaths conditioned by MD 5-K dried 3–3.5-fold faster to the hay storage water content (200 g/kg) than those without conditioning.

Keywords: mower-conditioner; permanent grassland; swath water content; frequency of rotation

The rate of herbage wilting in the field after cutting can be accelerated by conditioners that crimp and bruise plant stems alongside but do not affect leaves, or stems are fractured at a certain span (30–50 mm). Those techniques can be used in various combinations, depending on machinery type and construction.

The conditioning of crop at mowing increases the rate of wilting and allows for haylage harvesting on the day of cutting. Under rainy weather, moisture sorption by herbage increases but decreases easily again.

Crimping and abrasion disturbs the protective waxy film of stems at a number of places, but the plant structure is preserved and swath aeration is sufficient for good exchange of air and accelerated drying.

At traditional forage harvesting (cutting, turning, tedding) the required water content was achieved no earlier then the next day after cutting. By conditioning, the adequate water content was obtained on the day of cutting. Conditioning of fresh herbage has mechanical impact on plants but without increased losses by fragmentation. Water contained in plant cells is released freely due to the effects of machine working tools.

There are two technological principles of swath conditioners currently known:

a) bruising, fracturing and abrasion of stems,

b) squeezing or crimping of stems.

These two technological principles are provided by machines known as conditioners. The conditioners can be divided into two groups in compliance with the type of working tools they use:

A) finger conditioners,

B) roller conditioners.

The basic technological scheme is presented in Fig. 1. Results of a range of experiments (Lobotka 1976; Klin-

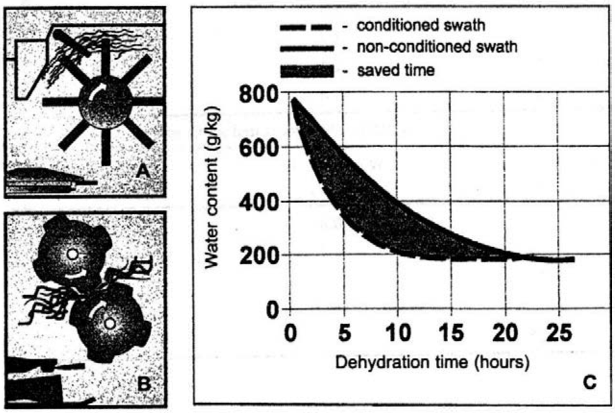


Fig. 1. The basic technological scheme of swath conditioners

A – Stem fracturing – finger conditioner

B – Stem squeezing and crimping – roller conditioner

C – Dehydration effects of conditioners

NER 1976; PŇAČEK 1980) favoured the mechanical treatment. The conditioned swaths dried more evenly. Under favourable weather conditions, mown herbage can be preserved as haylage on the day of cutting without any other treatment (very important). Within one day, dry matter (DM) content of swath increased from the initial 275 g/kg to 468 g/kg, that is appropriate to preserve herbage as wilted silage without additives. On the next day, DM content of herbage rose to 637 g/kg, that is sufficient for making hay with additional drying by cold air.

MATERIALS AND METHODS

Field and laboratory trials were carried out to study the following parameters:

a) basic characteristics of ground area covered by sward,
b) sward characteristics,
c) environment characteristics,
d) swath characteristics.

At the trials, ZETOR 72 45 HORAL tractor and MD 5-K conditioner were used.

MD 5-K conditioner technical information:

Total working width	(mm)	3,222
Total length	(mm)	1,300
Total height	(mm)	1,228
Weight	(kg)	530
Working span width	(mm)	2,100
Rotor working diameter	(mm)	546
Number of working tools	(pieces)	20
Basic frequency of rotation	(s)	12.5
Working efficiency	(km/hour)	3–7

The field trials were performed at the site of PD Liptovská Teplička Cooperative Farm.

RESULTS AND DISCUSSION

Table 1. Sward and ground area characteristics

		4 June 1996	6 June 1996
Slope gradient	(°)	3–5	4–7
Ground area volume	(kg/m)	1.578	1.480
Ground area water content	(g/kg)	653.4	421.2
Penetration resistance	(Mpa)	2.2	1.5
Mean herbage yield	(kg/m)	1.84–2.05	2.86–3.10
Sward height	(mm)	294.9	405.5
Sward water content	(g/kg)	820–870	810–850

Botanical composition of sward was as follows:

– grasses 85%,
– legumes 7%,
– other herbs 8%.

Weather conditions during the trials

Velocity of water deficit is a function of parameters, such as air humidity and temperature, wind speed and sunshine, that are influencing temperature and humidity of the atmosphere.

The data measured during the research are given in Table 2.

Swath characteristics

The impact of rotor movement on mown plants was determined by statistical analysis of 500 plants.

The damage of plants was assessed visually, namely partly broken stems, visible abrasion, broken leaf blades, squeezed spots on stems.

Table 2. Weather conditions during the trials

4 June 1996		Overcast day, before a thunderstorm		
Time (hours)	Relative humidity (%)	Air temperature (°C)	Wind velocity (m/s)	Solar radiation (W/m)
12.00	80	20	1.5	328
14.00	81	23	2.2	154
16.00	82	22	2.1	98
18.00	82.5	20	3.4	53
6 June 1996		Sunny, temperature measured in the sun		
Time (hours)	Relative humidity (%)	Air temperature (°C)	Wind velocity (m/s)	Solar radiation (W/m)
9.00	64	17	0.8	369
11.00	59	23	1.7	500
13.00	44	27	2–3	477
15.00	47	28	2	423
17.00	46	25	2–3	408

Table 3. Plant length in the conditioned swath

		4 June 1996	4 June 1996	6 June 1996
Frequency of rotation	(min)	760.0	860.0	860.0
Maximum length	(mm)	690.0	740.0	690.0
Medium length	(mm)	316.3	300.9	411.0
Minimum length	(mm)	80.0	60.0	70.0

It was recorded that

- at 760 min frequency of rotation and mean plant length of 316.3 mm:
  - 47.2% of plants showed 1–2 damaged spots,
  - 28.8% of plants showed 2–2.5 damaged spots,
  - 19.6% of plants showed 3–4 damaged spots,
  - in total, 95.6% of plants were damaged;
- at 860 min frequency of rotation and mean plant length of 300 mm:
  - 26% of plants showed 1–2 damaged spots,
  - 33% of plants showed 2–2.5 damaged spots,
  - 27.8% of plants showed 2.5–4 or 5 damaged spots,
  - in total, 86.8% of plants were damaged.

The higher frequency of rotation resulted in increased number of bruised plants, namely 48.4% of plants had 2.5–4 damaged spots at the rotation frequency of 760 min and 60% of plants had 2.5–4 or 5 damaged spots at 860 min frequency of rotation. The number of bruised plants with 1 or 2 damaged spots at 860 min frequency of rotation dropped nearly twofold in comparison with the identical number of damaged spots at 760 min frequency of rotation.

Considering the number of damaged spots, the efficient frequency of rotation ranged between 800 and 860 min and the bottom value was specified by lower amount of lacerated and fallen-off leaves.

The analysis showed on average 90% plant damage from the viewpoints of drying out and kinematics of the conditioner movements (especially the rotor).

Velocity of water deficit decrease

The velocity of water deficit decrease ranks among the most important parameters of forage harvesting techniques. The parameter was determined by the loss of water in a sample of herbage over the defined time intervals. In the trial, the sample weight (m_t) was determined once in 2 hours and the water content of swath was calculated as follows:

$$W_t = \left[\frac{m_0}{m_t}(W_0 - 1) + 1\right] \cdot 100\,(\%)$$

where: W_0 – initial water content in the sample (%),
m_0 – initial sample weight at W_0 (kg, g),
α – the constant calculated from the measured data.

The course of mean water content in the conditioned and non–conditioned swaths is given in Tables 4 and 5.

CONCLUSIONS

The mathematical statistical analysis of field and laboratory trials showed that the significant amount of bruised plants ranged between 86.8 and 95.6% in swaths treated by MD 5-K conditioner (Fig. 2).

Such a degree of plant damage was sufficient for the required accelerated velocity of swath wilting and drying. In the trials, the frequency of rotation was 760 and 860 min. The slower rotation (760 min) resulted in less off-fallen bruised leaves. The impact of the working rotor of the

Table 4. Mean water content in the non-conditioned swath over the time after cutting

Date	4 June 1996		6 June 1996	
α	0.0095	0.0019	0.022	0.021
Time (hours)	Swath water content (%)	Swath water content (%)	Swath water content (%)	Swath water content (%)
0	87.10	86.70	85.20	83.90
2	85.46	85.15	81.53	80.44
4	83.85	83.63	78.02	77.14
6	82.27	82.14	74.66	73.96
8	80.72	80.67	71.45	70.92
10	79.20	79.23	68.37	68.00
12	77.71	77.82	65.46	65.21
14	76.25	76.43	62.61	62.52
16	74.81	75.07	59.91	59.95
18	73.40	73.73	57.34	57.49
20	72.02	72.41	54.87	55.12
22	70.67	71.12	52.50	52.85
24	69.34	69.85	50.24	59.68

Table 5. Mean water content in the non-conditioned swath over the time after cutting

Date	4 June 1996		6 June 1996	
α	0.0019	0.0019	0.033	0.029
Time (hours)	Swath water content (%)	Swath water content (%)	Swath water content (%)	Swath water content (%)
0	85.76	84.53	83.80	84.20
2	82.89	81.37	78.44	79.45
4	80.12	78.34	73.43	74.97
6	74.44	75.42	68.74	70.75
8	74.85	72.61	64.35	66.76
10	72.35	69.90	60.24	63.00
12	69.93	67.29	56.39	59.45
14	67.59	64.78	52.49	56.10
16	65.33	62.37	49.42	52.94
18	63.15	60.04	46.26	49.95
20	61.04	57.80	43.31	47.14
22	59.00	55.65	40.54	44.48
24	57.02	53.57	37.95	41.98

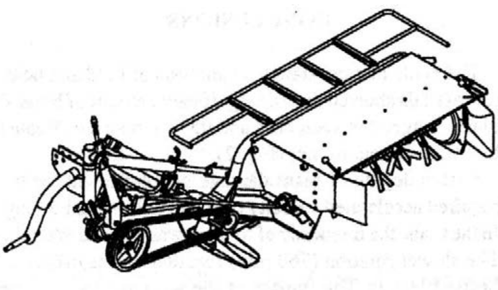


Fig. 2. MD 5-K conditioner

conditioner on swath was significant at permanent grassland. Under similar field and climatic conditions, the mechanically conditioned swath dried up to the hay storing humidity 3–3.5-fold faster than the non-treated swath.

Under sunshine and air temperature of 28°C, the decrease in humidity of non-conditioned swath was 11.06–12.8% within 6 hours, and the decrease in the conditioned swath was 12.55–16.21%.

The use of conditioner in forage harvesting is not only an option, but a necessity. Only by incorporation of the conditioner into the forage harvesting machinery a continual harvest can be achieved required by new ecologically clean techniques especially for wilted silage making without additives and with the objective of good quality parameters of feeds.

References

KLINNER W.E., 1976. Mechanical and Chemical Field Treatment of Grass for Conservation. Silsoe, NAIE: 1–27.

LOBOTKA I., 1976. Výskum mechanizovanej manipulácie s jemno-stebelnými krmovinami v aridných oblastiach na pokose. [Výskumná správa.] Rovinka, VÚPT: 61.

PŇAČEK F., 1980. Štúdium vhodného zariadenia pre mechanickú dehydratáciu trávnych porastov. [Výskumná správa.] Banská Bystrica, VÚLP: 126.

Received 2 February 2000

Upravovače pokosu v zbere tenkostebelných krmovín

ABSTRAKT: Po pokosení rastlín pri zbere krmovín sa ich životné pochody nezastavujú, ale prebiehajú po určitú dobu ďalej. Prívod živín a vody postupne slabne a nastáva obdobie dehydratácie rastlín. Aby sa predišlo zbytočným stratám živín v pokose, je potrebné obdobie dehydratácie maximálne skrátiť, to znamená čím rýchlejšie znížiť počiatočnú vlhkosť zberanej krmoviny, ktorá sa pohybuje okolo 800 g/kg, na 350–550 g/kg. Požiadavka zrýchlenia procesu sušenia rastlín po mechanickej úprave je v súlade s biologickými procesmi, ktoré prebiehajú v pokosených rastlinách. V príspevku sú uvedené výsledky poľno-laboratórnych skúšok prototypu mechanického upravovača pokosu, integrovaného celku s diskovou kosačkou. Zistili sme, že upravovač pokosu (kondicioner s označením MD 5-K) výrazne naruší stavbu rastlín a listovú plochu v rozsahu 86,8–85,6 % v upravenom pokose. Toto porušenie rastlín je postačujúce na požadované zvýšenie rýchlosti vysýchania pokosu. Účinok aktívnych prvkov pracovného rotora pri upravených pokosoch z trávnych porastov bol preukazný. Pri rovnakých podmienkach pokosy upravené mechanickým upravovačom MD 5-K vyschli na skladovateľný obsah vlhkosti sena (200 g/kg) trikrát až 3,5-krát rýchlejšie než neupravené pokosy.

Kľúčové slová: upravovač pokosu; trvalé trávne porasty; vlhkosť pokosu; frekvencia otáčania rotora

---

Corresponding author:

Ing. ĽUBOMÍR GONDA, CSc., Výskumný ústav trávnych porastov a horského poľnohospodárstva, Mládežnícka 36, 974 21 Banská Bystrica, Slovenská republika, tel.: + 421 88 41 32 541–3, fax: + 421 88 413 25 44, e-mail: gonda@vutphp.sk

Impact of the mechanical treatment of fodders on their drying speed

J. Šesták, J. Gaduš, G. Ryban, J. Pršan, C. Gyurián

Slovak University of Agriculture, Faculty of Mechanization, Nitra, Slovak Republic

ABSTRACT: Quick drying of freely mowed fodders in the field makes it possible to shorten the period from their mowing to storage. It also decreases the loss of nutrients as well as dry substances and ensures quicker renewal of a new cover. Mowed fodders left in the field for 2–24 days lose 1.2% of dry substances per day. To make the process of drying quicker, various types of mechanical deformations of plants are applied, which is done by means of constructionally appropriately arranged elements. The most important is the use of stalk cutters and grinders. It was determined that the period of cover withering with the production of 25–30 t/ha of green substance, if grinders, tedders and drum trimmers are applied, is about 8–10 hours what is suitable for ensuring of 35 up to 48% of dry substance content. Intensity of drying depends on many factors. First, it is the proportion of air humidity, its temperature, saturation deficit, solar radiation, speed of the air above the mowed fodders and windblast convection. Among the inner factors it is the ability of plants to bind water. The loss of water is very quick with mowed plants and it gradually decreases and finally it stops. The paper presents a new approach to mechanical deformations of mowed fodders. Field experiments with the aggregate – disk mower of the type MARAGON MD 5 with an adapted drum trimmer – showed its full utilization in operation. Technological change of its mechanical efficiency was ensured by means of application of a comb and a shield into the fodder flow. Comparison of untreated and treated mowed fodders showed the following practical conclusions: the biggest effect on the speed of drying of the mowed fodder has the application of a trimmer shield into the fodder flow; the biggest impact on micro deformations of plants is due to the shield; application of the shield into the fodder flow creates the best form of the mowed fodder (line teddered, vertically formed with an effective wind blast).

Keywords: fodders; mechanical treatment; drying

The treatment of mowed fodders means employing energy, chemical processes or herbicides in such a way, that in plants begin such physical and chemical changes, which conduce to reduction of the moisture content (water) in plants. In practice many mechanical effects lead to unsuitable deformation of plants, which lead to (especially when rain) high loss of nutrients and decrease of quality of the fodder. By reducing these undesirable effects, especially in mechanical parts, as well as leaving the rows of mowed fodders in open row form, we can get suitable microclimatic conditions as the basis for the development of aggregates assembled from a mower and a drum trimmer.

The technological and constructional classification of trimmers is based on their basic influence on mowed fodders (KLINNER 1975). They include, first of all, the grinders with different types of grinding cylinders (ŠESTÁK et al. 1992). Their working widths range between 1–3 m, diameters of cylinders are 0.165–0.264 m, rotor speeds are 6.9–9.2 m/s, pressures between the cylinders are 40–50 N/cm and their deformation efficiencies are 10–18% (KOROLOVICS et al. 1978).

The second types of trimmers are the drum trimmers. These deform the surfaces of plants, and this causes that the active surface of plants for the evaporation of free water raises. At the same time the rows with "chimney" effect are created, and the microclimatic conditions of drying are improved. Usually they are assembled either with the rotational mowers or with the disk mowers. They can also operate independently with the rail placed at the front. The field tests, carried out by ŠESTÁK et al. (1992) and ŠTRÁFELDA, VELICH (1981), proved that in European conditions these are the most suitable ones.

MATERIAL AND METHODS

The MARAGON MD 5 mower assembled with a drum trimmer was used in the field tests, which had to prove the effect of mechanical treatment of fodders on drying speed. The overall view of the aggregate can be seen in Fig. 1; the basic technical and exploitation parameters are in Table 1.

Table 1. Basic technical and exploitation parameters of the aggregate

Tractor		ZTS Turbo 18345
PTO speed	(rpm)	540
Mean working speed	(m/s)	1.35
Working width of the mower	(mm)	2,050
Type of the mower		MARAGON MD 5
Number of working discs	(pcs)	5
Number of knives per disc	(pcs)	2
Width of the trimmer rotor	(mm)	1,400
Diameter of the trimmer rotor	(mm)	550
Number of fingers on the rotor	(pcs)	18
Rotor speed	(rpm)	750
Placement of the aggregate		hydraulically changed

Fig. 1. The overall view of the aggregate

The experiments were carried out in the location of Žirany, part of the School Agricultural Farm Kolíňany, from June 9 through June 11, 1998.

The soil parameters can be seen in Table 2.

The humidity of soil and plants was determined according to standard STN 46 7092. The penetration resistance was measured according to standard STN 47 0121.

The input characteristics of plants are described in Table 3, the botanical combination of plants is shown in Table 4.

Table 2. Terrain parameters

Tilt angle of the pavement	(deg)	3–5
Density of the soil	(kg/m³)	1,430
Moisture content in the soil	(%)	40.80
Penetration resistance of the soil	(Mpa)	202

Table 3. Stand characteristics

Parameter		Measurement		
		1	2	3
Mean crop	(kg/m²)	2.76	2.90	2.60
Mean height of the plants	(m)	0.72	0.68	0.78
Moisture content	(%)	62.00	63.50	58.20

Table 4. Botanical composition of the stand

Plant	(%)
Kentucky blue grass	26
Meadow fescue	10
Orchard grass	21
False oat	4
Clovers	21
Meadow grass	5
Other plants	13

The characteristics of mowed fodder were gathered from six rows: first two rows were disarranged – mowed fodder was created by means of the disc mower KUHN GMD 500, the following two rows were arranged by means of a trimmer shield into the fodder flow and the last two rows were arranged by means of application of a raising comb into the flow of the mass behind the disc mower. These parameters can be seen in Table 5.

The speed of water deficiency (loss of humidity in mowed fodders) was determined by means of weighting the mowed fodder on measurement frames in defined time intervals (in principle every two hours). The observed row was carefully slid on the wire frame in such a way that its structure and construction was deformed only to minimum by the aggregate. Every two hours (in average) the mass of the sample on frame ($m_{(t)}$) and quotient of the momentary moisture content were calculated with the use of formula:

$$W_{(t)}=\left[\frac{m_0}{m_{(t)}}(W_0-1)+1\right]\cdot 100\,(\%) \qquad (1)$$

where: m_0 – the initial weight of fodder on the measurement frame,
W_0 – the quotient of the moisture content of fodder whose weight is m_0. It was determined in a laboratory by drying the sample up to the constant mass.

Table 5. Experiment organization

Number of the row	Treatment	Weight per meter (kg/m)	Mean height of the rows (cm)
1	untreated	4.7	7.3
2	untreated	5.0	6.8
3	comb	5.0	7.5
4	comb	5.1	6.9
5	shield	4.6	7.3
6	shield	4.1	8.2

Simultaneously, following parameters were recorded by means of a thermo-hydrograph changes of air humidity and its temperature. The anemometer was used to measure the air ventilation, described by airflow velocity above the mowed fodders. These and other supplementary climatic data are fixed in the graphical demonstration of the process of drying. The shape of the fodder rows is shown in Fig. 2, measurement of the rows profile can be seen in Fig. 3.

Fig. 2. The shape of the fodder rows

Fig. 3. The rows profile measurement

RESULTS AND DISCUSSION

The measured and calculated values of the speed of water deficiency – the speed of drying are listed in Table 6. The initial moisture content was determined in the first measurement of that day by drying the substance into the constant mass in a laboratory. Other changes of fodder relative humidity were calculated by equation (1).

The full characteristic of drying process is shown in Figs. 4–6. In the working diagrams climatic conditions were added under the condition, that it does not rain.

Some approximation functions with high evidence were statistically added to all measured values in such a way as it is described in pictures. The determined approximation function in the formula (2) seems to be applicable:

$$y = A \cdot e^{-k \cdot x} \qquad (2)$$

where: y – the fodder moisture content (%),
x – the drying time (h),
A – a constant.

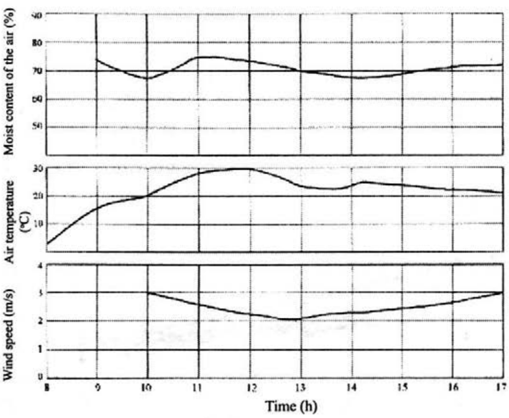
The signs in the figures correspond to this: h – fodder treated by the comb, c – fodder treated by the shield, ku – disarranged fodder.

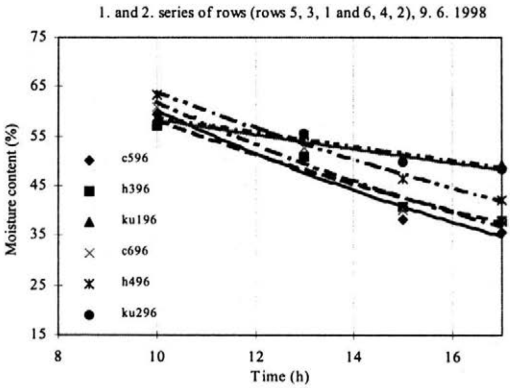
Table 6. Moisture loss in swaths

Date	Time	Untreated				Treated by the comb				Treated by the shield			
		1st row		2nd row		3rd row		4th row		5th row		6th row	
	(h)	moisture content (%)	weight (kg)	moisture content (%)	weight (kg)	moisture content (%)	weight (kg)	moisture content (%)	weight (kg)	moisture content (%)	weight (kg)	moisture content (%)	weight (kg)
	10	58.06	4.70	57.72	5.00	57.18	5.00	63.34	5.10	59.30	4.60	60.96	4.10
9. 6.	13	54.35	4.26	53.53	4.55	47.99	4.12	53.16	3.99	47.65	3.58	49.53	3.17
1998	15	51.69	4.03	50.91	4.31	42.70	3.74	47.30	3.55	41.19	3.18	43.13	2.81
	17	49.16	3.83	48.42	4.10	37.99	3.45	42.09	3.23	35.60	2.91	37.56	2.56
	8	52.51	4.10	44.23	3.79	47.60	4.09	46.09	3.47	45.30	3.42	45.50	2.94
	10	48.84	3.81	41.14	3.59	40.93	3.62	39.63	3.10	38.37	3.04	38.54	2.60
10. 6.	12	45.43	3.57	38.27	3.42	35.19	3.30	34.08	2.84	32.50	2.77	32.65	2.38
1998	14	42.26	3.37	35.59	3.28	30.26	3.07	29.30	2.64	27.53	2.58	27.65	2.21
	16	39.31	3.21	33.11	3.16	26.02	2.89	25.19	2.50	23.32	2.44	23.42	2.09
	18	36.56	3.07	30.80	3.05	22.37	2.76	21.66	2.39	19.75	2.33	19.84	1.20
	8	30.35	2.79	35.60	3.28	26.18	2.90	27.19	2.57	26.03	2.53	26.13	2.17
	10	27.67	2.69	32.45	3.13	25.22	2.86	26.20	2.53	24.92	2.49	25.01	2.13
11. 6.	12	25.22	2.60	29.60	3.00	24.30	2.83	25.24	2.50	23.85	2.46	23.95	2.10
1998	14	22.99	2.53	26.97	2.89	23.42	2.80	24.32	2.47	22.84	2.43	22.92	2.08
	16	20.96	2.46	24.58	2.80	22.56	2.76	23.43	2.44	21.86	2.40	21.94	2.05
	18	19.10	2.41	22.41	2.72	21.74	2.74	22.58	2.41	20.93	2.37	21.01	2.03

Every treatment, as it was described in the methodology part of this article, was carried out twice, and the even and uneven rows were assessed separately.

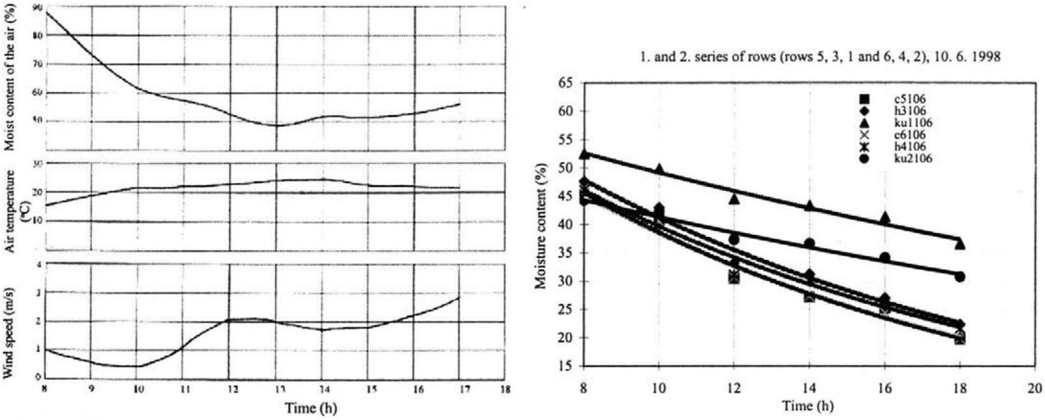
The process of drying in the first day (9. 6. 1998), shown in Fig. 4, proved that the lowest speed of drying was achieved in untreated fodder (ku). The moisture content of fodder decreased from 58.6% (57.7%) to 49.15% (48.4%) in the period from 10 a.m. to 5 p.m. This is also reflected in the low value of exponent in the approximation function: –0.0266 (–0.0271). The highest influence on drying had the application of the shield, when the exponent expressing the drying speed is –0.0742 (0.0781) and the moisture content decreased from its initial value of 59.3% (60.96%) to 35.5% (37.5%). The influence of the application of a comb on mechanical damage compared to the shield was lower, what is represented by exponents: –0.062 (–0.060).





$y = 131.64e^{-0.0781x}$ $R^2 = 0.9497$; $y = 76.535e^{-0.0271x}$ $R^2 = 0.9257$; $y = 117.23e^{-0.0604x}$ $R^2 = 0.9835$; $y = 108.6e^{-0.0624x}$ $R^2 = 0.9496$; $y = 76.832e^{-0.0266x}$ $R^2 = 0.9632$; $y = 130.05e^{-0.0742x}$ $R^2 = 0.9489$

Fig. 4. Characteristics of drying process – 9. 6. 1998



$y = 69.239e^{-0.0343x}$ $R^2 = 0.9668$

$y = 88.237e^{-0.0826x}$ $R^2 = 0.9829$

$y = 86.962e^{-0.0746x}$ $R^2 = 0.981$

$y = 58.531e^{-0.0349x}$ $R^2 = 0.9753$

$y = 85.904e^{-0.0805x}$ $R^2 = 0.9729$

$y = 83.272e^{-0.0742x}$ $R^2 = 0.9667$

Fig. 5. Characteristics of drying process – 10. 6. 1998

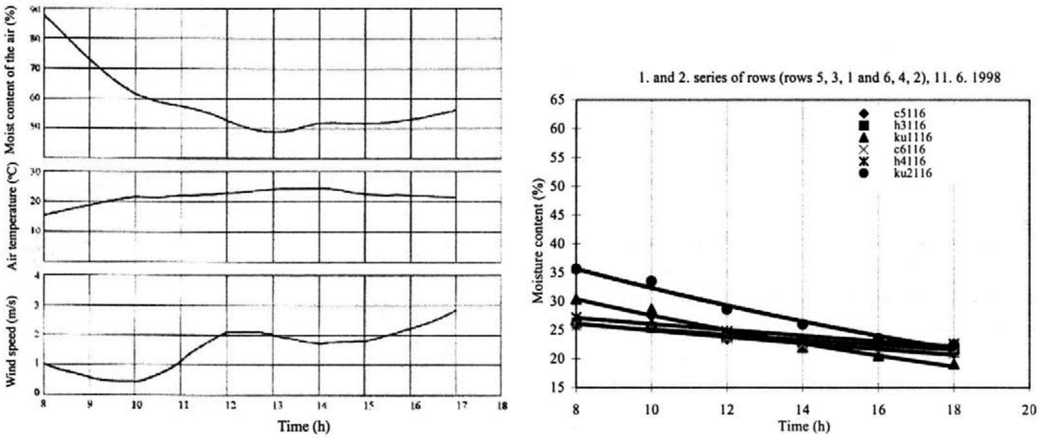
The evaluation of drying speed in 1st day proved, that:

- the highest influence on drying had the shield, which was implemented into mechanical damage of the fodder; the intensity of releasing humidity compared to the untreated fodder was 2.8 times higher;
- the influence of shield compared to the comb is 1.25 times higher.

Evaluation of the 2nd day of running experiments (10. 6. 1998) revealed, that the untreated fodder takes back the least humidity (~ 4%) (Fig. 5). The row treated by the shield takes back the highest humidity (~ 8.5%). The highest intensity of drying showed again, however, the treated rows (by shield) – the exponents of the approximation functions –0.0805 (–0.082) prove that. The difference of the moisture content was ~ 25% during the whole process of drying. After such treatment the fodder reached the appropriate moisture content for storage: 20%.

Untreated fodder was drying the longest time, what is documented by the exponent values of –0.034 and –0.0349.

The drying speed of fodders treated by the shield was ~ 2.3 times higher than that of untreated fodder.



$y = 44.835e^{-0.0487x}$ $R^2 = 0.9763$

$y = 30.375e^{-0.019x}$ $R^2 = 0.9783$

$y = 31.653e^{-0.0234x}$ $R^2 = 0.942$

$y = 31.461e^{-0.0232x}$ $R^2 = 0.9789$

$y = 52.933e^{-0.0494x}$ $R^2 = 0.9802$

$y = 31.902e^{-0.0202x}$ $R^2 = 0.9369$

Fig. 6. Characteristics of drying process – 11. 6. 1998

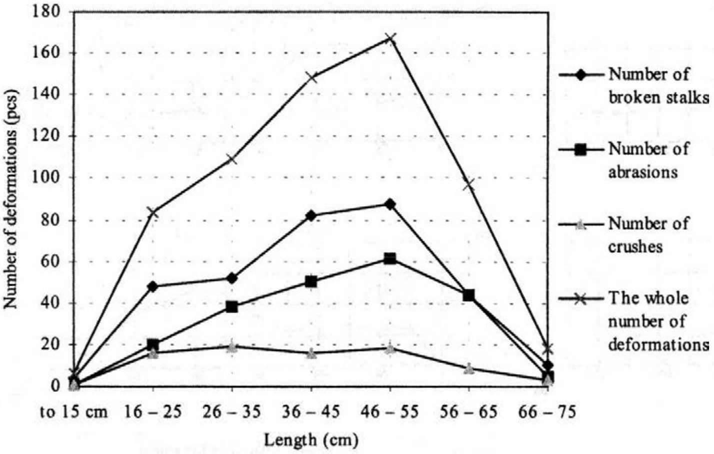


Fig. 7. Deformation of plants in rows 1 and 2

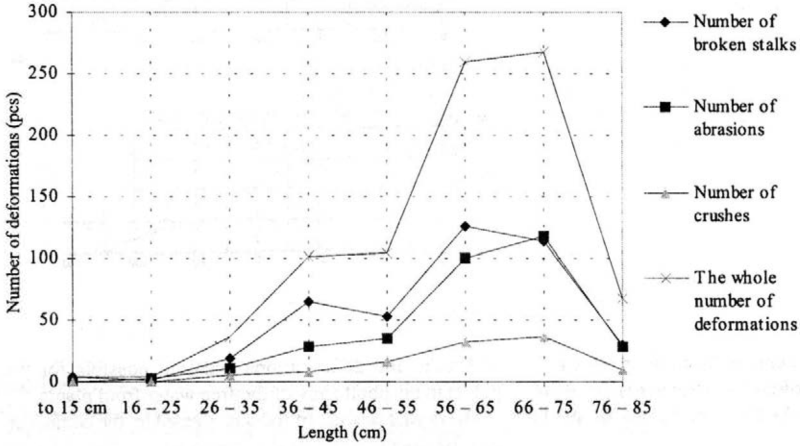


Fig. 8. Deformation of plants in rows 3 and 4

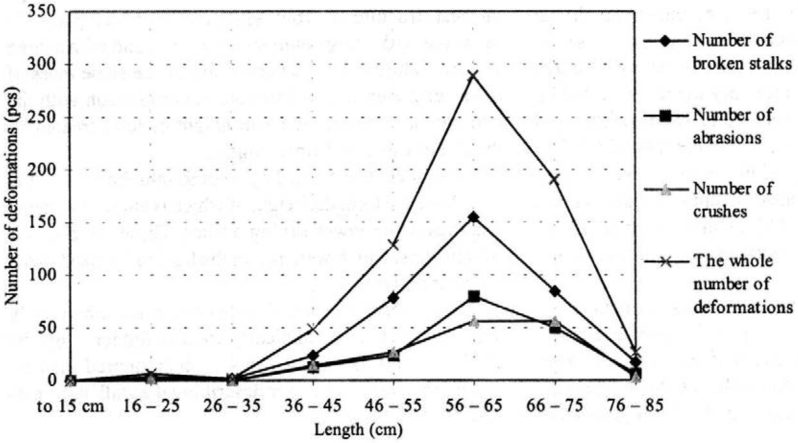


Fig. 9. Deformation of plants in rows 5 and 6

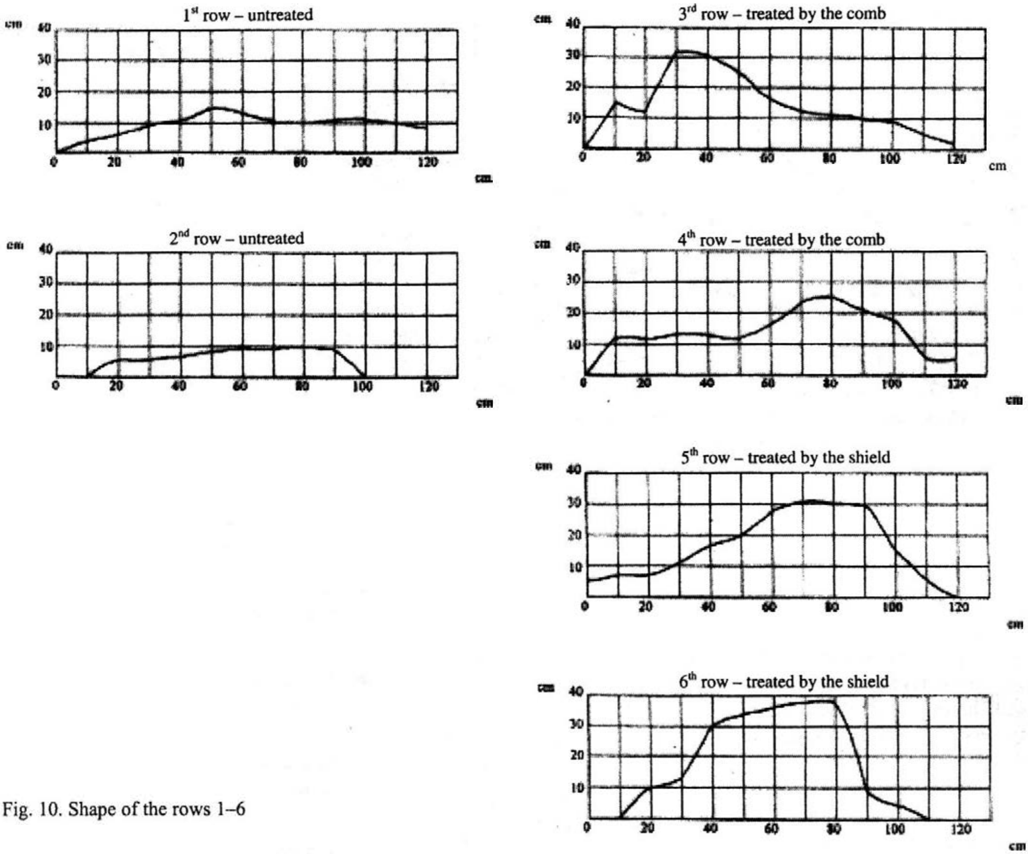


Fig. 10. Shape of the rows 1–6

The efficiency of implementing the comb into the mechanical treatment is expressed by exponents (–0.0746 and –0.0742), and is lower by 8% than the one the shield used to have.

Summarizing the results of both days, we can declare that the drying speed on the second day was higher.

The results of the 3rd day (11. 6. 1998) of the experiment, shown in Fig. 6, proved that the drying speed rapidly decreased on this day. Logically, the lowest intensity of drying had the rows of fodders treated by the shield, what is documented by exponents of approximative curves: –0.019 and –0.023. Then, more quickly dry the rows treated by the comb – the coefficients were: –0.023 and –0.020 – and achieved the storageable moisture content (~ 22%). The highest intensity of drying had untreated mowed fodder, which had the values of exponents of approximation curves as follows: –0.0487 and –0.0494. Untreated mowed fodder achieved also almost the storageable relative humidity (19.1% and 22.4%).

A supplementary parameter, describing mechanical deformation of stalks, is shown in Figs. 7–9. The characteristic of deformation backs up the results of drying in full range. Applying the mechanical treatment by the shield, the highest deformation was found out (Fig. 9). The high number of breaks and deformations makes it possible for the plants to evaporate any of the free water from plants.

The drying process of fodders, treated by the comb, can also be documented by the mechanical deformation of plants (Fig. 8).

The shape of the mowed fodder rows fixed in picture 10 unambiguously proves the conclusions made above. It is evident that mowed fodder treated by the shield, had the best structure of a row, when stalks are well placed in the space with a large number of air gaps and with a large vertical value. Under the condition of the same mass of rows per meter, it is visible that in comparison with the two untreated rows, the mean height of rows treated by the shield was 2.5–3 times higher.

The fodder rows treated by a comb into the flow of the mass have the form the height of which is almost the same; this means the lower drying ability. These are also the conclusions, which were set on the basis of a speed mean of water deficit.

The complete course of drying process unambiguously proved, that the mechanically treated fodder – by the shield – dries speediest. This is documented also by a supplementary parameter describing the stalk deformation.

References

KLINNER W.E., 1975. Design and performance characteristics of an experimental crop conditioning system for difficult climates. J. Agric. Engng Res., *20*: 149–165.

ŠESTÁK J., SKLENKA P., ŠKULAVÍK L., RYBAN G., 1992. Bubnový upravovač krmovín. Acta Technol. Agric. Univ. Agric. Nitra, XXXIII: 15–28.

KOROLOVICS L. et al., 1978. A szálastakarmányok optimális fonnyasztását bistosító gépi eljárásokról. Szolnok, Szolnok Mérnöki Irodája.

ŠTRÁFELDA J., VELICH J., 1981. O výsledcích hodnocení žacích strojů při sklizni prvních jetelovin a travního porostu z pícninářského hlediska. [Zpráva V–130.] Praha, VŠZ: 2–48.

Received 15 January 1999

Účinok mechanickej úpravy krmovín na rýchlosť ich vysušovania

ABSTRAKT: Rýchle vysušovanie voľne pokosených krmovín na poli umožňuje skrátenie doby od kosby do uskladnenia, znižuje stratu živín aj sušiny a zaisťuje rýchlejšiu obnovu nového porastu. Pokos ponechaný na poli 2–24 dní stráca denne 1,2 % sušiny. Aby sme urýchlili proces vysychania, aplikujeme rôzne typy mechanických porušení rastlín, ktoré vykonávame konštrukčne vhodne usporiadanými prvkami. Najvýznamnejšie je použitie miagačov a lámačov stebiel. Bolo stanovené, že doba zavädnutia porastov s produkciou 25–30 t/ha zelenej hmoty pri uplatnení miagačov, čechračov a bubnových upravovačov je okolo 8–10 hodín, čo vyhovuje na zabezpečenie obsahu sušiny okolo 35–48 %. Intenzita vysychania je závislá od mnohých faktorov. Predovšetkým je to podiel vlhkosti vzduchu, jeho teplota, sýtostný doplnok, slnečné žiarenie, rýchlosť vzduchu nad pokosom a konvekcia prúdu vzduchu. Z vnútorných činiteľov je to schopnosť rastlín viazať vodu. Úbytok vody je u pokosených rastlín veľmi rýchly, postupne slabne a nakoniec zastane. V príspevku prezentujeme nový prístup k mechanickému poškodzovaniu pokosu krmovín. Poľné experimenty agregátu – disková kosačka typu MARAGON MD 5 s adaptovaným bubnovým upravovačom – preukázali jeho plnú využiteľnosť v praxi. Technická zmena mechanického účinku bola zaistená zaradením hrebeňa a clony do prúdu krmoviny. Pri porovnávaní neupravených pokosov s pokosmi upravenými sme zistili tieto praktické závery: najväčší účinok na rýchlosť vysúšania pokosu trávnatej zmesi má zaradenie clony upravovača do toku hmoty; najväčší účinok má clona na mikropoškodenie rastlín; zaradením clony do toku hmoty je vykreovaný najvhodnejší tvar pokosu (riadok načechraný, vertikálne vyformovaný s efektívnym prúdením vzduchu).

Kľúčové slová: krmoviny; mechanická úprava; sušenie

Corresponding author:

Prof. Ing. JOZEF ŠESTÁK, CSc., Slovenská poľnohospodárska univerzita, Mechanizačná fakulta, Tr. A. Hlinku 2, 949 76 Nitra, Slovenská republika, tel./ fax: + 421 87 360 73, e-mail: jozo.sestak@post.sk

A proposal for evaluating the operating state of agricultural tractors

M. Fajman, J. Ondráček

Mendel University of Agriculture and Forestry, Faculty of Agronomy, Brno, Czech Republic

ABSTRACT: A comparative method of the multistate performance ability evaluation of an agricultural tractor is presented in the analysis of 16 Zetor tractor operation. The computation principle and sequence are described on one of the tractors. As a criterion is used the performance availability characteristic (PAC). Development of PAC in operational life and overall characteristics of tractors are divided into four groups by unified range, which are then analyzed.

Keywords: tractor; dependability; performance ability; state model; multi-state model

The quality is a very important property of an art. It is the decisive factor of economic growth, protection against the market loss and has a very strong influence on economic criteria (Synek et al. 1996).

The quality from a technical side of view can be presented as a complex of entity properties that influence the ability of satisfying respective customer's needs. In this general statement the entity can mean a product such as a process (Nenadál et al. 1998). For the technological practice this complex evaluation is more precise when dividing the general property into particular properties. This contribution deals with one of them – dependability.

Dependability (sometimes translated also as reliability) is the collective term used to describe the availability performance and its influencing factors (reliability performance, maintainability performance and maintainability support performance) – ČSN IEC 50 (191) (Mezinárodní elektrotechnický slovník – Spolehlivost a kvalita služeb – International Electrotechnical Vocabulary – Dependability and quality of services). What means another property subcomplex. For evaluating dependability measures can be used, different characteristics depending on the entity, its operation and the analysis method.

Classical quantitative methods are based on a probability analysis of the file of monitored objects. Principles come from mathematical theory of probability and they are developed in practical prescriptions for the practice. The complex of such practical example can be found e.g. in the ČSN 01 0103 (Výpočet ukazatelů spolehlivosti dvoustavových soustav – Computation of reliability characteristics of two-state systems).

The advantage of these kinds of methods is in the relatively high precision of results that can be used for general purposes, for estimation of the future behavior of the entity or better to say of a set of entities.

The disadvantage of this kind of method is in the description of complex engineering units. Basic methods use only two states of the art model that can recognize two states of the watched object: the operation and the non-operating state.

The operation is defined as the state when an item is performing a required function under given conditions. On the other side, the non-performing state describes the state of a required function not being performed under the same conditions, caused by various influences e.g. a failure, lack of work etc. For dependability evaluation only failures of a non-performing state are considered. The problem is to define states between an operation and a failure state. In one part system any failure means total failure of such system. But in the operation of machines like tractors, which have more repairable parts, not any failure means the total failure of the system.

There are developed methods of analysis that can describe such complex units (FTA, Markov models, Monte Carlo, etc. – e.g. Starý 1998), but their utilization is "limited". They require precise definition of the relationships of components and their meaning for the function of the object, or knowledge of dependability characteristics (e.g. distribution function) of components or are assigned to utilization in the development phase of the product (Lenk 1995). These methods are suitable and very well applicable in electronics, but in most cases of engineering entities we have at disposal only limited information about components and likely the most information that is available deals with overall performance of the watched object in its own operation.

That is why the goal of this presentation is to suggest a simple method for evaluation of the operating state, in this case an agricultural tractor, that would be able to interpret operational data without knowledge of dependability characteristics of the whole tractor and its main assemblies as well.

This work arose under the cooperation with Zetor, a. s., namely with Testing Laboratories (VVZT/T) section Dependability. Thus the method is slightly influenced by the needs and input data parameters, but it is assigned for general purpose.

METHODS

During their operational life while working in agricultural operation were 16 tractors (detailed characteristic is given later in Table 4) monitored under the methodology of VVZT Zetor, a. s. (Zetor, a. s., 1998). This methodology is based on an original methodology used in VVZT/T for dependability testing, and new features dealing with data organization by board computers and computer analysis are added. The methodology supposes that the tractor is equipped with an operational clock or better with a board computer. The staff has to write down the time of operation, the implement used, the amount of added fillings, any maintenance intervention and the failure or needed repair if such event occurs.

All the operation data were collected in "tractor books", which are Excel workbooks, one for each tractor. From the operational data analysis is important for further evaluation mainly the proportion of operational hours, worked in each type of work.

Methodology, all input data and analyzed data are archived in Department of Agriculture Machinery Mendel University of Agriculture and Forestry, Brno and VVZT/T Zetor, a. s. Some detailed information about tractors is not available because of classified character of their content due to property rights of Zetor, a. s.

The main idea for this method of evaluation comes from the statement that every failure somehow influences the performance of the entity. As a conclusion it means the restriction of functional abilities of this entity. If any failure occurs, we can quantify the reduction of the required function of a part or assembly by some coefficient. Defining the dependence of each such assembly and their relationships to the whole unit, we obtain a coefficient that describes the immediate performance ability of the whole entity.

Specifically for Zetor tractors the producer recognize following five main assemblies:
- engine,
- gear box, including PTO,
- chassis,
- hydraulics,
- electric installation.

The purpose of dividing the entity into subentities consists in easier consideration of the failure influence on the performance ability of the subentity than for the whole unit. Thus any of subentities could be divided into its subentities if needed. Then the coefficient of the performance availability reduction for the respective assembly (part) is assigned to each of occurred failure.

It has to be admitted, that the value of the coefficient strongly influences the result and, without strict methodology prescription, it brings some degree of subjectivity to the result. This method is thus convenient for comparison inside company e.g. comparison in time or after design changes, and the best result is obtained, if one person is responsible for quantification of the influence.

For more accurate evaluation of a multifunctional unit we should consider the influence of the failure to each of the possible function types. For agricultural tractors we distinguish the following operations:
- transportation work,
- ploughing/ploughing with EHR,
- active implement handling,
- passive implement handling (without ploughing),
- overall operation – from the operational data we take the proportion of work in above mentioned categories and the overall equals to the weighted arithmetic mean by the proportions.

Five main assemblies and five operation types (without overall characteristics) constitute the matrix of coefficients that transform the influence of any failure from the respective part to the whole unit. All specific examples of evaluation are taken from the data of Z73_1012 tractor. Table 1 shows the transcription of operation times to an operation proportion data array.*

Values of the second table in Table 1 are used as weight in overall characteristic of failure effect on the operational availability of the tractor. Overall characteristic is then evaluated as a weighted mean by the operation proportion.

Table 2 shows the transcription matrix for the operational availability evaluation. The first group of numbers represents presumptive importance of the assembly for the proper operation in a proportion expression. These values

Table 1. Operational proportion evaluation

Utilization of the tractor — 73_1012 — Z 7340

Period of monitoring: from 1. 1. 1990 to 31. 12. 1999

Tractor was monitored in part of the period from 1. 6. 1997 to 15. 8. 1999

Operation	Sum of operating hours	Plowing	Tillage	Seeding	Harvest operation	Transportation	Fertilization plant protection	Remainder
Utilization (Mh)	2,136	398	37.5	54.5	340.5	1,202	6.5	97

Operation type	Transportation	Plowing	Active implement handling	Passive implement handling	Check column
Proportion (%)	61	19	1	2	100

*The representation is a product of software solution, which is part of the work.

Table 2. Transcription matrix and performance availability coefficient (PAC) evaluation

		Engine	Gear box	Chassis	Hydraulics	Electrical installation	Check	Proportion	
Assembly	Transportation	25	25	30	5	15	100	**60**	
	Plowing	30	20	20	25	5	100	**19**	
	Plowing (EHR)	30	20	20	20	10	100		
	Passive implement	30	20	20	25	5	100	**2**	
	Active implement	28	28	18	22	4	100	**19**	
Criteria of performance availability reduction	**General**	**1**	**1**	**1**	**0.9**	**0.89**			
	Transportation	1	1	1	1	1			
	Plowing	1	1	1	1	1			
	Plowing (EHR)	1	1	1	1	1			
	Passive implement	1	1	1	1	1			
	Active implement	1	1	1	1	1			
							Π (%)		*PAC* (%)
Calculated criteria of performance availability reduction	Transportation	1.000	1.000	1.000	0.966	0.890	86.0	51.584	
	Plowing	1.000	1.000	1.000	0.839	0.962	80.8	15.344	
	Plowing (EHR)	1.000	1.000	1.000	0.869	0.925	80.5		
	Passive implement	1.000	1.000	1.000	0.839	0.962	80.8	1.615	
	Active implement	1.000	1.000	1.000	0.857	0.970	83.1	15.791	**84.3**

were estimated and then consulted, but the values can be discussed or further optimized.

There is an example of two failures in the second group of numbers. The first one occurred in the electric installation and the second one influenced the function of hydraulics (0.9). Calculating the values in the third group of numbers and taking their product we obtain the value of reduction for operation types and then we calculate the overall characteristic – performance availability characteristic (PAC), which is the last number down on the right. Presented values correspond to operation state of the Z73_1012 tractor on September 10, 1997.

The values in the third group are calculated by the formula $C = B^{\frac{kA}{100}}$, where B means proper column in the row "General"* of numbers and A is proper item of matrix in the first group of numbers. The value of coefficient k is 6.644, which is the value that is a solution of two conditions:

- if the influence of any assembly were the same and one value in the row general were 0.9 and others equaled to 1 (operation without any failure), then PAC should be lower then 90%,
- under the same precondition and all numbers in the row general equal to 0.5 then PAC should be close to 0% (further operation is not possible).

These two conditions guarantee the ability of dividing units and assemblies into subassemblies which enables the k coefficient to be calculated for systems with different amount of assemblies. (The form of power function has an advantage in the product, if there is a total failure of any assembly, its coefficient is then 0, what automatically means PAC 0% – total unavailability of performance of the tractor.)

Then Π column contains the product of the values in the proper rows, these values, corrected by weight of proportion in operation, are in the column next to and their sum is the PAC value.

Every failure which occurred in the operation of the tractor is thus considered and at any time of the tractor operational life the computation could be used for getting the characteristic of the performance availability.

An advantage of this kind of consideration is a contemporary effect of several failures taken to the calculation. When some of failures remained unrepaired, then the development of the performance availability of the unit got the development similar to the chart in Fig. 1.

A part of this work was the creation of software under MS Excel that helps to evaluate PAC values during the operational life of each tractor. The development of PAC values at the monitored tractor Z73_1012 is shown in Fig. 1.

For the ordinate of the chart there are possible two data bases. Presented is the operational life in Mh, but for the owner the base in days could be also interesting. These tractors were monitored with the purpose to find the cause of failures, so in many cases the repair period was longer, than it would be in normal operation, therefore the daily data base is not considered in this contribution.

An original presumption in creating the matrix of the coefficient and the consideration of the failure influence was, that values of PAC under 50% mean so high reduction of functionality, that the operation of the tractor was not under normal conditions eligible. Experience from the analysis of other tractors shows that in this consideration of failures and these coefficients this boundary is at about 30%. The chart in Fig. 1 could be compared to charts of other tractors, but for statistical interpretation some one-number characteristic is necessary.

For the evaluation of such criteria was chosen the following method. All peaks in the chart are considered as the lowest value they achieve in the operational hour to which they belong. The width of the peak level is defined

---

*The second group of numbers could be used for higher precision of the state of art evaluation. They express, how the failure influences the functionality of assembly and these rows can closer explain the influence to proper operation. This could be done for greater file of tractors and consideration this method as suitable principle of an analysis. They are not in use in this contribution.

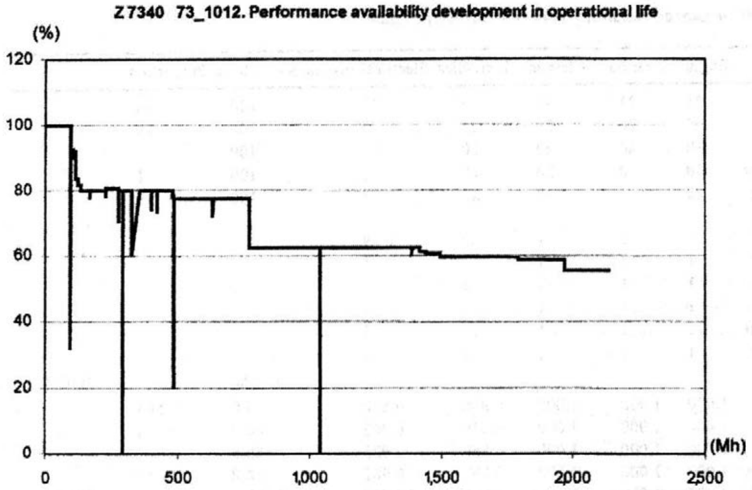


Fig. 1. Development of PAC for monitored tractor

by the difference in data bases between two peaks or one Mh is for peaks that represent a failure which was immediately repaired. The interval of 100% was divided into 20 intervals and the frequency of each interval hits is thus counted. The analysis is shown in Table 3.

The weighted mean over the interval from 0 to 100% is then labeled as criterion of the total characteristic, the higher the value the better the performance availability of the tractor during all monitored periods.

RESULTS AND DISCUSSION

The above described kind of evaluation was calculated for the sixteen monitored tractors. These 16 Zetor tractors

Table 3. Frequency analysis of the PAC development chart

Midpoint of interval	Lower limit of interval	Upper limit of interval	Frequency (Mh) Transportation	Plowing	Plowing (EHR)	Passive implement	Active implement	Overall
2.5	0	5	2.5	2.5	2.5	2.5	2.5	2.5
7.5	5	10	1	0	0	0	0	0
12.5	10	15	0	0	0	0	0	0
17.5	15	20	0	0	1	0	0	0
22.5	20	25	0	0	0	0	0	1
27.5	25	30	1	0	0	0	0	0
32.5	30	35	0	1	0	1	0	1
37.5	35	40	0	1	1	1	0	0
42.5	40	45	0	0	0	0	2	0
47.5	45	50	0	0	0	0	0	0
52.5	50	55	169	0	30	0	0	0
57.5	55	60	555.5	199	641	199	30	641
62.5	60	65	670	1,203.5	731.5	1,203.5	641	753.5
67.5	65	70	0	1	1	1	731.5	0
72.5	70	75	3	275	277	275	1	10
77.5	75	80	283	342	340	342	452	276
82.5	80	85	327	0	0	0	165	340
87.5	85	90	14	0	0	0	0	1
92.5	90	95	9	1	10	1	1	9
97.5	95	100	101	110	101	110	110	101
Weighted sum			143,763	144,065	141,485	144,065	150,788	144,945
Sum of data base (Mh)			1,931	2,136	2,136	2,136	2,136	2,136
Criterion			67.30	67.45	66.24	67.45	70.59	67.86

as follows can be divided into four groups by four units in each group.

Tractors are situated in groups by their construction type that represents the unified range UR I and UR III. Unified range UR III is then divided in three subgroups by construction type. This division corresponds to the design base of tractors and is also influenced by the possibilities in monitoring. Detailed information is in Table 4.

Table 4. Monitored tractors divided into groups by unified range and construction type

UR I			UR III95		
Mark	Type	(Mh)	Mark	Type	(Mh)
Z63_1006	*Z 6340*	2,229	Z95_1008	*Z 9540*	3,190
Z73_1012	*Z 7340*	2,136	Z95_1240	*Z 9540*	3,163
Z73_1146	*Z 7340*	3,919	Z95_1259	*Z 9540*	2,154
Z73_1458	*Z 7340*	2,932	Z95_1261	*Z 9540*	3,318
UR III105			**UR III6V**		
Mark	Type	(Mh)	Mark	Type	(Mh)
Z105_1182	*Z 10540*	4,093	Z115_81	*Z 11540*	68
Z105_1278	*Z 10540*	4,390	Z115_82	*Z 11540*	1,723
Z105_65	*Z 10540*	6,192	Z116_1024	*Z 11641*	1,264
Z105_66	*Z 10540*	5,876	Z116_80	*Z 11641*	831

Table 5. Results of PAC for group of monitored tractors

Range	UR I	UR III95	UR III105	UR III6V
Transportation	82.93	79.59	62.34	97.28
	67.30	93.33	83.41	39.95
	95.64	73.56	69.39	97.50
	96.14	91.93	68.50	66.44
Plowing	76.36	66.36	65.39	97.35
	67.45	96.51	91.65	44.74
	96.18	73.37	65.31	97.50
	96.49	91.94	68.58	70.32
Plowing (EHR)	76.36	69.31	65.40	97.35
	66.24	94.77	87.60	43.27
	96.19	73.07	67.75	97.50
	96.48	92.19	68.44	70.32
Passive implement handling	76.36	66.36	65.39	97.35
	67.45	96.51	91.65	44.74
	96.18	73.37	65.31	97.50
	96.49	91.94	68.58	70.32
Active implement handling	76.37	70.01	67.65	97.28
	70.59	96.51	94.72	38.83
	96.19	73.76	67.77	97.50
	96.18	91.68	70.79	62.58
Overall	78.79	74.08	64.17	97.28
	67.86	94.98	87.56	41.35
	96.20	73.46	67.69	97.50
	96.17	91.50	69.33	66.45

Table 6. ANOVA results

Analysis of Variance for PROV.PROV – Type III Sums of Squares

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
MAIN EFFECTS					
A:PROVOZUS.Rada	2250.3497	3	750.1165	2.483	0.0676
B:PROVOZUS.Operace	1.2459	5	0.24919	0.001	1.0000
INTERACTIONS					
AB	106.26877	15	7.0845847	0.023	1.0000
RESIDUAL	21749.16	72	302.07169		
TOTAL (CORRECTED)	24107.026	95			

Multiple range analysis for PROV.PROV by PROVOZUS.Rada

Method: 95 per cent LSD

Level	Count	LS Mean	Homogeneous Groups
3	24	72.682083	X
4	24	76.175000	XX
2	24	82.920417	X
1	24	84.524583	X

Contrast	Difference	Limits
1–2	1.60417	10.0039
1–3	11.8425	10.0039*
1–4	8.34958	10.0039
2–3	10.2383	10.0039*
2–4	6.74542	10.0039
3–4	–3.49292	10.0039

*denotes a statistically significant difference

This table shows the mark that is used for inner differentiation (last numbers are the serial numbers of the tractor), production type of the tractor and monitored period of tractor life that is considered for the evaluation (tractors of UR III6V are the most up to date design, so they could not achieve longer values).

For the comparison of the monitored file of tractors the two-factor analysis of variance was used.

Input table is in Table 5. We do not calculate the difference among tractors, that is why proper marks of tractors are not presented, but the order from Table 4 is kept for orientation.

There are tested contrasts of a "failure rate" among different construction ranges, possible contrasts in performance availability for respective considered operations and possible interactions in ANOVA. Testing hypothesis (H_0) is: among tested tractor unified ranges there are no significant differences in the total criterion of the performance availability characteristic in any of the operation types.

Obtained results are presented in Table 6.

At first it has to be admitted, that the amount of items in the file is not large enough to fit the normal distribution, thus the discussion of the results has to be considered on lower level of accuracy.

With probability 93.2% we reject the hypothesis, but we cannot say that there are statistically significant differences of overall performance availability among tested unified ranges of Zetor tracors in operations. Significant difference is not found among operations, what is expected, because of the relatively similar coefficients of influence of the main assemblies on the operation functionality and of not using the coefficients of the functionality reduction directly on operation types.

Interaction is also not significant, what could be represented, as there is not significant difference in influence of occurred failures by different tractor ranges on different operations. It means that all tractor ranges "react" to failures relatively similarly by the same reduction in performance availability.

In testing contrasts significant difference occurs among UR I range and UR III105 and the same applies for UR III95 and UR III105, but significant difference is not among UR I and UR III95 and the other group UR III105 and UR III6V. The best value of tested criteria were achieved by UR I. (Contrasts in categories that had not significant level in ANOVA were tested but are not presented, because no significant differences were obtained.)

CONCLUSION

As it is written above, obtained results do not entitle anybody to generalize them in the way of saying which unified range is better or worse. For this statement the input data file should be at least five times larger and the proper tractors should be better matched to typical representants of each unified range. The goal of the contribution is to present the suggested method in a practical application.

It is clear that results of this method are partly influenced by subjectivity, but it was suggested for internal utilization in VVZT/T Zetor, a. s., and for this purpose we find it applicable. In holding the same input parameters it can clearly search out the differences in the development of construction, evaluate the influence of new design of any assembly or part in range of reliability. We find the results clear to discuss and to be explained clearly to customers, so the method can be used in marketing strategy of producer (e.g. John Deere: *Reliability is our strength*).

A great part of the work was the creation of Excel VBA modules that content macros for operation analysis, self-automatic failure filtering, overall characteristic computation, graphs of PAC plotting and frequent analysis of these charts. Automatic computation is necessary because the amount of data is really large even if the file is so small as in this case.

I hope the method comes to the use sometimes in the future, at least in VVZT Zetor, a. s., where however the present situation of the whole enterprise does no currently support really convenient work conditions.

References

LENK R., 1995. Zuvelässigkeitsanalyse von komplexen Systemen am Beispiel PKW-Automatikgetriebe. Stuttgart, Universität Stuttgart: 164.

NENADÁL J. et al., 1998. Moderní systémy řízení jakosti. Praha, Management Press: 283.

STARÝ I., 1998. Spolehlivost systémů. Praha, ČVUT: 120.

SYNEK M. et al., 1996. Manažerská ekonomika. Praha, Grada: 475.

ZETOR, a. s., MZLU Brno, 1998. Metodika sledování provozních parametrů traktorů Zetor. Brno: 45.

Received 25 May 2000

Příspěvek ke stanovení provozního stavu zemědělského traktoru

ABSTRAKT: Pro posuzování spolehlivosti komplexního systému, např. zemědělského traktoru, je při omezených vstupních datech problematické použití klasické teorie spolehlivosti stejně jako dalších metod. Pro tento případ zkušebny VVZT Zetor, a. s., je navrhována metoda vyhodnocení charakteristiky provozuschopnosti, která postihuje komplexnost opravitelného systému. Jednotlivým poruchám je přidělen koeficient, který popisuje snížení funkčnosti sledované skupiny. Maticí koeficientů vyjadřujících vliv dané skupiny na danou pracovní operaci je vliv poruchy převeden na vyjádření ovlivnění provozuschopnosti celého traktoru. Simultánní působení následků více poruch na různých funkčních skupinách i neodstraněných závad je tak možné posuzovat v časové základně Mh nebo dnů provozu. Jako příklad je uveden traktor Z7340 v. č. 1012 (obr. 1). Pro komparativní posouzení je provedena analýza četností v intervalu provozuschopnosti 0–100 %. Vážený průměr analyzované sady dat je kritériem, které lze porovnat mezi sledovanými prvky. Analýza 16 traktorů rozdělených podle unifikovaných řad je ukázkou tohoto postupu. Vzhledem k omezenosti rozsahu vstupního souboru mají však výsledky pouze omezenou platnost.

Klíčová slova: traktor; spolehlivost; provozuschopnost; model provozního stavu; vícestavový model

Corresponding author:

Ing. MARTIN FAJMAN, Mendelova zemědělská a lesnická univerzita, Agronomická fakulta, Zemědělská 1, 613 00 Brno, Česká republika, tel.: + 420 5 45 13 33 27, fax: + 420 5 45 13 20 93, e-mail: fajman@mendelu.cz

Analysis of main technological factors influence upon milk production economy

J. VEGRICHT, A. MACHÁLEK, F. PECHAČ

Research Institute of Agricultural Engineering, Prague, Czech Republic

ABSTRACT: This contribution analyzes the effect of dairy cows housing systems at various stable and farms modernizations. In total it was evaluated at 8 stables and farms for 93–734 dairy cows, each at least with three levels of technical equipment. Totally there was evaluated more than 24 variants of levels of average annual milk yield in range 4,000–8,000 litre. It is evident from the obtained results, that with growing milk yield the total production costs per milk production exponentially decreased for all evaluated variants. In the field of annual milk yield 6,500–7,000 litre this decrease has been significantly decelerated and following milk yield increases has influenced further milk production costs decrease slightly. An important effect on the milk production costs has the feed price. Its share on total costs increases significantly with growing milk yield and reaches up to 50% of total costs. In contrast with this, other items of milk production costs decrease with growing milk yield (wages, energy, depreciation), or their share expressed in percentage changes only slightly. It was proved the expected decrease of production costs with increased dairy cow's concentrations in stable and on the farm. The share of technological systems on total costs expressed in form of depreciation is relatively small (4–10%) and decreases with growing milk yield and number of dairy cows. Very low effect on the total production costs is produced technical equipment level. For example, on a farm with 401 dairy cows and a milk yield 6,500 l the difference of production costs between the best and the worst level of technical equipment is 1.4%. The contribution of modern technical systems in the field of labour costs, nutrition and utilization of animal production potential is dominant.

Keywords: dairy cows; stable modernization; technical equipment; farm size; milk production costs

The milk production economy expressed by production costs per 1 litre of milk on the one hand and by the realization prices of milk delivered to dairy and used on the farm for feeding purpose on the other hand as well as by-products price (farmyard manure, calves) or, as case may be, by some other revenues (e.g. insurance company payment), is influenced by some aspects which can be quantified only with difficulty.

In fact, there are no agricultural enterprises in the Czech Republic merely specialized towards milk production. The dairy cows together with other animals breeding, certain range of crops production and possibly other activities give a typical picture of the Czech farm.

To determine production costs per 1 litre of milk individual farmers use different methodical approaches. It regards mainly the feedstuffs and bedding costs determination, costs of some performances within agricultural enterprise having character of sub-delivery, single items costs charging from the field of other direct costs and administrative and production overhead. On the other hand there is a lack of uniform approach to the by-products assessment (calves, farmyard manure e.t.c.).

These facts then complicate determination of objective production costs per milk production as a whole and individual items of these costs.

Thus, it is evident, that the economical results of agricultural enterprise as a whole may be relatively easy determined. But production costs determination per unit of a specific product is loaded by certain mistake resulting from different cost charging of individual cost items.

The submitted paper intention is to find out some relations between the technical and technological level of stables and farms, animal yields, stables and farms size and production costs per 1 litre of milk.

METHODS

PRODUCTION COSTS DETERMINATION

For determination of production costs per 1 litre of milk we have chosen the usual structure of production costs (PODĚBRADSKÝ 1997; NOVÁK 1997) consisting of following items:
- wage and mandatory insurance, i.e. personal costs,
- feedstuffs and bedding,
- vet and breeding services,
- energy and fuel,
- depreciation,
- depreciation of animals,

This article has originated in connection with solution of the Grant projects National Agency for Agricultural Research (NAZV) of the Ministry of Agriculture of the Czech Republic No. 6515 – *Information and Expert System for Management of Technological Processes in Agricultural Production* and No. 6147 – *Utilization and Renovation of Agricultural Mechanization in Systems of Farming.*

– other direct costs,
– overhead.

The milk production costs calculation does not regard in this paper the by-products prices (manure, calves…) and other revenues connected with the milk production (e.g. insurance company payment) despite these revenues are obviously calculated and reduce the total costs per milk production.

Determination of individual items was realized by means of statistical research results transfer and adaptation carried out by other authors and organizations (PODĚBRADSKÝ 1997; KVAPILÍK 1995; VEGRICHT, PECHAČ 1998) and by their determination by model calculation.

It is necessary to state, that the character of obtained results corresponds with the chosen methodical approach. Further presented production costs per 1 litre of milk should be considered as result of realized simplification and determined presumptions.

The aim of that paper is not to determine absolute costs per 1 litre of milk, but to find effects influencing the costs and to quantify these effects in broad connections. There was investigated the effect of investment in stable and farm modernization in connection with different milk yield and dairy cows number on farm.

For determination of the model costs of individual stable modernization a combination of two methodical processes was used.

The essential was determination of reconstruction model method based on catalogue cards prepared for catalogue of reconstruction and modernization. Each catalogue card contains ground plan and sectional view of suggested variant of modernization and provides the constructional adaptations extent.

To the selected catalogue cards the general budget of modernization was calculated using the KROS programme which is being worked-up and updated by Institute of Civil Engineering Rationalization Prague.

To verify such suggested costs an extended research of implemented modernization efforts and their actual investment costs was realized.

By comparison and assessment of results of the both methodical approaches model investment costs of individual modernization were determined which is subject to further performed analysis. It concerns the model costs calculated in maximum possible extent without subjective effects and according to conditions of the individual investor.

The investment costs of technological equipment of stables and farms were calculated on base of their model equipment with necessary machines and systems for providing of operational processes linked with feeding, milking, milk treatment and storage, manure removing and necessary care for animals.

The farm equipment was determined in some variant from point of view of technical level and price as well as farm and stable size.

STABLE AND FARM ASSESSMENT

The selection of evaluated stables and farms was based on the need to verify effect of stable or farm of different size on the investment size per one housing stall and differently equipped stables depreciations share of total milk production costs.

We have issued from the fact, that the most extended are modernizations of stables K-96 and K-174.

For analysis of technological factors effect onto milk production economy the following stables and farms were selected:

a) K-96 stable modernization to free bedded box stable for 89–93 dairy cows with built-in milking parlour,
b) K-96 stable modernization to free bedded box stable for 115–121 dairy cows and separated herringbone milking parlour 2 × 6 with dairy,
c) K-96 stable modernization to free bedded box stable for 209–219 dairy cows and separated herringbone milking parlour 2 × 6 with dairy,
d) K-174 stable modernization to free bedded box stable for 174–182 dairy cows and separated herringbone milking parlour 2 × 6 with dairy,
e) 4-row byre with TP-191-VUZO stanchions modernization to free box stable for 276 dairy cows and separated herringbone milking parlour 2 × 6 with dairy,
f) farm for 303 dairy cows consisting of modernized stables K-96 and K-174 and separated herringbone milking parlour 2 × 12 with dairy,
g) farm for 401 dairy cows consisting of differently designed modernization of stables K-96 and K-174 and separated herringbone milking parlour 2 × 12 with dairy,
h) farm for 401 dairy cows consisting of differently designed modernization of stables K-96 and K-174 and separated herringbone milking parlour 2 × 12 with dairy,
i) farm for total number of 734 dairy cows consisting of two modernized stables TP-191-VUZO and one modernized K-174 and separated herringbone milking parlour 2 × 12 with dairy.

The individual stables a–e were evaluated as separated facilities, i.e. they are generally considered as separated dairy farms with necessary equipment.

Technological equipment was selected in four variants A–D enabling evaluation of various investments on depreciation and the share of total costs per 1 litre of milk. The depreciations are based on the law of income tax No. 586/1992 and its rate is 12.5% p.a. for technology and 2.5% p.a. for buildings of purchase price.

Variant A – the simplest (i.e. cheapest) variant presumes feeding by wagon with bottom conveyor, feedstuff unloading by loader with silage cutter, milking in simple inland milking parlour and farmyard cleaning by tractor scraper.

Variant B – the feeding is provided by mixing wagon with cutter, inland milking hall equipped by milk-flow meters and automated data collection processed by PC, automated cow identification by pedometers with measuring of motion activity, other as A.

Variant C – that variant utilizes a mixing feeding wagon with unloading cutter. Other equipment is identical as A.

Variant D – that variant differs from B by using of automated feeding boxes (AFB) for individual concentrates portioning with derived lower stable capacity. Not considered for utilization on farms.

RESULTS

The methodical approach presented in the section Methods were determined costs per milk production and size of single items for individual stables and farms. The obtained data were included into tables and graphs with aim to find out dependence of total costs and chosen costs items, particularly of investment for building and technological equipment, stable or farm size and average milk yield of herd.

TOTAL COSTS FOR MILK PRODUCTION

With respect to the limited extent of this paper it is not possible to present all obtained results for each of the analyzed variants and we even do not consider it purposeful. We only will present more general dependencies obtained by realized analysis and their commentary.

Fig. 1 presents the graph of dependence of production costs for 1 litre of milk per dairy cows yield and stable or farm size.

From the graph a clear dependence is evident of production costs and milk yield – unit costs per milk production decrease with growing milk yield. This decrease has generally exponential character. In the field of milk yield about 6,500 litre/year the decrease started to be well-balanced, i.e. further growth of milk yield has only slight influence upon production costs. From this fact it is evident that the milk yield decrease proper is not possible to be considered (after reaching of certain milk yield level) as dominant factor enabling expressive costs per 1 l of milk with production decrease and a reserve is required to be found in optimalization of other items.

Similar, but less expressive dependence was found out between production costs and stable and farm size. With growing number of animals housed on one farm the production costs decrease.

An example of costs items per milk production in dependence on annual average with yield at farm capacity of 401 dairy cows is presented in percentage in Fig. 2.

Distinctly dominant is the item of feedstuffs and bedding costs. There also are the major possibilities of economies. It concerns particularly the production costs per bulk feed decrease, optimization of feed portion, increase of feed nutrients utilization, increase of productive effectiveness of basic feed portion, decrease of losses during conservation and feeding, e.t.c. Another high cost item is overhead and other direct costs. The analysis of these items is very difficult with respect to the non-existence of unified methods from items content point of view. Generally it is possible to observe decreasing share of these costs in milk production costs with increased milk yield. It also may be

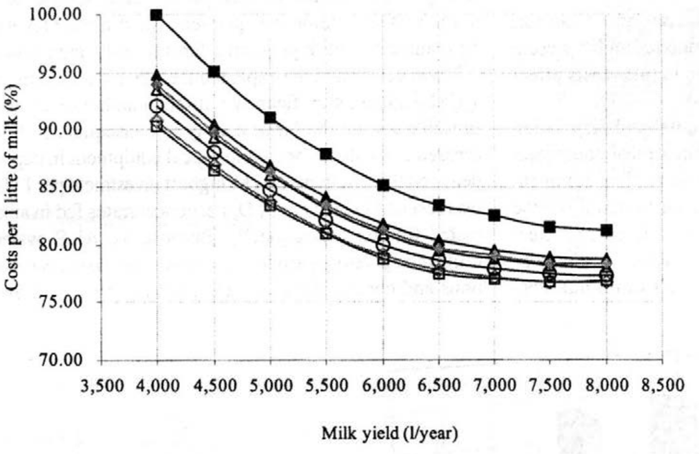


Fig. 1. Dependence of production costs per 1 litre of milk upon milk yield and stable and farm size

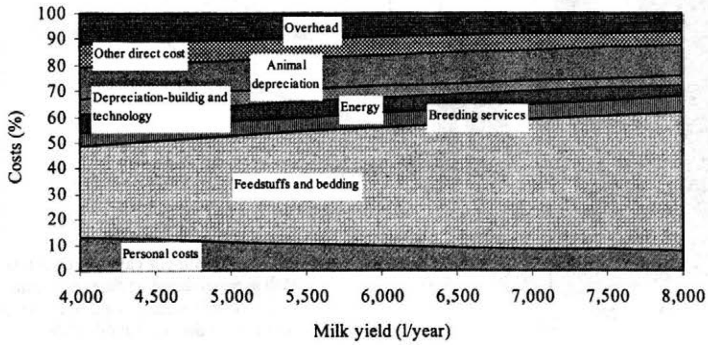


Fig. 2. Composition of cost items per milk production at different milk yields on the farm for 401 dairy cows consisting of modernized stable K-96, K-174 and separated milking parlour equipped according to variant B

expected that these items decrease with growing animals concentration with regard to improved conditions for breeding management. Totally, both the items are high and extremely predominant over e.g. building and technological equipment costs expressed by deprecations of tangible investment property.

Agricultural enterprises intending to improve their economy of milk production should pay attention to overhead and other direct costs and to exclude parasite and unnecessary parts of these costs.

The cost share to labour force expressed in the graphs as personal costs (wages + mandatory insurance) decreases with increasing milk yield. The calculation of these costs was based on uniform need of labour for all evaluated variants (50 h/cow/year) and price of labour (70 Kč/h). It is evident, that there exists a certain space for cost reduction. But it is necessary to be aware, that reduction of these costs by 10% will bring decrease of total costs per milk production by about 1%. We consider as more purposeful the increased skill of workers, care for animals increase, high-quality performance of individual labour operations, reproduction observation e.t.c. The labour quality improvement in these fields will bring synergetic effects in other costs items (feed, milk yield, health care and insemination costs, maintenance…).

The breeding services, veterinary care and animals depreciation may be influenced only in small range, because they depend on factors which the agricultural enterprise can affect only slightly.

The building and technology costs create only small part in contest of total costs per milk production and at present they do not play any significant role in total costs effectiveness.

On the other hand, the constructional and disposition solutions of stable or farm and technological equipment have significant effect on other cost items. The dominant effect of building and technology is applied mainly on the labour need and derived personal costs. An important effect that is observed in the field of feeding where mechanization decides about feed losses and feedstuffs nutrients utilization. The milking device decides about the health state of lactal gland and quality of milk. Milking parlours are going to be a centre of dairy farm management because there are obtained the most important information on animals breeding. Construction and technological systems create environment for animals and influence labour conditions of workers, social aspects and work attractiveness. Similarly there are no doubts about positive effect of modern technological systems on the stable and farm management level.

Total evaluation of construction and technology effect per milk production costs can be summarized:
- minimum direct effect on costs expressed by depreciation of tangible investment property,
- significant positive effect on the rate of all other cost items.

EFFECT OF COSTS OF BUILDING AND TECHNOLOGICAL EQUIPMENT OF STABLE OR FARM ON MILK PRODUCTION COSTS

Generally, the effect of building and technology costs was presented in the preceding part. In that part are analyzed in details investments connected with modernization of stables and farms introduced in part 2 in dependence on different level of technological equipment according to variants A–D, also presented in the part Methods.

Investment costs for individual stables and farms calculated per one cow stall (UM) are presented in Figs. 3–5. In Fig. 6 is presented an example of buildings and technologies depreciation in dependence on different level of equipment and milk yield on a farm for 400 dairy cows.

It was confirmed the expected fact, that investment per 1 UM decrease significantly with the number of animals in stable and on the farm, mainly in consequence of decreased costs share for technological equipment in dependence on the UM number. The highest investment per 1 UM was reached in the variant D, i.e. concentrates fed in automated feeding boxes (AKB). Because the AKB system utilization gives up particularly at larger animal concentrations and concentrates are being fed together with bulk

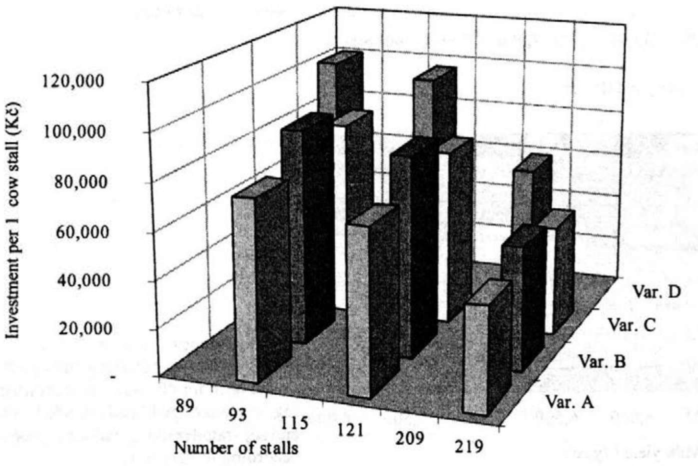


Fig. 3. Investment calculated to 1 cow stall in dependence on dairy cow number and level of technical equipment in differently modernized stable K-96

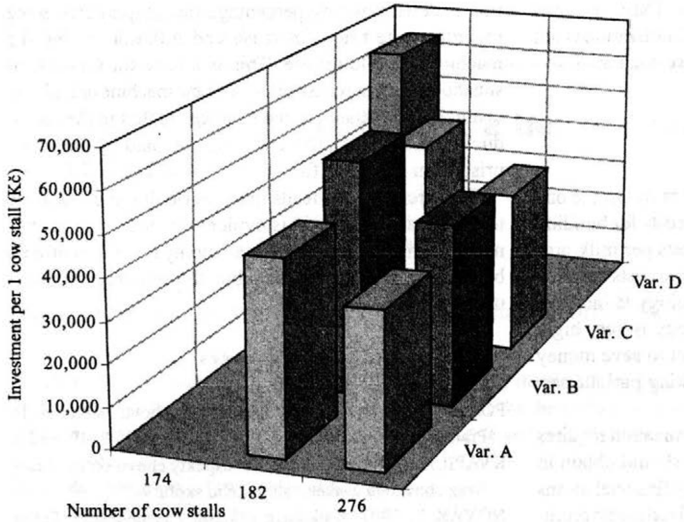


Fig. 4. Investment costs calculated to 1 cow stall in dependence on dairy cow number and level of technical equipment in differently modernized stable K-174

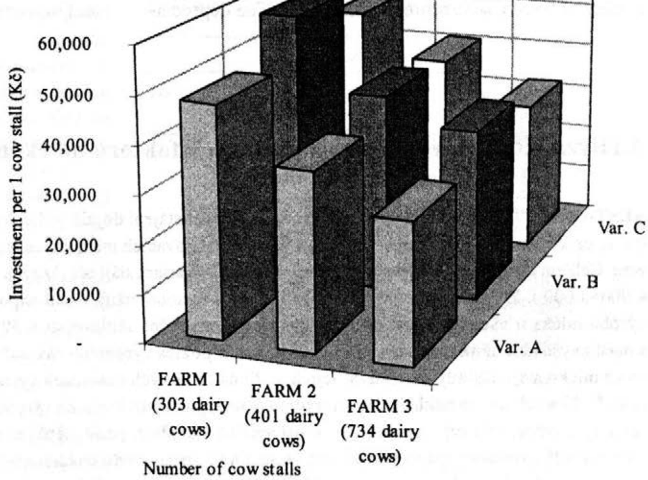


Fig. 5. Investment costs calculated to 1 cow stall in dependence on dairy cow number and level of technical equipment on farm for 303–734 dairy cows

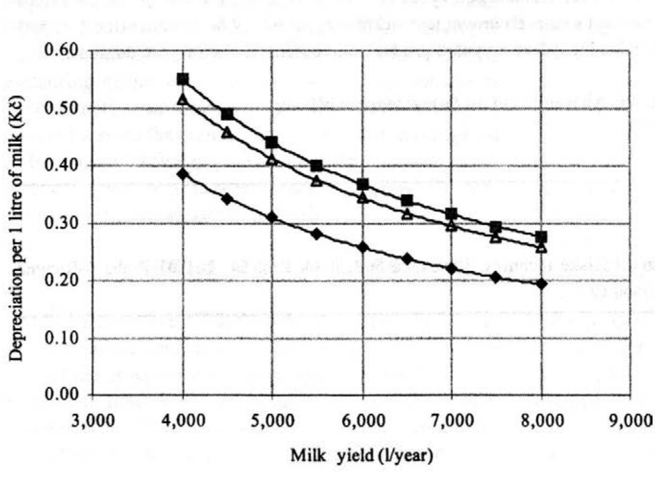


Fig. 6. Buildings and technology depreciations calculated to 1 litre of milk in dependence on milk yield and level of technical equipment on farm for 401 dairy cows

feed in form of complete feeding portion (TMR) the variant D on farms and stable TP-191-VUZO utilization is not considered and only the variants A–C are evaluated.

CONCLUSION

The potential investor decision is not easy. On the one hand it is quite evident, that the share of costs for building and technological equipment of total costs per milk production is slight. Even difference of relative costs between stable and farm equipped by top technology is inappreciable, but contribution of that technology is very high. These arguments lead to the decision not to save money spent for technological equipment (milking parlour particularly).

On the other hand stable or farm modernization requires significant capital which the enterprise should obtain in form of loan. Theoretically these necessary financial means the enterprise should have in the fund of fixed assets reproduction. Nevertheless, the current practice of financial means accumulation in that fund leads to the great inequality of fixed assets reproduction needs. The depreciation is determined by percentage rate of purchase price regardless the prices increase and inflation during the machine or building life. This is a base for creation of situation, when purchase price of a new machine or building is much higher than are the sources created in the reproduction fund. This difference must be paid by the enterprise from its net profit.

This circumstance leads many agricultural enterprises to the situation, when it is evident the necessary investment in order to improve their economy results (as proved by the analysis performed), but the required financial means are not available.

References

PODĚBRADSKÝ Z., 1997. Ekonomika chovu skotu – I, II. Praha, Stud. Inform. ÚZPI, Ř. Živoč. Výr., 4/97: 49 + 67 s.

KVAPILÍK J., 1995. Ekonomické aspekty chovu skotu. Praha, Svaz chovatelů českého strakatého skotu: 67.

NOVÁK J., 1997. Kalkulace nákladů v zemědělství. Praha, Met. Zeměd. Prax., ÚZPI, 5/97: 37.

VEGRICHT J., PECHAČ F., 1998. Investiční a technologická analýza modernizace stáje K-174. Zeměd. Techn., *44*: 101–106.

Received 17 November 1999

Analýza vlivu hlavních technologických faktorů na ekonomiku výroby mléka

ABSTRAKT: V příspěvku je analyzován vliv systémů ustájení dojnic v různě řešených modernizacích stájí a farem. Hodnotilo se celkem osm stájí a farem o velikosti 93–734 ustájovacích míst, každá minimálně se třemi úrovněmi technického vybavení. Celkem tak bylo modelově hodnoceno více než 24 variant stájí při různých úrovních průměrné roční užitkovosti v rozsahu 4 000–8 000 l. Ze získaných výsledků vyplývá, že s rostoucí užitkovostí exponenciálně klesají celkové výrobní náklady na výrobu mléka u všech hodnocených variant. V oblasti roční užitkovosti 6 500–7 000 l se tento pokles výrazně zpomaluje a další zvyšování užitkovosti má již jen malý vliv na pokles výrobních nákladů na mléko. Rozhodující vliv na výrobní náklady na mléko mají náklady na krmiva. Jejich podíl na celkových nákladech významně roste se stoupající užitkovostí a dosahuje až 50 % z celkových nákladů. Naproti tomu ostatní složky nákladů na výrobu mléka s rostoucí užitkovostí klesají (mzdové náklady, energie, odpisy) nebo se jejich procentuálně vyjádřený podíl mění jen nepatrně. Prokázal se očekávaný pokles výrobních nákladů s rostoucí koncentrací dojnic ve stáji a na farmě. Podíl technologických systémů na celkových nákladech vyjádřený formou odpisů je relativně malý (4–10 %) a klesá s rostoucí užitkovostí a počtem dojnic ve stáji a na farmě. V podstatě zanedbatelný vliv na celkové výrobní náklady má úroveň technického vybavení – např. na farmě pro 401 dojnic při užitkovosti 6 500 l je rozdíl výrobních nákladů mezi nejlepší a nejnižší úrovní technického vybavení 1,4 %. Přitom přínosy moderních technických systémů v oblasti pracovních nákladů, výživy a využití produkčního potenciálu zvířat jsou dominantní.

Klíčová slova: dojnice; modernizace stájí; technické vybavení; velikost farmy; výrobní náklady

Corresponding author:

Ing. JIŘÍ VEGRICHT, CSc., Výzkumný ústav zemědělské techniky, Drnovská 507, P. O. Box 54, 161 01 Praha 6-Ruzyně, tel./fax: + 420 2 57 95 12 46, e-mail: vuztl.05@bon.cz

The losses of oil flax during a harvest made by combine harvesters

B. HANOUSEK, J. KRUPIČKA, F. STEHLÍK

Czech University of Agriculture, Technological Faculty, Prague, Czech Republic

ABSTRACT: The measurements of the Horsch stripper and the E 527 combine harvester were carried out during the oil flax harvest. The losses of seeds were considerably higher for the Horsch stripper than the for direct harvest with utilization of combine harvesters E 527, E 514, John Deere 2066 and New Holland TX 68.

Keywords: stripper; flax for oil; seed losses; harvester

The approach to the growing problems of harvest technology and the utilization of oil flax for industrial and food-processing purposes started in the Czech Republic in 1989. Agronomic technology of oil flax was solved in arid areas on sand or sand-loam soils. This region has the reducing trend of cereals and fodder plants and decontaminate plants in poor ecological areas in North and West Bohemia and on soils with larger content of cadmium.

The harvest of oil flax was solved with a utilization of combine harvesters, that do not need any special adjustment for direct harvest after the defoliation of flax growth. With regard to fibrous material cutting it is necessary to ensure the perfect condition of cutting mechanism. With respect to seed losses it is necessary to ensure the optimal adjustment of the separating mechanism.

In 1994 the Horsch firm rented a stripper to the Department of Agricultural Machines of the Czech University of Agriculture in Prague for testing its functional ability during oil flax harvest. With respect to informative features of tests, the losses of the seeds were faind out behind the stripper. The stripper was installed on the combine harvester CLAAS 208 Mega in working regimes only (Table 1).

Since 1995–1998 (with exception of 1996 when the measuring of harvest losses was not carried out due to unfavourable conditions) the direct harvest technology of oil flax by using the combine harvesters was investigated on the important flax growers' farms. The harvest conditions and quantity of harvest losses after using the combine harvester are specified in Table 2.

Table 1. The losses of the seeds behind the Horsch stripper and E 527 combine harvester during oil flax harvest

Horsch stripper		
Travelling speed (km/h)	Revolutions of reel (r.p.m.)	Losses behind the stripper (%)
4	490	1.98
	700	5.06
	(test 1) 833	1.92
	(test 2) 833	0
	991	3.7
6	490	4.64
	700	not stripped
	833	4.63
	991	6.25
8	490	5.78
	700	not stripped
	833	2.72
	991	3.28

E 527 combine harvester			
Travelling speed (km/h)	Losses (%)		
	reaping table	harvester	combine harvester
4–5	0.26	0.24	0.25

MATERIAL AND METHODS

In 1994 the harvest losses measuring of oil flax seeds was carried out behind the Horsch stripper on the plain field of the co-operative farm Chýně in a not defoliated uniform oil flax stand (variety Anteres, moisture content of seeds 10%). The biological yield of seeds was 1.8 t/h. The harvest losses, adequate to every referred test, were counted as the average from 6 samples (number of seeds on a square of 0.5 m^2); incidentally picked up on the tested area of 3 × 90 m.

Since 1995–1998 the tests were aimed to losses determination during the direct harvest of oil flax by using of combine harvesters. The quantity of the losses was determined from 6 samples (number of the seeds on the square of 0.5 m^2) always picked up behind a left part (L), behind a right part (R) and behind the middle part of the reaping machine and the combine harvester. The real harvest conditions are specified in Table 2.

Table 2. Harvest technology of flax for oil in Czech Republic

Company (year)	Variety	Yield (t/ha)	Moisture of seeds (%)	Direct harvest by using of combine harvester					
				Machine		Harvest losses (%)			
				Mark	v (km/h)	Table L	Table R	Harvester	Average
Mr. Naxera (95)	Segedi	2.17	10.6	E 514	4–5	1.47	1.18	0.81	1.14
ZD Staňkovice (95)	Defolia-	2.797	10.4	John Deer 2066	3.5–4	0.52	0.41	0.47	0.468
ZD Zhoř (97)	tion	2.11	10.5	John Deer 2066	7–8	1.02	3.64	3.17	2.6
	of			New Holland TX 68		0.36	1.41	2.63	1.47
ZD Zhoř (98)	growth	1.61	10.1	New Holland TX 68	10	2.44	3.95	5.93	4.11

THE RESULTS OF THE TESTS

The harvest losses are shown in Table 1 (behind the stripper with four possible regimes of stripper reel revolutions and travelling speeds). Similar results are in Table 1 for the E 527 harvester.

The results of 1995–1998 operating tests are specified in Table 2.

DISCUSSION AND CONCLUSION

The results of tests can be described by this conclusion: the losses of seeds during a harvest of oil flax by Horsch stripper were mostly considerably larger under the comparable conditions than at the direct harvest by using an E 527 combine harvester. According to Horsch firm references the oil flax harvest was carried out during stripper testing in Germany successfully. According to Mr. Noris Hobson from Silsoe Research Institute (United Kingdom) it is also possible to harvest the oil flax by using the stripper successfully. It is estimated that the harvest losses will be ca. 1% larger than in the direct harvest by using the combine harvester. On the base of our experiences obtained from tests it is possible to conclude that the losses of seeds behind the stripper are caused by purse cracking (influence of reel combs) and by problematic ventilating effects of reel (impact on free seeds).

The operating tests carried out in 1995–1998 proved that the harvest losses of oil flax seeds after combine harvesters are acceptable under the condition of sufficient technological responsibility of the harvest personal.

References

HANOUSEK B., 1998. Problemy zbioru lnu olejovego v Republice czeskiej. Current Problems of Agricultural Engineering. Szeczin, IIRAR: 35–37.

HANOUSEK B., KRUPIČKA J., STEHLÍK F., 1999. Řešení sklizně olejného lnu v ČR. Sbor. z mezinár. konf. Zemědělské inženýrství na přelomu 20. a 21. století. Praha, ČZU: 132–135.

Received 9 February 2000

Ztráty při sklizni olejného lnu žacími mlátičkami

ABSTRAKT: V roce 1994 jsme zjišťovali ztráty semene při sklizni olejného lnu za očesávacím stolem firmy Horsch. Stůl byl instalován na sklízecí mlátičce CLAAS 208 Mega. Výsledky jsou uvedeny v tab. 1. V letech 1995–1998 byly zjišťovány ztráty semene při sklizni olejného lnu sklízecími mlátičkami E 514 a John Deere 206 firmy New Holland TX 68. Výsledky uvádí tab. 2. Z výsledků pokusů vyplývá, že ztráty semene za očesávacím stolem firmy Horsch byly za srovnatelných podmínek větší než za žacím stolem sklízecí mlátičky E 527. Provozní pokusy z let 1995–1998 prokázaly, že při dostatečné technologické kázni obsluhy lze sklízet olejný len žacími mlátičkami s přijatelnými ztrátami semene v rozmezí 0,46–4,11 %.

Klíčová slova: očesávací stůl; olejný len; ztráty semene; žací mlátička

Corresponding author:

Prof. Ing. BLAHOSLAV HANOUSEK, CSc., Česká zemědělská univerzita, Technická fakulta, 165 21 Praha 6-Suchdol, Česká republika, tel. + 420 2 24 38 41 34, fax: + 420 2 20 92 13 61, e-mail: hanousek.praha@worldonline.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 vytištěný na papíru formátu A4. K rukopisu je vhodné přiložit disketu s textem práce, popř. grafickou dokumentací 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 vše hno podstatné, co je obsaženo ve vědecké práci, má obsahova základní číselné údaje včetně statistických hodnot. Je uveřeňován a měl by být autory dodán v angličtině a češtině.

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

Úvod (bez nadpisu) by mě 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. 1 2001

CONTENTS

OBSAH

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 24 25 51 06, fax: + 420 2 22 51 40 03, e-mail: braun@uzpi.cz ● Sazba a tisk: ÚZPI Praha ●

Rozšiřuje Ústav zemědělských a potravinářských informací, referát odbytu, Slezská 7, 120 56 Praha 2