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Static low-level bruising in pears

J. BLAHOVEC[1], M. VLČKOVÁ[1], F. PAPRŠTEIN[2]

[1]*Czech University of Agriculture, Prague, Czech Republic*
[2]*Research Institute for Pomology Ltd. Holovousy, Czech Republic*

ABSTRACT: Stress-induced enzymatic browning is one the most important limiting factor of product quality in case of soft fruits (apples, cherries, pears etc.) and soft vegetable (e.g. potato tubers). The bruise extent is expressed by bruise volume depending on the total work of loading and/or the energy absorbed in course of loading. The pears, var. Clapps' and Lucas' were tested in loading – unloading compression test between two plates with aim to find suitable indicator of the pear sensitivity to bruising. The bruise spots were cut and their volume was determined from the observed cross section. The tests showed that the usual parameters used for evaluation of bruise sensitivity (BRC, BS) had limited ability to describe the variety differences as well as the special properties at low level bruising. The suitable mechanical parameters for this purpose were found: elasticity degree and especially hysteresis losses applied to the characteristic low level deformation states ($BV = 0$ and $BV = 0.5$ cm^3).

Keywords: pears; bruising; compression; impact; bruise volume; absorbed energy; hysteresis losses; quality

Fruit bruising is one of the most important factors limiting the mechanisation and automation in harvesting, sorting and transport of soft fruits and vegetable, including potatoes. Dark spots appearing near the product surface are due to the previous mechanical contacts of the products with other bodies. Force loading the fruit can be very variable (JOHNSON 1987), ranging from static to dynamic. Bruise extent is usually described in terms of bruise volume (BLAHOVEC et al. 1991) which is in a tight relation to the product quality. SCHOORL and HOLT (1986) estimated that one bruise spot about 10 cm^3 of volume formed on an apple surface promotes 50% reduction of its storage time. STUDMAN (1995) lists fourteen factors affecting bruising of apples, but the role of some of them is slightly controversial. The most important bruise factor in every case is the loading extent which is usually expressed in the terms of loading or absorbed energy (HOLT, SCHOORL 1977).

HOLT and SCHOORL (1977) originally described the relation between bruise volume and the absorbed energy as a simple linear function where constant term is equal to zero and the slope is termed as the Bruise Resistance Coefficient (BRC). Other factors affecting the apple bruising may be reflected in BRC. This very fruitful but yet controversial idea was used by HOLT and SCHOORL (1983, 1984) and others, e.g., BRUSEWITZ and BARTSCH (1989) and KAMPP and NISSEN (1990). BRC is a term that increases when bruise resistance decreases, or when bruise volume increases. The proportional character of the relation between the bruise volume and the absorbed energy does not enable the undamaging level of loading to be defined. Similarly as BRC the Bruise Sensitivity (BS) is defined as a ratio of bruise volume and loading energy (KAMPP, NISSEN 1990). Hyde and his students (e.g. HYDE, INGLE 1968; BAJEMA, HYDE 1998; MAT-

HEW, HYDE 1997) use the reciprocal value of the BRC, so called bruise resistance (BR).

It was shown that for static bruising the obtained BRC and BS values are not constant – the bruise volume increases non-linearly with increasing of both energies – loading and absorbed (apples – BLAHOVEC et al. 1997; cherries – BLAHOVEC et al. 1996). For fruits of the higher quality, the conditions corresponding to no and/or very little bruise damage are the things of the most importance. The evaluation of this area by two separate BRC (BS) values was proposed in a previous paper (BLAHOVEC 1999).

In this paper the relations between bruise volume, the absorbed energy, the loading energy, the degree of elasticity (DE) and the relative absorbed energy were studied onto two pear varieties by quasi-static loading up to definite stress with the aim to obtain more information about bruising at different loading extents.

MATERIALS AND METHODS

Clapps' Pear and Lucas' Pear were harvested in the orchard of the Research Institute for Pomology Ltd. at Holovousy in North-Eastern Bohemia. The fruits were harvested in a stage of harvesting maturity. The details about harvesting dates and store conditions prior testing are given in Table 1. Every test was carried on forty defect free fruits that were divided into the four groups with ten fruits. The fruits were than compressed individually between two plates by constant deformation rate 0.167 mm/s. The fruits' axis was oriented to be parallel with the compression plates. After reaching of the desired force (20, 40, 60, and 80 N for fruits included in the separate groups) the fruit was unloaded by the opposite deformation rate. All the loading-unloading tests

Table 1. Basic information about the fruits (40 fruits for every experiment)

| Variety | Date | | Storing | |
	Harvest	Test	Cold (4°C)	Tempering before test (20–22°C)
Clapps'	4. 9.	5. 9.	--	24 hours
	15. 10.	24. 10.	15. 10.–23. 10.	24 hours
Lucas'	15. 10.	25. 10.	15. 10.–23. 10.	48 hours
	15. 10.	29. 10.	15. 10.–23. 10.	120 hours

were performed in Universal Testing Machine (UTM) Instron (model 4464) at usual laboratory conditions (temperature 20–22°C). The obtained loading curves were evaluated by the UTM software and the following parameters were obtained (Fig. 1, BLAHOVEC et al. 1996, 1997): loading energy (W_L), unloading energy (W_U), absorbed energy ($W_A = W_L - W_U$), maximum deformation (D_1), inelasic deformation (D_2), degree of elasticity ($DE = 1 - D_2/D_1$) and hysteresis losses ($HL = W_A/W_L$).

Early variety Clapps' pear was stored after the harvest at room temperature and tested approximately after 24 hours of storing. Late variety Lucas' Pear was stored 8 days in cold store about 4°C and than was left 1–5 days tempered at room temperature (Table 1).

After test the fruits were left on the table in a laboratory at room temperature (20–22°C) for about 24 hours. During this interval the colour of the bruised parts of the fruit flesh changed from the original to brown (HOLT, SCHOORL 1977). The fruits were then cut in the mid-

dle of the two bruised spots perpendicularly to the fruit surface and the diameters (d) and depths (h) of the spots were measured. These were used to calculate the bruise volume of the individual spot based on the formula given by BARREIRO (1999):

$$V = \pi d^2 h/6 \qquad (cm^3) \qquad (1)$$

This formula gives results (BLAHOVEC 2001) comparable to the values of bruise volume obtained by the classical formula (MOHSENIN 1970; HOLT, SCHOORL 1977).

RESULTS AND DISCUSSION

Examples of the obtained loaded-unloaded curves are given in Fig. 2. The figure shows that character of the loaded-unloaded curve was approximately the same for different levels of loading, but the area of hysteresis loop became larger with increasing level of loading. The parameters characterising the loop and bruise volume are given in Table 2. Loading energy, absorbed energy, and bruise volume increased with increasing load level, depending also on variety and tempering at room temperature prior testing. Least significant difference (LSD) is so high that significant differences can be determined only among the results obtained at the highest load levels (80 N). Similar conclusion can be made in relation to bruise volume. The calculated BRC and BS depend on the load level characteristically (BLAHOVEC et al. 1997; BLAHOVEC 1999). Variability of BRC and BS has at
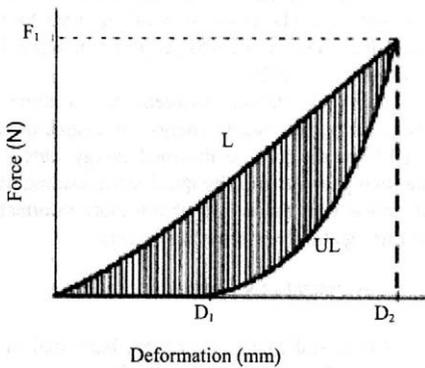
Fig. 1. Schematic representation of the loading test of a pear between two plates. It consists of two parts: loading of the fruit (L) at a constant strain rate up to total compression force F_1, followed by unloading at the same but reversed strain rate (UL). The first parts begin at zero force and zero deformation and ends at force F_1 and deformation D_1, the second part begins at the end state of the first part and ends at zero force and deformation D_2. The area between loading part and the axis D represents loading energy W_L, the unloading energy W_U – the recovered part of the loading energy – is represented by the area between unloading part and the axis D. The marked area between the curves L and UL is the so called absorbed energy
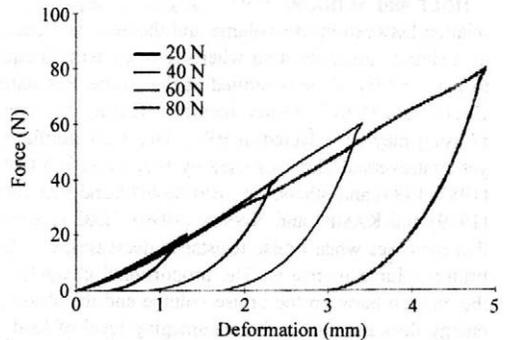
Fig. 2. An example of the obtained deformation curves (Lucas' Pear after days of tempering at room temperature). The numbers denote level of loading in Newtons

Table 2. Mean values of measured quantities in sets of ten specimens with ANOVA analysis of influence of variety (V), load level (L) and pre-test tempering at room temperature (T)

Variety	Force (N)	Loading energy (mJ)	Absorbed energy (mJ)	Bruise volume (cm³)	BRC (cm³/J)	BS (cm³/J)	Deformation (mm)	Hysteresis losses (%)	Elasticity degree (%)
Clapps' 1st day	20	11.2	4.8	0.0	0.0	0.0	1.2	41.7	75.4
	40	42.3	24.2	0.9	32.2	19.8	2.3	56.4	62.7
	60	113.2	82.4	5.1	56.9	42.2	3.9	71.6	41.5
	80	214.7	167.1	10.7	58.1	45.4	5.3	76.0	38.8
Lucas' 1st day	20	10.3	3.6	0.0	6.4	2.5	1.2	34.8	75.9
	40	47.8	28.1	0.2	5.4	3.3	2.7	53.9	59.8
	60	86.6	50.0	0.2	3.3	2.2	3.2	56.8	60.2
	80	147.1	90.0	0.8	5.6	4.1	4.0	59.4	59.3
Lucas' 2nd day	20	11.5	4.9	0.0	1.6	0.6	1.3	42.7	67.6
	40	45.9	26.3	0.3	9.9	6.0	2.6	56.6	58.0
	60	91.2	56.0	0.4	6.8	4.5	3.4	60.8	55.0
	80	163.9	109.2	1.9	13.1	9.5	4.4	65.4	53.5
Lucas' 3rd day	20	15.7	8.8	0.0	0.6	0.3	1.7	56.1	59.6
	40	69.5	52.0	3.0	56.1	42.3	3.5	74.2	40.7
	60	205.6	175.3	15.8	86.1	73.1	6.5	84.2	28.3
	80	345.2	298.7	24.0	72.8	63.5	8.2	85.3	28.8
Anova and Fisher's LSD protected test	Variety (V)	*	*	*	*	*		*	
	Load (L)	*	*	*	*	*	*	*	*
	Tempering (T)	*	*	*	*	*	*	*	*
	VL	*	*	*	*	*	*	*	
	LFT	*	*	*	*	*	*		*
P = 0.05	LSD	135	212	1.55	0.38	0.4	0.65	0.94	2.1

least two sources: different individual stage of maturity of the individual fruits and mainly the highly non-linear character (BLAHOVEC 1999) of dependence between bruise volume and corresponding energy quantity (load energy for BS and absorbed energy for BRC).

Low LSD values were obtained for deformation, hysteresis losses and elasticity degree, for which trivial correlation with the bruise volume is visible in Table 2. The deformation and the hysteresis losses increased with increasing bruising volume and elasticity degree expressed the opposite sense of changes. Both deformation and elasticity degree is not too sensitive to variety and seems to be less suitable as an indicator of sensitivity to bruising of different varieties. The hysteresis losses should be preferred for this purpose. These relations have to be discussed more deeply before making the final conclusions.

The relations between bruise volume (V) and most of the mechanical parameters (denoted as X) were modelled by the following power equation:

$$V = A \left(\frac{X - X_{sh}}{X_0}\right)^n \quad \text{for } X \geq X_{sh} \quad (2)$$

where A (in cm^3) and n (dimensionless) are parameters and X_0 is dimensional constant with the same dimension as X. Parameter X_{sh}, shift of X, represents maximum value of parameter X at which no bruise on the pear should be observed. Fig. 3 contains real plot of the bruise volume against hysteresis losses as a representant of X in Eq. (2). The obtained parameters A, HL_{sh}, and n are given in Table 3.

For plots of the bruise volume against the elasticity degree (ED) the model equation (2) had to be modified into the following form:

$$V = B \left(\frac{ED_0}{ED}\right)^m - V_0, \quad \text{for } ED/ED_0 < (B/V_0)^{1/m} \quad (3)$$

Fig. 4. Bruise volume plotted against elasticity degree – all obtained results are included into the figure. The results are approximated by shifted power equation – see Eq. (3)

where B and m are parameters similar to A and n in Eq. (2), ED_0 is the dimensional constant and V_0 is a shift in V. Bruise volume V equales zero for ED higher than $ED_0.(B/V_0)^{1/m}$. The obtained parameters B, V_0, and m are given in Table 4. The shift in ED: $ED_{sh} = ED_0.(B/V_0)^{1/m}$ is also given in the table.

Low-level sensitivity of fruits to bruising can be expressed by parameters corresponding to zero bruise volume and bruise volume 0.5 cm^3 (BLAHOVEC 1999, 2001). For hysteresis losses these values are displayed in Fig. 5. Two conclusions relating to the tested pears can be made according to the data presented in this figure. The Clapps' Pear is more sensitive to bruising than Lucas' Pear, because both the evaluated values are lower than the corresponding values for Lucas' Pear – the bruise volume increased more quickly with increasing hysteresis losses. The values are not too sensitive to the state of ripening. Especially hysteresis losses

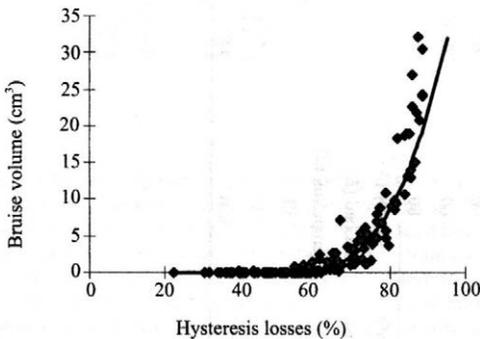Fig. 3. Bruise volume plotted against hysteresis losses – all obtained results are included into the figure. The results are approximated by shifted power equation – see Eq. (2)
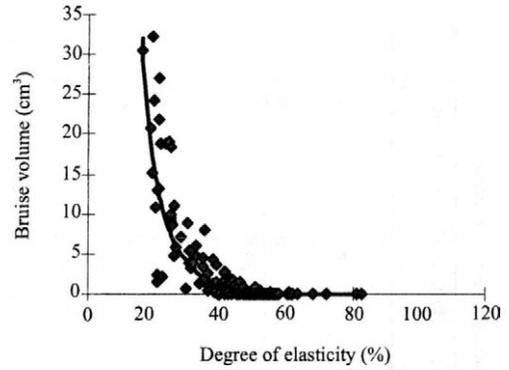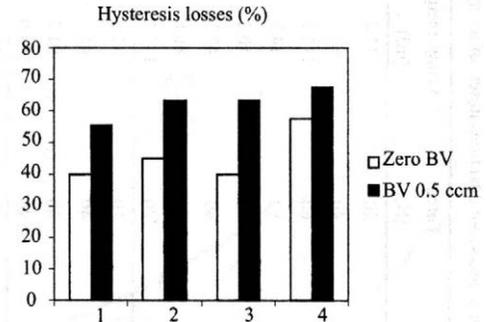

Fig. 5. Hysteresis losses corresponding to zero bruise volume (HL_{sh}) and $BV = 0.5$ cm^3 for the tested sets (1 – Clapps' Pear, 2 – Lucas' Pear 1st day, 3 – Lucas' Pear 2nd day, 4 – Lucas' Pear 3rd day)

Table 3. Parameters of Eq. (2) for hysteresis losses – for details see text

Variety		A $(10^{-6}\ cm^3)$	n	Shift: HL_{sh} (%)	R
Clapps' Pear		63.979	3.26	40.0	0.917
Lucas'	1st day	26.461	3.38	45.0	0.912
	2nd day	0.062	5.06	40.0	0.800
	3rd day	146.062	3.50	57.4	0.983
Lucas' Pear		3,424.132	2.36	54.6	0.890
Total		116.500	3.27	49.0	0.850

Table 4. Parameters of Eq. (3) for elasticity degree – for details see text

Variety		B $(10^6\ cm^3)$	m	V_0 (cm^3)	ED_{sh} (%)	R
Clapps' Pear		0.3058	2.91	1.00	75.7	0.940
Lucas'	1st day	298.0000	5.04	0.21	65.1	0.850
	2nd day	0.2740	2.96	1.35	61.9	0.759
	3rd day	1.5900	3.45	1.20	59.3	0.894
Lucas' Pear		1.2300	3.51	0.50	66.5	0.908
Total		0.3890	3.13	0.70	68.6	0.897

corresponding to the bruise volume 0.5 cm³ varied only slightly for the Lucas' Pear tempering at room temperature with differences up to 100 hours (Table 1). This is why the hysteresis losses corresponding to zero BV and $BV = 0.5$ cm³ seem to be good parameters for evaluation of the pear varieties susceptibility to bruising.

CONCLUSIONS

Hysteresis losses in loading-unloading test well correlate with directly observed bruise volume. For evaluation of the variety sensitivity to bruising the values of hysteresis losses corresponding to zero BV and BV 0.5 cm³ seem to be preferred before the corresponding values of the elasticity degree. Hysteresis losses increase with increasing loading and after reaching the characteristic value (higher than 40% in our tests) the first bruise spots. The higher is this value (and similarly the higher are hysteresis losses corresponding to BV = 0.5 cm³) the less sensitivity to bruising is the tested pear variety.

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Statická nízkoúrovňová deformace plodů hrušek

ABSTRAKT: Otlaky jsou jedním z nejdůležitějších limitujících faktorů pro stanovení kvality měkkých ovocných plodů (jablka,
třešně, hrušky atd.) a měkkých plodů zeleniny (např. bramborové hlízy). Velikost otlaku plodů je vyjádřena objemem těchto
otlaků, který závisí na celkové práci při zatěžování nebo na absorbované energii v cyklu zatížení. Odrůdy hrušek Clappova
a Lucasova byly testovány zatěžovacím a odtěžovacím tlakovým testem mezi dvěma rovnoběžnými deskami s cílem nalézt
vhodný indikátor pro citlivost plodů hrušek na vznik otlaků. Hnědá místa otlaků byla rozříznuta, poté byly sledovány geomet-
rické parametry otlaků pro přesný výpočet objemu otlaku. Test ukázal, že doposud používané parametry (BRC, BS) pro odhad
citlivosti plodů na otlak jsou méně vhodné pro popis meziodrůdových rozdílů a podobně i speciálních vlastností plodů při nízké
úrovni zatížení. Pro tento účel byly nalezeny vhodné mechanické parametry: stupeň elasticity a hysterézní ztráty, které se dají
dobře použít pro vznik otlaku při nízkých hladinách deformace ($BV = 0$ a $BV = 0,5$ cm³).

Klíčová slova: hrušky; otlaky; stlačení; vliv; velikost otlaku; absorbovaná energie; hysterézní ztráty; kvalita

Corresponding author:

Prof. RNDr. Ing. JIŘÍ BLAHOVEC, DrSc., Česká zemědělská univerzita, Technická fakulta, 165 21 Praha 6-Suchdol,
Česká republika
tel.: + 420 2 24 38 42 81, fax: + 420 2 20 92 13 61, e-mail: blahovec@tf.czu.cz

Effect of brewer's raw material on the course of main fermentation

J. MAREČEK[1], L. SYCHRA[1], H. NAJMANOVÁ[2]

[1]Mendel University of Agriculture and Forestry, Brno, Czech Republic

[2]Litovel Brewery, Czech Republic

ABSTRACT: The paper brings an assessment of the influence of the primary raw material (malt) on incrementally growing problems of main fermentation in beer production. The problems in question are low rate and poor attenuation and they mainly occur in the classical yeasting technology. Operational and laboratory tests were made on the basis of a technological research of operation. The operational tests were focused on the effect of yeasting temperature, yeast strain, and physiological influence of the inoculum on the problem solution. The laboratory tests were made with individual malt types and included a verification of the starter dose, yeast strain and bottoms content on the course of yeasting. Fermentation tests included five malt samples. The quality of malts processed in the brewery as measured by the currently used analytical criteria did not exhibit differences big enough to make the analyses capable of suggesting problems in yeasting and final fermentation, not speaking of the problem of premature yeast sedimentation. It followed from the operational research that the values of dissolved oxygen in cooled wort were ranging from 6.9–7.8 mg/l. The tests showed a highly significant dependence of apparent extract on yeasting time, both in cold yeasting (2.9–3.5% mass toward the end of yeasting) and in warm yeasting (2.4–3.3% mass toward the end of yeasting).

Keywords: malt; hopped wort; fermentation; extract; β-glucans; friability; final attenuation; diastatic power

Yeasting failures in beer production represent a serious problem that makes the fermentation longer and sometimes even stopped. They can impair beer quality due to changed sensorial properties of beers. The prolonged yeasting time needed for reaching the required attenuation impairs the use of the fermenting room and if there is not enough space in it, the brewery has to fill barrels with beer, which is considerably green, which eventually can results in the quantity of insufficiently attenuated beer.

Yeasting depends on a number of parameters, which affect the irregular course of fermentation. It might be induced by an immediate change of an important regulation element or by a combination of several factors. It can however also result from a slowly working factor whose impacts appear only after a certain time of its operation. Reasons of fermentation problems can be essentially sought in the used yeast, breach of technological conditions, and in the composition of hopped wort.

A fermentation failure in operational conditions is usually sought in yeast. Yeast responds very sensitively to any changes of wort composition as well as to any changes of technological parameters, which will sooner or later reflect in its activity and hence in the course of fermentation. In this connexion, its basic technological properties such as the rate and measure of wort yeasting as depending on the equipment of yeast cells with enzymes, capacity of flocculation and sedimentation must be respected. Lower attenuation of hopped wort by the yeast strain with medium-yeasting capacity cannot be considered a yeasting failure since it is a characteristic feature of the strain (KREGER 1984; LODDER 1970).

One of the fermentation failures due to yeast can be a low starter dose with high sludge content (sometimes even 45%) in the case that yeast is not properly washed, or different DM contents. It can also be a poor physiological condition of yeast due to repeated employment when the yeast gradually degenerates and its fermentation power is decreasing. Yeast is often a carrier of contamination – both by foreign yeast and by coliform and lactic acid bacteria which restrict the activity of culture yeast by utilizing live substances and by the production of their metabolites thus being a cause of serious yeasting disorders. The result is usually insufficient yeasting of hopped wort and unfavourable impact on the sensorial character of beer.

Another reason of poor fermentation may be the mechanical contamination of yeast surface by sludge substances of colloidal nature, which would restrict the uptake of nutrients from the environment due to the reduction of active yeast surface, slow down the exchange of substances and which would eventually result – apart from the longer yeasting time also in the premature sedimentation and impaired yield of yeast.

Table 1. Quality of malting barley

Sample	RE45 (%)	KN (%)	F (%)	H (%)	GG (%)	P (%)	BG (mg/l)
1	37.4	37.7	81.0	91.5	5.9	9.4	222
2	35.8	36.8	79.0	91.2	5.0	9.8	206
3	40.9	39.4	82.2	94.2	2.2	9.7	202
4	35.1	38.1	82.0	94.2	1.4	9.9	181
5	36.8	39.3	84.4	96.0	0.6	9.8	148

Note: RE45 – relative extract at 45°C; KN – Kolbach number; F – friability; H – homogenity; GG – glassy grains; P – protein content;
BG – ß-glucan content

Yet another reason can be technological factors such as the yeasting temperature or the method and intensity of wort aeration.

The course of fermentation is also affected by the composition of hopped wort, which can influence the yeast activity by its content of important substances. The wort composition is given by the quality of raw materials and by the mashing technology (EBC 1998; BASAŘOVÁ et al. 1993; DONHAUSER et al. 1986; DONHAUSER, WAGNER 1990; EINSIEDLER et al. 1997; HAGE et al. 1981; HILL et al. 1998).

MATERIAL AND METHODS

The measurement was made with five samples of the standard hopped wort, collected at certain time intervals. The process of manufacture included milling, douphing in and mashing, lautering, hops cooking, wort cooling and the main yeasting. The goal was to introduce the extract substances of malt and hops into the solution at optimum rates and composition and to ensure in this way both sufficient nutrients for the metabolism of yeast and an adequate bitterness of final beer.

Malts were sampled for qualitative analyses prior to the milling (Table 1).

Mashing was made for two mashes. Boiling was made three times (Dose 1: all hops extract when holding together, to use CO_2 – Barth extract – 1 kg alpha; Dose 2: 25 minutes after boiling the entire dose of bitter hops, high-content aromatic hops mixture Bor + Sládek – 4 kg, K_h = 8.62, maltster – 2 kg, K_h = 5.60; Dose 3: 20 minutes prior to the end of hops boiling – the entire dose of fine aromatic hops – 15 kg Tršice, K_h = 3.23). The process took 120 minutes. The wort was pre-cooled and additionally cooled with ice-cold water to achieve the starting temperature of 6°C.

The goal of the main yeasting is incomplete fermentation of sugar-containing substances at the simultaneous development of ethyl alcohol, carbon dioxide and secondary metabolites. Wort treated to the required stages was started in fermenting vats or attenuation tanks with about 0.5 l thick yeast per 1 hl wort (i.e. approximately 12–16 mil cells in 1 ml wort). Starter dose in the fermentation tanks was 1 l thick yeast per 1 hl wort. Maximum temperature of the main yeasting was 10–2°C (according to the strain of yeast employed).

The next step consisted of laboratory and operational fermentation tests.

The laboratory fermentation tests included three types of strains, i.e. No. 95 – an operational strain from the Hanušovice brewery (2nd employment), No. 7 – the operational strain from the Litovel brewery (1st employment), and No. 7sb – in the laboratory propagated pure culture made of a collection of brewer's yeast cultivated at the Research Brewing and Malting Institute in Prague. Wort used for the tests was the operational wort from Malt 1, aerated in the laboratory, apparent extract 12.1% mass, pH 5.9, yeasting temperature 8.0°C. Malt used for the tests was analysed in the Agricultural Research Institute Kroměříž to standard methodologies (EBC 1998; MEBAK 1979).

The statistic program UNISTAT v.5.1 statistically processed the test results.

RESULTS AND DISCUSSION

The laboratory tests of fermentation were made with the congression wort for the comparison sample, tested sample and unsatisfactory sample. The operational tests were made for cold employment of yeast with temperature below 10°C and for the warm employment with temperatures of 10°C and 12°C.

OPERATIONAL TESTS

The studied basic qualitative parameters of the samples did not indicate any extremely low values of cytolytic and proteolytic modification and hence the following out impact of the low proportion of fermentable sugars and insufficient amount of utilizable aminoacids onto the normal course of yeasting. The first three samples exhibited some problems with the flow-down of the first wort, with a relatively high content of β-glucans, and hence increased sorption onto the yeast cells. The quality of malt assessed in this way was mediocre and did not indicate the warning incapacity of use of this raw material with respect to possible problems during the process of fermentation.

The above finding was corroborated also by an analysis of worts cooked of the respective malts. The content of N-substances (total nitrogen 770 to 860 mg/l) and the level of high-molecular proteins were standard average;

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Table 2. Quality of wort samples

Wort – sample No.		1	2	3	4	5
Total nitrogen	(mg/l)	840	826	777	860	845
Proteinous nitrogen	(mg/100 ml)	51.10	48.60	47.20	52.40	51.60
α-aminonitrogen	(mg/l)	240	250	246	252	248
Reducible sugar	(mg/100 ml)	7.31	7.36	7.38	7.26	7.02
Total glucan	(mg/100 ml)	1,229	1,203	1,136	1,228	1,124
α-glucany-dextrin	(mg/100 ml)	1,212	1,164	1,118	1,168	1,102
α-glucan	(mg/l)	167	164	182	180	152
Apparent final attenuation	(%)	86.20	86.40	86.40	86.60	88.20
Cu	(mg/l)	0.11	0.11	0.11	0.10	0.11
K	(mg/l)	393	393	396	394	390
Ca	(mg/l)	22	24	28	26	28
Fe	(mg/l)	0.09	0.08	0.06	0.07	0.09
Zn	(mg/l)	0.08	0.10	0.10	0.12	0.16
Mg	(mg/l)	59	58	55	56	55

the content of N-substances usable by the yeast as represented by the value of α-aminonitrogen was favourable (240 to 252 mg/l – Table 2).

The content of total higher-molecular glucans or dextrins ranged around the upper limit of the measured values, which corresponded well to the relatively low proportion of fermentable sugars in total wort extract as expressed by the value of reducing sugars. The detected levels are neither extreme nor unfavourable regarding the fact that the Czech beer type is characterized by full flavour and rather medium fermentation. The actual proportion of fermentable extract components as given by the value of feasible attenuation is relatively high and does not signal a low proportion of utilized substances. The measured content of β-glucans – possibly influencing the flow-down and fermentation – was increased in the three samples and even exceeding the generally accepted limit of 200 mg/l. The content of bottoms in the fermenting wort was considerably high, indicating a danger of yeasting being possibly affected by the adsorption of turbidizing substances on yeast cells. A detailed analysis of turbidizing substances and their components is rather complicated. In any case, the substances participating in the process may be both polysaccharides (α- and β-glucans) and higher-molecular proteins (Table 2).

The pH values of sweet worts or hopped worts are modified by lactic acid SP-80 as early as during pre-mashing in orders to support the activity of hydrolytic enzymes. An analysis of metal ions revealed low wort zinc content (optimum = 0.15–0.30 mg/l), which is important for the growth of yeast (Table 2). The content of calcium was in contrast favourably low (higher concentrations would support yeast sedimentation).

Other measured elements exhibited no extremities. A microscopic examination of starting yeast for the respective variants showed a very favourable friability

– less than 0.5% of dead cells and a minimum amount of microscopically detectable foreign substances. The measured values of yeast vitality were very high.

Oxygen dissolved in the cooled wort was measured right at filling the open vessels and its values were ranging between 6.9–7.8 mg/l. The generally accepted optimum of 8 mg/l was never exceeded; however, this did not indicate that the measured results had to be necessarily considered unambiguously negative. The situation can be described in such a way that one could see large oxygen bubbles in the peep hole and the efficient dissolution of air-bound oxygen in the wort did not occur.

The course of the main yeasting of the respective malts under test as dependent on various temperatures is documented in Tables 3 and 4. The starting dose of yeast differed only negligibly in the respective variants, there was no automated dosing of starter in operation; yet, the second day of yeasting showed the generally equal cell counts in the uplifts in all vats.

A comparison of the main fermentation in all malts under test and employment of two different temperatures in the first four samples showed that there was a high residual extract and a low cell count in the uplift towards the end of the main yeasting and particularly at the low temperature, which would not provide good conditions for the normal course of final fermentation. As expected, the course of main yeasting at the temperature of 12°C was much faster with a rapid sedimentation of yeast occurring between Day 4 and Day 5 of yeasting at extract values and counts of yeast cells acceptable for final fermentation.

The fifth sample exhibited an improved cell count in the uplift and a lower residual apparent extract before barreling.

A statistic evaluation of the measured results indicated that there was a highly significant dependence of apparent extract on yeasting time both at using warm and

Table 3. The course of main fermentation with cold yeast employment

Sample	1			2			3			4			5		
Conditions	B3 2. pitching cold convection to 10°C pumping at 6°C			B3 1. pitching cold convection to 10°C pumping at 6°C			B3 1. pitching cold convection to 10°C pumping at 7°C			B2 1. pitching cold convection to 10°C pumping at 7°C			B5 2. pitching cold convection to 10°C pumping at 7°C		
	temperature (°C)		AE	temperature (°C)		AE	temperature (°C)		AE	temperature (°C)		AE	temperature (°C)		AE
Period (day)	6:00[1]	18:00[1]	(% mass)	6:00[1]	18:00[1]	(% mass)	6:00[1]	18:00[1]	(% mass)	6:00[1]	18:00[1]	(% mass)	6:00[1]	18:00[1]	(% mass)
1	6.20	6.60	12.30	6.10	6.60	12.25	7.00	7.50	12.20	7.00	7.60	12.25	7.10	8.00	12.25
2	7.50	8.30		7.40	8.20		8.30	8.70		8.30	8.90		8.90	9.30	
3	8.70	9.60		8.60	9.70		10.00	10.00	7.00	10.00	10.10	7.00	9.90	9.80	
4	10.20	10.00	7.00	9.90	9.90	7.00	10.00	10.00	6.00	10.10	10.00	5.90	10.10	10.00	5.70
5	9.60	9.60	6.20	9.40	9.50	6.00	10.20	9.80	4.80	10.00	9.80	5.00	9.80	9.60	3.90
6	9.60	9.70	5.00	9.40	9.40	5.20	9.40	9.40	3.60	9.80	9.80	4.20	6.80		2.90
7	9.60	9.60	4.10	9.40	9.30	4.60	9.40	8.40	3.40	9.40	9.40	3.60			
8	9.60	9.50	3.40	9.20	9.00	4.00	7.50	6.50	3.30	9.40	8.40	3.40			
9	9.50	9.30	3.30	8.80	8.40	3.60	6.40	5.80	3.20	7.40	6.50	3.30			
10	9.30	7.00	3.20	8.00	8.00	3.50				5.80		3.20			

Note: AE – apparent extract; [1]time of control

Table 4. The course of main fermentation with warm yeast employment

Sample	1			2			3			4			5		
Conditions	B2 2. pitching warm convection to 12°C pumping at 6°C			B1 1. pitching warm convection to 12°C pumping at 6°C			B2 1. pitching warm convection to 12°C pumping at 7°C			B4 1. pitching warm convection to 12°C pumping at 7°C			B4 2. pitching warm convection to 12°C pumping at 7°C		
	temperature (°C)		AE	temperature (°C)		AE	temperature (°C)		AE	temperature (°C)		AE	temperature (°C)		AE
Period (day)	6:00[1]	18:00[1]	(% mass)	6:00[1]	18:00[1]	(% mass)	6:00[1]	18:00[1]	(% mass)	6:00[1]	18:00[1]	(% mass)	6:00[1]	18:00[1]	(% mass)
1	6.00	6.40	12.30	6.20	6.60	12.25	7.00	7.60	12.20	7.00	7.50	12.25	7.40	8.40	12.25
2	7.20	8.10		7.40	8.00		9.60	10.60		8.20	9.20		9.60	9.60	
3	9.20	10.40	7.00	8.80	9.90		11.80	11.90	5.90	10.80	11.80	6.10	10.80	11.60	6.00
4	11.60	11.80	5.90	10.60	10.90	7.00	11.90	10.80	3.20	11.90	12.10	4.10	11.60	10.60	3.90
5	11.80	11.30	4.20	11.80	11.40	5.80	10.60	9.80	3.00	10.80	9.60	2.80	9.20	7.40	2.80
6	10.80	9.80	3.40	10.00	9.80	4.00	8.80	7.80	2.90	8.00	7.40	2.70	6.80		2.40
7	9.80	6.80	3.30	8.70	7.80	2.80	6.40		2.80						
8				6.40		2.70									

Note: AE – apparent extract; [1]time of control

Table 5. Laboratory attenuation test

Strain No.	Hopped wort	Starter dose ($\times 10^6$/ml)	pH (–)	Apparent extract (% mass)	Apparent attenuation (%)
95 (operating)	filtered	8.00	4.20	2.70	77.70
	non filtered	7.90	4.20	3.30	72.70
7 (operating)	filtered	8.00	4.20	3.40	71.90
	non filtered	8.20	4.30	4.50	62.80
	non filtered	11.90	4.25	4.20	65.30
7sb (muster)	non filtered	8.40	4.25	4.90	59.50

cold yeast employment. The fact was corroborated by correlation coefficients whose values ranged between –0.90066 up to –0.9927 for the respective samples under test.

LABORATORY TESTS

Results of the laboratory yeasting tests focused on the effect of wort bottoms and in the standard operational strain No. 7 also on the size of the starting yeast dose are presented in Table 5. It follows from the Table 5 that markedly better results in the both strains were found in the filtered wort rather than in the unfiltered wort, with a more pronounced effect of filtration being shown in the strain No. 7. The strain No. 95 yeasted by 10% deeper under the identical conditions, which corresponded with the characteristics of the strains under test.

The higher starting dose in the strain No. 7 showed to be favourable from point of view of the fermentation depth. The comparison collection strain exhibited worse

results, was propagated for the tests in another wort and was not yet adapted either by the propagation station or by the operation.

The tests unambiguously evidenced the adverse influence of wort-contained sludges as well as that of the used operational yeast strain. A comparison of results from the laboratory tests with the congression sweet wort focused on the effect of malt on the course of fermentation recorded significant differences (Fig. 1).

Monitoring of apparent extract (unsatisfactory malt) revealed a considerably poorer attenuation (Fig. 1); at the same time, the turbidity value characterizing cell counts in the uplift was markedly higher in the comparison malt from the year 1995 at the end of yeasting the relative turbidity units being nearly zero in other two malts, which would correspond to the cell concentration of approx. 10^5 per 1 ml. The combination of the two results points to considerably better conditions for yeasting and final fermentation in the case of using qualitative malts and clearly shows an adverse effect of

Comparison malt
$y = 0.084x^2 - 1.5438x + 10.158$
$R^2 = 0.9836$

Unsatisfactory malt
$y = 0.1002x^2 - 1.5348x + 10.696$
$R^2 = 0.9937$

Tested malt
$y = 0.1141x^2 - 1.8531x + 10.796$
$R^2 = 0.9869$

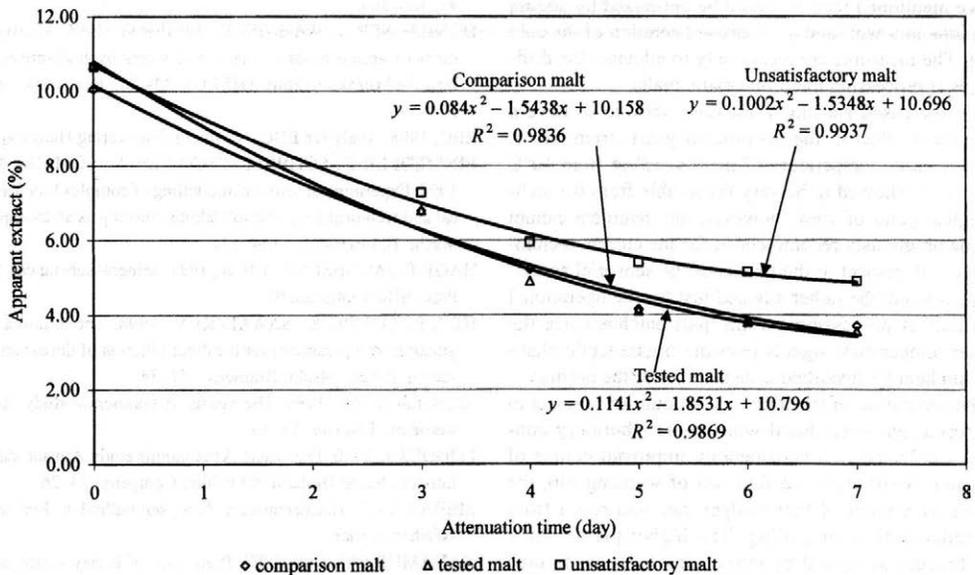◇ comparison malt   △ tested malt   □ unsatisfactory malt

Fig. 1. Laboratory test of yeasting with congression level

tested malts produced from barley harvested in 1996 and 1997 (samples 1 through to 4) on the quality of sweet wort made of them (PSOTA 1997, 1998).

The malt sample No. 5 (harvest year 1998) exhibited a much more favourable condition. According to the results, the malt quality that should be detectable by the current analysis did not signal any serious warning from problems that occurred during the process of fermentation in 1997 and 1998 (PSOTA 1999). There was a study presented at the EBC Congress held in Maastricht in 1997, which dealt with the factor responsible for the premature yeast flocculation (NAKAMURA et al. 1997). The incidence of this factor was evidenced in malt and is expected to occur also in barley. In chemical terms the substance in question is to be an acidic polysaccharide that has not been closer determined yet and the susceptibility of different yeast strains to the same is not yet known.

The statistic analysis showed a high dependence of yeasting time on apparent extract, which was further evidenced by the following correlation coefficients: –0.97313 for the comparison malt; –0.96573 for the malt under test; and –0.96295 for the malt marked as bad and unsatisfactory. The highest dependence was apparently found in the sample of the comparison malt.

CONCLUSION

A complex analysis of the technological research, operational and laboratory tests led to the following conclusions: The currently used yeast strain No. 7 is at a very good physiological condition. The yeasted wort exhibited deficient amounts of zinc and dissolved oxygen, which are factors influencing the yeast multiplication and metabolism during the initial stages of the yeasting process. In order to eliminate the problems the above mentioned factors should be optimized by adding zinc ions into wort and by improved aeration of the cold wort. The measures are meant only to alleviate the difficulties at processing the problematic malts.

The increased starting yeast dose showed to have a favourable effect in the operational yeast strain No. 7. The increased temperature of main yeasting from 10°C up to 12°C showed to be very favourable from the technological point of view; however, the treatment cannot be unambiguously recommended for the current technologies with respect to the results of the sensorial assessment. It would be rather advised just for the operational solutions at processing certain malt batches since higher temperature signals possible organoleptic changes and hence a disturbed taste stability of the product.

The separation of the increased amount of bottoms in the fermented operational wort in the laboratory conditions reflected in a considerably improved course of yeasting. Apart from the function of whirling tub, the increased amount of fine sludges can also result from the reduced time of boiling. The higher pH of worts was brought to normal by introducing lactic acid purac SP-80 to acidify the mash, which helped to optimize the activity of hydrolytic malt enzymes.

The quality of malts boiled in the Litovel brewery in the years 1997 and 1998 and assessed to the current analytical criteria was mediocre. Perhaps the last malt No. 5 boiled in 1999 (from the harvest in 1998) exhibited somewhat better values of β-glucans in malt. The difficulties with the main yeasting can also be caused by the factor of "premature yeast sedimentation" as assumed from the results of the performed laboratory tests, which cannot be detected even by a special malt analysis. It is not known yet to what measure the presence of this factor depends on the harvest year and variety of barley, warehousing technology or the measure of its influence on the individual yeast strains. Therefore, it would be helpful to make tests with malts from other malting houses (preferably from a classical floor malt house) and possibly also some more extensive tests with the strain No. 95 which seems to be less sensitive to the factor in question than the strain No. 7. A certain guideline at predicting the malt behaviour could be the determination of malt fermentability in the own laboratory. A basis for measurements must be standard malt with the fermentability II-normal. Most important for the calculation of fermentability is the value of apparent extract on the eighth day of yeasting. Hops used for the preparation of wort are no less important as it must correspond to the hops processed in the brewery. These were reasons why the determination at the Research Institute of Brewing and Malting in Brno was cancelled.

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Vliv suroviny pivovarské výroby na průběh hlavního kvašení

ABSTRAKT: Práce hodnotí vliv základní suroviny (sladu) na narůstající problémy hlavního kvašení při výrobě piva. Jedná se o pomalý průběh a nízké prokvašení. Problémy se projevují především v klasické technologii kvašení. Byl proveden technologický průzkum provozu a na jeho základě realizovány provozní a laboratorní zkoušky. Provozní zkoušky byly zaměřeny na vliv teploty kvašení, použitý kvasničný kmen a fyziologický vliv inokula na řešení potíží. V návaznosti byly realizovány laboratorní zkoušky jednotlivých druhů sladu (ověření zákvasné dávky, kvasničného kmene a obsahu kalů na průběh kvašení) a kvasné zkoušky. Pro kvasné zkoušky bylo použito pět vzorků sladu. Kvalita sladů zpracovávaných pivovarem hodnocená na základě běžných analytických kritérií nevykazuje tak výrazné rozdíly, aby se podle rozborů dalo usuzovat na problémy kvašení a dokvašování, a hlavně na problém předčasné sedimentace kvasnic. Z provozních sledování vyplynulo, že hodnoty rozpuštěného kyslíku ve zchlazené mladině se pohybovaly v rozmezí 6,9–7,8 mg/l. Následně se prokázala vysoce významná závislost zdánlivého extraktu na době kvašení, a to jak u studeného (2,9–3,5 % hm. na konci kvašení), tak i u teplého kvašení (2,4–3,3 % hm. na konci kvašení).

Klíčová slova: slad; mladina; kvašení; extrakt; β-glukany; friabilita; konečný stupeň prokvašení; diastatická mohutnost

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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

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Influence of housing and feeding systems of pig farms on production costs

J. VEGRICHT, A. MACHÁLEK, F. PECHAČ

Research Institute of Agricultural Engineering, Prague, Czech Republic

ABSTRACT: There was evaluated in total 96 sow farms variants for 944–953 animals with different systems of housing (semi-grate with scraper or under-grate tank and pipe manure transport, deep litter) and feeding (bulky dosing device, pipe feeding, AKB). Further there were evaluated 7 variants of stables for pig fattening of capacity 5,400–5,760 pigs. From point of view of total investment costs per 1 housing place the difference between the most expensive and cheapest variant of sows farm was 23.5%. It impacts on costs for depreciations so the depreciation of the most expensive variant was by 35% higher than of the cheapest variant. But from point of view of total costs per 1 feeding day the costs are for the technically most sophisticated variant only by 3.5% higher than for the cheapest variant. These increased costs could be compensated e.g. by better results of rearing i.e. by higher amount of reared piglets by one sow annually. In the pigs fattening the difference of total investment costs per one housing place between the cheapest and most expensive variant is 69.4% and 130.2% for depreciation evaluation. From point of view of costs per 1 kg gain the difference between the both limiting variants is 7.0–9.6%. This difference then must be balanced by higher gains and better conversion of feed.

Keywords: sow keeping; pigs fattening; technical equipment; production costs

The important branch of agricultural production is sow-keeping and pig-fattening. Considerable factor deciding about economical result of keeping is production cost per unit of final product, i.e. weaned piglet or 1 kg of gain. In professional literature are presented many papers focused on monitoring of production costs within pigs keeping (PODĚBRADSKÝ 1998, 1999; NOVÁK 2000), but there is a lack of detailed farms and stable comparisons with different housing systems and variant technical feeding systems and evaluation of their effect on production costs.

A lot of agricultural enterprises are now deciding about modernisation and new construction of stables for pigs keeping as necessary condition for competitiveness maintenance in still more difficult economical environment. The experiences show that main criterion for their decision about housing technology often is investment costs height. Comparison of different technological systems of housing, feeding and manure removal under comparable conditions is not verified so far and this the potential investor decides only on basis of his/her experiences even influenced not quite objective information of dealers. The scope of the submitted paper is analysis of variant solved systems of housing, feeding and manure removal in stables for sow-keeping and pig-fattening and determination of their effect on technical and economical parameters of farm. The paper follows up with similar analysis of technical and technological systems of dairy cow keeping (VEGRICHT 2001) and both these works give a comprehensive view on problems of variant technological systems utilisation in principal sectors of livestock production and their effect on production costs.

METHODS

These were suggested according to variants model designed stables for sows keeping (farrowing house; saw pigs, mating sows and in-farrowed sows housing), stables for piglets after keeping and for pigs fattening. There also was taken into account solution through present stable modernisation by new technical systems and new construction of stables and farm with necessary technical equipment.

For evaluation of different feeding and housing systems effect were chosen prospective technical and technological systems (VEGRICHT 1998, 1999; SCHWARZ 2000; SEUFERT 2000, and others) complying with present demands of particular pig categories for housing, nutrition, environment, and welfare. The evaluated technical and technological systems and general capacities of stables are entirely presented in Table 1.

The stables capacity for individual pig categories was designed to comply with closed herd turnover under

Table 1. Evaluated variants of stables for pigs keeping, survey of basic parameter

Pigs category	Variant	Stable capacity, pigs	Housing	Feeding	Excrement removal
Pigs fattening 5,440–5,760 housing places	1.1	4 × 1,440	pens for 12 pigs semi-grate	self-feeders	under-grate trough with plug and pipe transport
	1.2	4 × 1,440	pens for 12 pigs semi-grate	trough with sensors	under-grate trough with plug and pipe transport
	2.1	4 × 1,440	pens for 20 pigs semi-grate	tubus feeder	under-grate trough with plug and pipe transport
	2.2	4 × 1,440	pens for 40 pigs semi-grate	cross troughs	under-grate trough with plug and pipe transport
	3.1	4 × 1,360	pens for 40 pigs semi-grate	trough with sensors	deep litter
	3.2	4 × 1,360	pens for 40 pigs, deep litter	tubus feeder	deep litter
	3.3	4 × 1,360	pens for 40 pigs, deep litter	self-feeders	deep litter
Farrowing house 228 housing places	7.1	2 × 114	farrowing pens semi-grate	bulky feeder	under-grate trough with plug and pipe transport
	7.2	2 × 114	farrowing pens semi-grate	liquid feeder	under-grate trough with plug and pipe transport
	7.3	2 × 114	farrowing pens semi-grate	bulky feeder	scrapers in under-grate space
	7.4	2 × 114	farrowing pens semi-grate	liquid feeder	scrapers in under-grate space
Sow pigs and mating sows 236–249 housing places	8.1	245	individual cages, semi-grate	bulky feeder	under-grate trough with plug and pipe transport
	8.2	245	individual cages, semi-grate	liquid feeder	under-grate trough with plug and pipe transport
	9.1	249	individual cages, semi-grate	bulky feeder	under-grate trough with plug and pipe transport
	9.2	249	individual cages, semi-grate	liquid feeder	under-grate trough with plug and pipe transport
	9.3	249	individual cages, semi-grate	liquid feeder	scrapers in under-grate space
	10.1	236	multibox on deep litter	bulky feeder	deep litter
	10.2	236	multibox on deep litter	liquid feeder	deep litter
In-farrowed sows 480 housing places	11.1	480	pens for 60 sows, deep litter	passing through automated feeding boxes	under-grate trough with plug and pipe transport
	11.2	480	pens for 60 sows, deep litter	passing through automated feeding boxes	deep litter
	12.1	480	pens for 8 sows semi-grate	simultaneous feeding at longitudinal troughs	under-grate trough with plug and pipe transport
	12.2	480	pens for 8 sows semi-grate	simultaneous feeding at round troughs	under-grate trough with plug and pipe transport
	12.3	480	pens for 15–16 sows, deep litter	electronical individual boxes not passing through	under-grate trough with plug and pipe transport
	12.4	480	pens for 15–16 sows, deep litter	electronical individual boxes not passing through	scrapers in under-grate space

presumption that on the farm is totally 944–953 housing places for sows and other facilities (piglets after keeping, pigs fattening) correspond by their capacity. For individually evaluated variants are considered the model determined production parameters (number of reared piglets per sow and year, daily gain, losses, etc.) as an important aspect of stable capacity determination.

The construction costs and its technological equipment are based on presumption of a new facility and there are involved necessary costs for storage slurry reservoir and concentrates container. Excluded are costs for farm engineering network, roads, fence, and plot price e.t.c. These costs have to be calculated according to concrete local situation. The costs calculation was based on the Czech stables suppliers' basis and their technical equipment. For the presented reasons these data have only orientation character and can differ from real costs paid by the specific investor. For purpose of this work
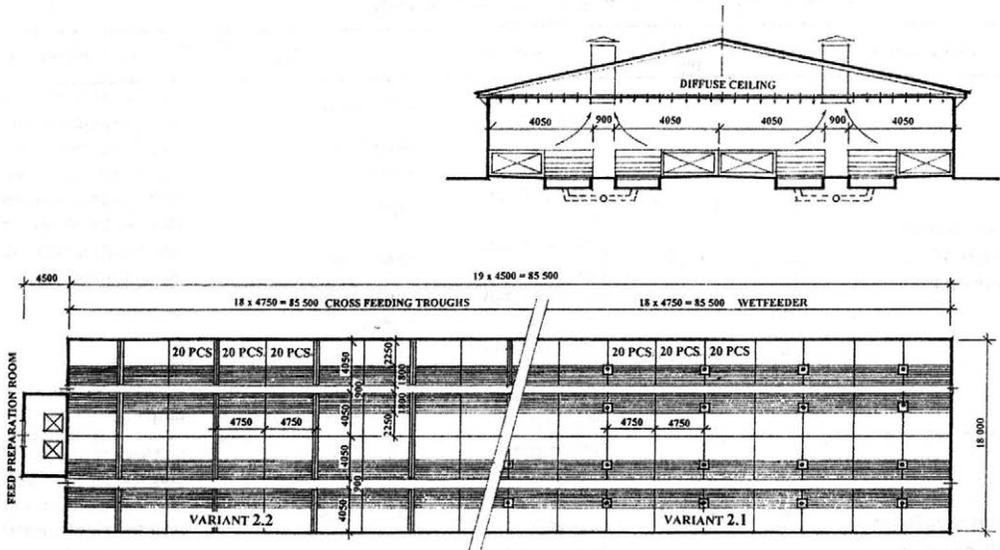
Fig. 1. Stable for pigs fattening with pigs housing in partial slotted floor pens and straight flush system (variant 2.1, variant 2.2)

the method of investment costs determination is sufficient because:

– These costs represent average costs are determined by the identical method under comparable conditions for all evaluated variants.

– Purpose of this work is not to determine absolute value of investment costs but comparison of particular variants of technical systems and housing under identical conditions and individual factors influence analysis for production costs of final product.

As the current stables modernisation concerns, the costs must be stipulated individually because their strong influencing by present level of modernised stables and other farm equipment. Generally it is presumed they reduction compared with a new construction.

For all evaluated stables there were worked up the catalogue sheets involving proposal of constructional-technical solution including ground plan and cross-section with marked the most important dimensions and technical equipment of stable for feeding and housing of pigs.

In Fig. 1 is presented an example of construction and layout of stable for pigs fattening with pigs housing in partially grated pens with under-trough plug for a short-time excrements storage and manure pipe transport form stable. Similarly were worked up also other evaluated stables.

For all evaluated stables there were worked up catalogue sheets involving proposal of construction and design including ground plan and cross-section with the most important dimensions and technical equipment of stable for feeding and housing of pigs.

Using this basis there were designed various possible types of farms for pigs breeding utilising technological systems presented in Table 1.

For evaluation of individual variants are decisive the production costs expressed e.g. by costs per one feeding day or 1 kg live weight gain.

These costs were calculated in structure so far usual for the Czech Republic, i.e.:

1. Costs for feed and litter
2. Personal costs
3. Animals depreciation
4. Tangible fixed assets depreciation
5. Other costs (overhead, vet-care cost, services, repairs etc.)
6. Interests for credits spent for construction and technology.

Costs for tangible investment property depreciation and interests of credits were derived from the calculation of necessary investment costs (presumption of costs fully covered by credit).

The item "other costs" was based on results of investigation performed by Research Institute of Animal Production Prague and Research Institute of Agricultural Economy Prague. Other data were determined by calculation using data based on literature and adapted for need of this work.

RESULTS

In the field of stables for sows keeping there were evaluated 96 different variants of farms containing solution of sow stables (mating sows, in-farrowed sows

Table 2. Basic information about selected sow farms

| Farm variant for sows keeping | Total number of housing places | Technological systems on farm according to Table 1 | | | Total investment cost (10³ CZK) | Investment cost per 1 housing place (10³ CZK) |
		farrowing house	stable for saw pigs and mating sows	stable for in-farrowed sows		
F20	944	7.1.	10.1.	11.2.	32,109	34
F68	944	7.3.	10.1.	11.2.	32,429	34
F92	944	7.4.	9.3.	11.2.	34,504	37
F1	953	7.1.	8.1.	11.1.	35,131	37
F49	953	7.3.	8.1.	11.1.	35,451	37
F71	944	7.3.	10.1.	12.3.	36,584	39
F58	957	7.3.	9.1.	12.2.	36,763	38
F3	953	7.1.	8.1.	12.1.	37,269	39
F42	957	7.2.	9.3.	12.4.	39,002	41
F81	957	7.4.	9.2.	12.1.	39,883	42

and farrowing houses) and 7 variants of stables for pigs fattening.

For the purpose of analysis there were selected 10 variants of farms sows keeping (from total amount 96) involving complex spectrum of costs (most expensive, cheapest, medium) and technologies (litterless, deep litter, variant systems of feeding). Detailed information about these farms incl. investment costs, are presented in Table 2. On the graph in Fig. 2 are presented total costs per 1 feeding day of evaluated farms and their composition according to above mentioned calculation scheme.

From point of view of total investment costs per 1 housing place the difference between the cheapest and most expensive sow farm was 23.5%. It has influenced the costs and depreciation, i.e. depreciation of the most expensive variant was by 35% higher as compared with the cheapest variant.

In graph in Fig. 2 are presented total costs per 1 feeding day of evaluated farms for sows keeping and their composition according to above mentioned calculation scheme.

From the presented figures is evident, that there is not a significant difference between individually evaluated
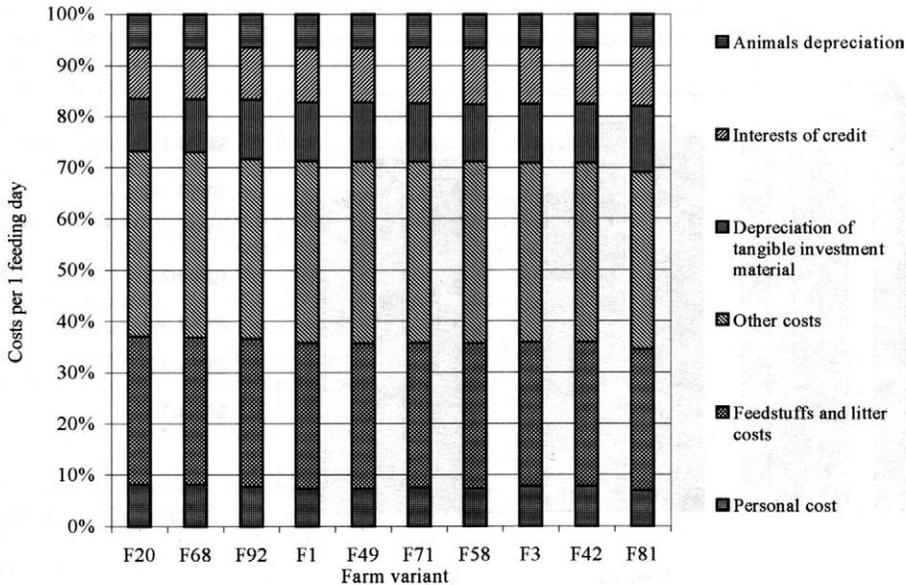

Fig. 2. Effect of technology on costs composition of different variants of sows farms
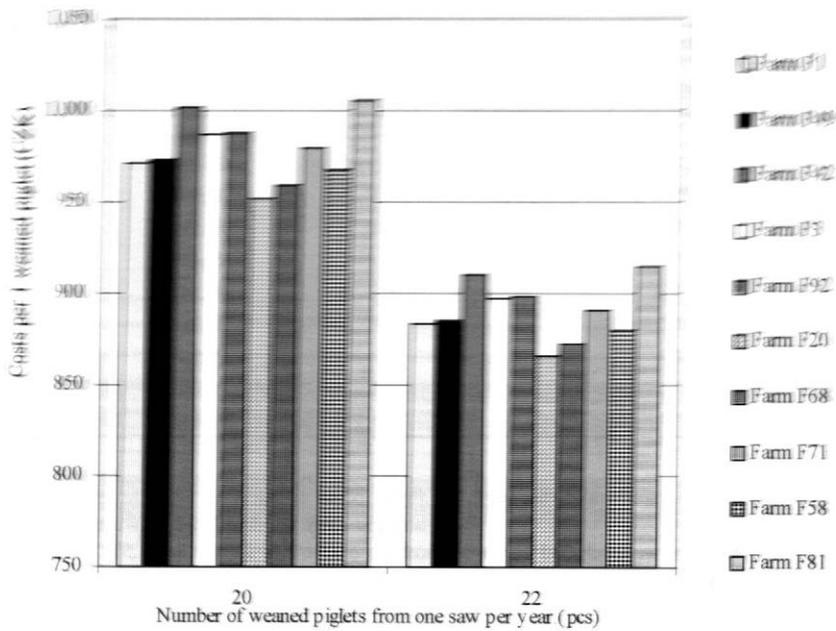
Fig. 3. Costs per 1 weaned piglet in selected farm variant for sows keeping

variants from point of view of total costs and costs per sow and feeding day. The difference between the technically most sophisticated and the cheapest variant is only 3.5%. It may be derived from this fact an important knowledge, that the investor should decide not only according to the total investment costs height, but also take into consideration how the chosen technology provides conditions for optimal nutrition, living and production environment of sows, reproduction, welfare, labour conditions of workers, farm management etc. Optimisation
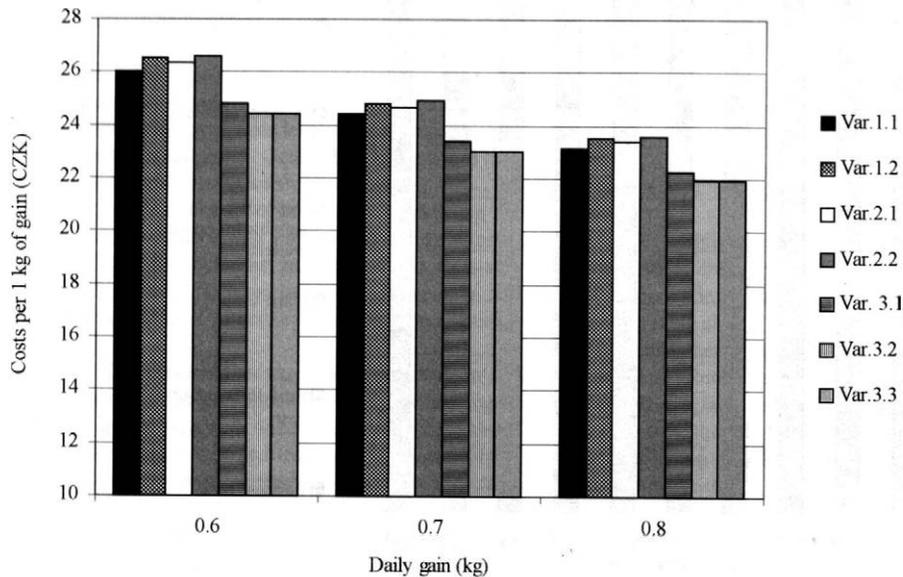

Fig. 4. Effect of technological system in pigs fattening and daily gain on costs per 1 kg of gain (at consumption of 3.1 kg of feed per 1 kg of gain)

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of these parameters contributes to improvement of all investigated indicators. Suitable technical equipment and technological systems create synergic effects, which contribute to larger number of reared piglets.

In graph in Fig. 3 are presented total costs per 1 weaned piglet on selected farms in dependence on number of reared piglets from one sow per year. From this graph is evident, that mainly results of piglets rearing decide about the sow farms economy. Increased number of reared piglets has considerable effect on economy and in most cases its increase by 1 piglet even eliminates effect of increased investment costs connected with application of a more sophisticated technical system. Therefore it is evident that investment costs are important, but their effect is limited from point of view of final production costs of final product (costs per 1 reared piglet). Therefore is necessary to take care for optimal environment created by theirs systems and welfare for sows and piglets, reduction of piglets loss, e.g. by overlying, optimisation of sows and piglets nutrition etc.

In the pigs fattening were evaluated 7 variants of housing and feeding technical systems as presented in Table 1. The difference of total investment costs per 1 housing place between the cheapest and most expensive variant is 69.4% and when depreciation is considered – 130.2%.

In graph in Fig. 4 is presented dependence of production costs per 1 kg of gain of chosen housing and feeding system and daily gains and constant consumption of feed per 1 kg of gain. Similar dependence is possible to be found between production costs of the housing system and feed consumption per 1 kg of gain at constant daily gain. It is evident that the effect of housing and feeding systems on total costs per 1 kg of gain is higher in comparison with farms for sows keeping when the most considerable effect on the production costs is due to the feed consumption per 1 kg of gain.

When deciding about housing and feeding systems for pigs it is necessary to pay attention mainly to systems enabling nutrition optimisation (phase nutrition, feeding management according to consumption competitive behaviour reduction, e.t.c.), environment optimisation, computer aided management, etc. These systems enable individual care for each animal and increase of daily gain and feed conversion improvement and thus also total improvement of feeding. The increased investment costs are compensated by benefits reached through higher utilisation of nutrients contained in the feed, shorter time of fattening and better utilisation of stable.

DISCUSSION AND CONCLUSION

Economical results are dominantly decided upon by parameters of reproduction and yields (mainly number of reared piglets from one sow per year, daily gain, feed conversion). Stable and its technical equipment must create best possible conditions for optimisation of these parameters. In sows breeding it concerns mainly the individual case for each sow, reduction of absolute exclusion of all stress factors and situations, support of natural behaviour, optimisation of nutrition in dependence upon reproduction cycle, weight and age of sow, optimisation of production environment and welfare and other important factors. A suitable technological system has to enable an automated observation and evaluation of all important parameters and their utilisation for computer aided breeding management with use of convenient manager's programmes.

Decision about the most suitable technological system for a specific user is difficult, because there is often a lack of relevant information and verified knowledge. It is e.g. a historical discussion if is better to feed animals by dry, moisture or liquid feeding mixtures (recently has predominated the opinion that the liquid feed improves milk production of suckling sows), further decision about optimal size of sows group and their fixation at least for a certain part of reproduction cycle (newly has been expressed the recommendation of big groups of sows 100–150 and even more in one group in contrast to so far usual 25–30 or 10–15 sows in one group. In addition there is not unambiguously decided the problem of either restrictive or ad libitum feeding. The similar questions are also topical for pigs fattening. To answer these questions extended investigations and assessments were carried out and other were implemented or are under preparation by means of computer systems. Results of the investigation are not always quite unambiguous and are affected by factors of difficult identification or the clear interpretation is not possible at all.

From the point of view technical systems of feeding and housing may be claimed, that there is possible to satisfy almost any requirements of drying and to provide an appropriate device. The decision of a specific user about system convenience depends on his experiences, knowledge, needs and conditions. The investment costs are of course an important parameter, but from the productive costs aspect is more important how the chosen housing system will contribute to provision of optimal nutrition, what conditions will be created for animals environment optimisation, reproduction, breeding management based on topical data and knowledge, how it contributes to improve the care for animals and how it enables the automated control of animals health status, failures and deviations from determined parameters diagnostics, etc.

If technical and technological systems will meet these conditions and requirements then they will contribute by the synergetic effect to keeping economy improvement as a whole and total benefits will prevail considerably over the starting investment costs.

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Vliv systémů ustájení a krmení na farmách pro chov prasat na ekonomiku chovu

ABSTRAKT: Bylo hodnoceno celkem 96 variant farem prasnic pro 944–953 zvířat s různými systémy ustájení (polorošt se shrnovací lopatou nebo podroštovou vanou a potrubní dopravou hnoje, hluboká podestýlka) a krmení (objemový dávkovač, potrubní krmení, AKB). Dále bylo hodnoceno sedm variant stájí pro výkrm prasat s kapacitou 5 400–5 760 zvířat. Z hlediska celkových investičních nákladů na 1 ustájovací místo byl mezi nejdražší a nejlevnější variantou farmy prasnic rozdíl 23,5 %. To se promítlo do nákladů na odpisy tak, že velikost odpisů u nejdražší varianty byla o 35 % vyšší než varianty investičně nejúspornější. Ale z hlediska celkových nákladů na jeden krmný den jsou náklady u technicky nejdokonalejší varianty jen o 3,5 % vyšší než u varianty nejlevnější. Tyto zvýšené náklady mohou být vykompenzovány např. lepšími výsledky v odchovu, tj. zvýšením počtu selat odchovaných jednou prasnicí za rok. Ve výkrmu prasat je rozdíl celkových investičních nákladů na 1 ustájovací místo mezi nejlevnější a nejdražší variantou 69,4 % a 130,2 % při hodnocení velikosti odpisů. Z hlediska nákladů na 1 kg přírůstků je rozdíl mezi oběma krajními variantami 7,0–9,6 %. Tento rozdíl musí být potom vyrovnán vyššími přírůstky a lepší konverzí krmiva.

Klíčová slova: chov prasnic; výkrm prasat; technické systémy; náklady

Corresponding author:

Ing. JIŘÍ VEGRICHT, CSc., Výzkumný ústav zemědělské techniky, Drnovská 507, P. O. Box 54, 161 01 Praha 6-Ruzyně, Česká republika
tel.: + 420 2 33 02 22 81, fax: + 420 2 33 31 25 07, e-mail: vuzt1.05@bon.cz

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Comparing the operation of control valves in milking machines with the pressure reducing valve-equipped control unit from the viewpoint of vacuum level

J. FRYČ

Mendel University of Agriculture and Forestry, Brno, Czech Republic

ABSTRACT: One of essential requirements imposed on milking machines is the maintenance of constant vacuum with the changing air volume consumed by the milking machine. This should be ensured by the control valve. The author developed a unit with the pressure-reducing valve to control vacuum at the simultaneous control of vacuum pump operation, which makes it possible to reduce the consumption of electric energy. The paper deals with a comparison of the operation of commonly used control valves with the operation of the designed vacuum control unit. It was demonstrated by the measurements of vacuum values at different air flows and by the subsequent statistic assessment of results that the function of the designed control unit is comparable with the best control valves used. It should be pointed out however, that the vacuum measurements were carried out at stabilized air flow conditions and could therefore not capture dynamic properties of the vacuum control methods of milking machines being compared.

Keywords: milking machine; vacuum control; control valve; vacuum stability

Research and development in the field of milking technology is usually focused on the issue of technological parameters of milking machines, i.e. on the effort to accommodate the milking machine operation to the requirements of animals in terms of respecting their individuality as the milking machine works directly with a very sensitive organ – mammary gland of the animal. One of essential requirements is the maintenance of the constant vacuum with the changing volume of air consumed by the milking machine. This should be ensured by the control valve. The contemporary method of vacuum control is based on the characteristics of the vacuum pump operating at constant rotations, i.e. on the dependence of vacuum on the rate of air flowing through the vacuum pump. It follows from this dependence that if we wish to achieve a constant vacuum, the vacuum pump must be flown through by a constant amount of air. Regarding the fact that the air volume sucked in by the milking machine is variable in time, vacuum would exhibit considerable fluctuations without a controlling device. The control valve's function consists therefore according to SZLACHTA and SZEWCZYK (1983) in letting in such a volume of atmospheric air into the vacuum system that the sum of air volumes sucked in by the milking machine and by the control valve in a unit time is constant.

PŘIKRYL et al. (1997) claim that the development of these control valves went from simple devices with a spring or weight, over their minute design improvements up to control servo-valves which are almost exclusively used today and in whose design no essential changes have been seen in recent years.

A disadvantage of the control valves with spring or weight according to LOWE (1981) is the fact that the value of vacuum in the entire system is changing in dependence on the air flow rate through the control valve. The fact that the sucked-in air flows through the valve makes the value of vacuum on the valve seat somewhat lower than in other parts of the vacuum system. The difference gets larger with the gradual opening of the control valve, which makes the value of vacuum growing as well. Regarding this negative property, manufacturers of milking machines have adopted so called control servo-valves which open and close according to the pressure detected not directly in the control valve itself but at a certain distance from the valve. The measure has markedly improved the vacuum stability.

This controbution deals with a comparison of the commonly employed control valves with the unit designed for vacuum control. A detailed analysis of parameters of this unit was presented by FRYČ (2002).

MATERIAL AND METHOD

The author of the paper designed a unit with the pressure-reducing valve to control vacuum at the simultaneous control of vacuum pump operation. This method of regulation and its technical solution are patent-protected. No additional atmospheric air is required to be sucked in for vacuum control. The vacuum pump is passed
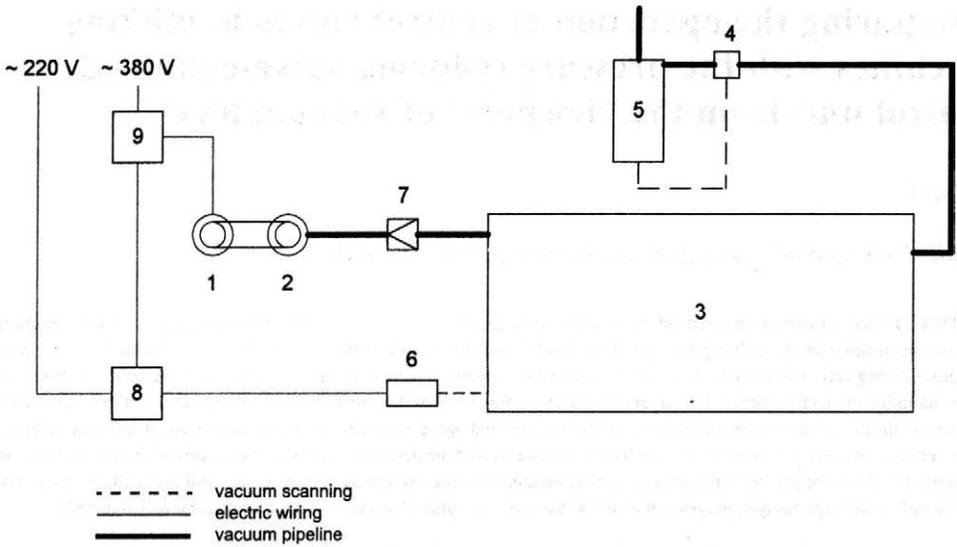
Fig. 1. Control unit with pressure-reducing valve – Functional diagram
1 – electric motor; 2 – vacuum pump; 3 – big air chamber; 4 – pressure-reducing valve; 5 – small air chamber; 6 – vacuum transducer; 7 – back-pressure valve; 8 – electronic control unit; 9 – electric motor control

through only by air consumed by the milking machine, which is considerably less than with the use of a classical control valve. The use of this special control unit with the pressure-reducing valve makes it possible to

considerably reduce the consumption of electric energy. The vacuum pump work can be controlled by changing rotations or by switching on/off. The principle of the unit is illustrated in Fig. 1. The vacuum pump set is con-
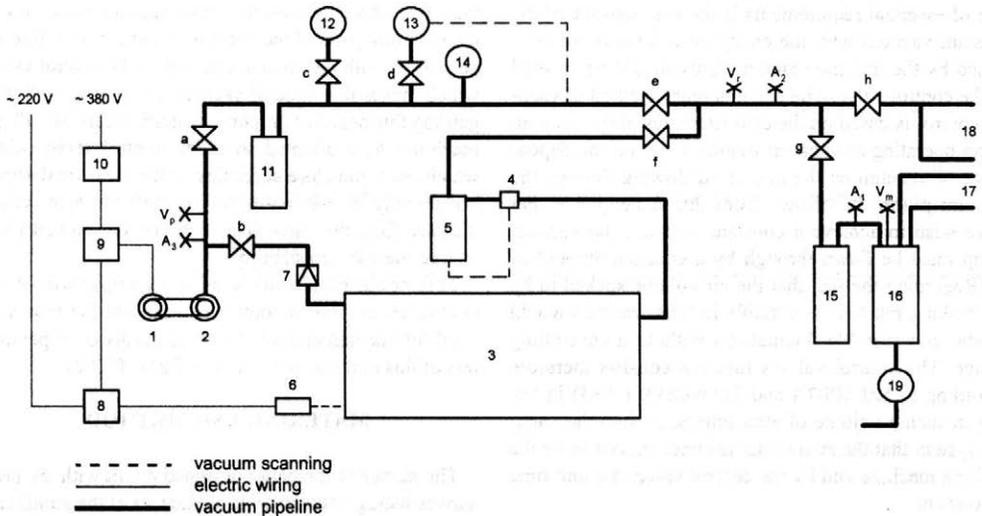
Fig. 2. Laboratory measurement installation – Functional diagram
1 – electric motor; 2 – vacuum pump; 3 – big air chamber; 4 – pressure-reducing valve; 5 – small air chamber; 6 – pressure transducer; 7 – back-pressure valve; 8 – control unit; 9 – electric motor control; 10 – electrometer; 11 – air chamber; 12 – control valve with weight; 13 – diaphragm-operated control servo-valve; 14 – vacuum gauge; 15 – sanitary trap; 16 – receiver; 17 – milk pipeline; 18 – air pipeline; 19 – milk pump
a – h – cocks; A – air flow rate measuring points; V – vacuum measuring points

nected directly to a large volume air chamber (hereinafter "big air chamber"). The connecting pipeline between the pump and the big air chamber is provided with a back-pressure valve so that reversed motion of the pump and hence undesirable air sucking does not occur due to the vacuum from the big air chamber when the electric motor is switched off. The vacuum in the big air chamber is maintained by the vacuum pump within a selected range $p_{n1} - p_{n2}$ ($p_{n1} > p_{n2}$) so that the minimum value (p_{n2}) is higher than the operating vacuum in the milking machine (p_{np}). This is ensured by a vacuum transducer which is scanning the immediate vacuum value in the big air chamber and steers the vacuum pump electric motor through an electronic control device. Between the big air chamber and the proper vacuum distribution system there is a special pressure-reducing valve with a small air chamber which is reducing the variable vacuum from the big air chamber to the adjusted value p_{np} providing at the same time for its stability.

The measurements were performed in the laboratory on a measuring apparatus which came into existence by modifying the milking machine for possible use of different methods of vacuum control. The scheme of the apparatus is presented in Fig. 2. With regard to the entirely different method of regulation when using the apparatus with the pressure-reducing valve, most of the diagnostic measurements could not be made in accordance with the Standard ISO 6690. This is why the measured vacuum pump characteristic was that with the control valve. The proper measuring procedure included vacuum control measurements in three variants: with a control valve with weight, with a diaphragm-operated control servo-valve, and with a control unit with the pressure-reducing valve.

The characteristic of the vacuum pump with the control valve defines a fundamental dependence between air consumption (air volume entering the vacuum system of the milking machine) and vacuum level. The measurements were made in accordance with to the following methodology:

1. Vacuum pump of the milking machine was put into operation and left working at operating vacuum for a minimum time of 15 minutes.
2. Adjustment of cocks for individual measurements was made as follows (Fig. 2):
   – Measuring the control valve with weight: cocks a, c, e – opened; cocks b, d, f – closed.
   – Measuring the diaphragm-operated control servo-valve: cocks a, d, e – opened; cocks b, c, f – closed.
   – Measuring the control unit with pressure-reducing valve: cocks b, f – opened; cocks a, e – closed.
3. Cocks g, h were closed to disconnect the air and milk pipelines.
4. Flowmeter was connected at the place A_2 and vacuum gauge was connected at the point V_r.
5. Flowmeter was at first completely closed and then gradually opening. Corresponding values of air flow and vacuum were recorded.

RESULTS AND DISCUSSION

According to the methodology, characteristics of the vacuum pump with control valve were measured for the control valve with weight, for the diaphragm-operated control servo-valve, and for the control unit with pressure-reducing valve. Each measurement was made six times and results were statistically assessed. Graphic
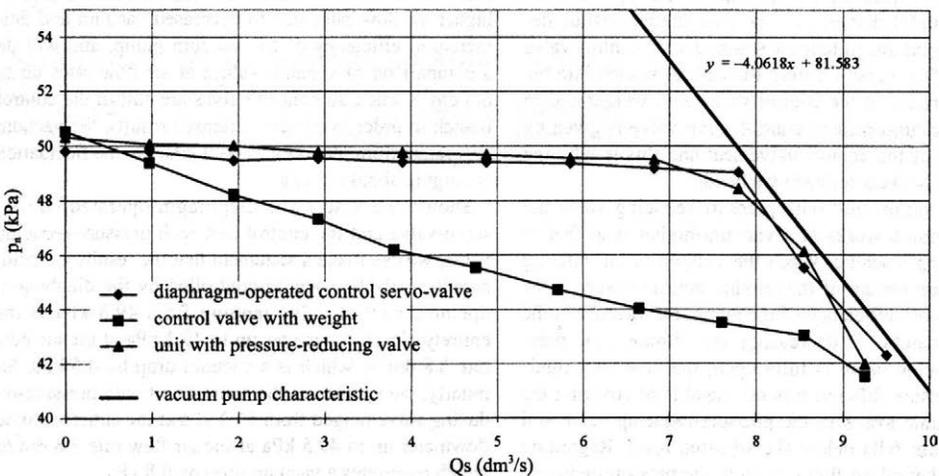

Fig. 3. Characteristic of vacuum pump with different control valves

dependences were constructed by using mean values. Standard deviations at measuring the diaphragm-operated control servo-valve, the control valve with weight and the control unit with pressure-reducing valve ranged from 0.06 to 0.13, from 0.07 to 0.13 and from 0.07 to 0.15, respectively.

The course of all three dependences with the vacuum pump characteristic is presented in Fig. 3. Each of these three dependences can be divided into a control branch and a passive branch. The control branch is the part of characteristic when the control valve is changing its parameters in dependence on the amount of air entering the vacuum system of the milking machine in order to maintain as constant a vacuum level as possible. This occurs for the control valve with weight and for the diaphragm-operated control servo-valve by letting in additional atmospheric air into the vacuum system so that the sum of air volumes sucked in by the milking machine within a time unit and passing through the control valve is constant and equals vacuum pump efficiency at the required vacuum. For the control unit with pressure-reducing valve this occurs by controlled valve opening into the space with higher vacuum so that an air volume can be sucked-off which precisely equals the amount of air entering the vacuum system of the milking machine.

The passive branch is the part of characteristic when the control valve cannot effect the vacuum level any longer. This occurs when the volume of air entering the vacuum system of the milking machine approaches, equals or exceeds the vacuum pump efficiency at the required vacuum. The supply of atmospheric air is entirely closed for the control valve with weight and for the diaphragm-operated servo-valve, and the passive branch should theoretically be identical with the vacuum pump characteristic. With respect to existing leakages, the passive branch and the vacuum pump characteristic are converging straight lines with a point of intersection on the horizontal for which it holds that $p_n = 0$, with the horizontal distance of the two characteristics determining the magnitude of losses due to control valve leakage. The transition from the control branch into the passive branch in the control valve with weight and in the diaphragm-operated control servo-valve is given by a closure of the control valve seat and this is why the transition is characterized by a bend.

In the control unit with pressure-reducing valve the vacuum pump works at a vacuum higher than that in the milking machine. When the volume of air entering the vacuum system of the milking machine exceeds the instantaneous efficiency of the pump, the vacuum in the big air chamber is decreasing and although the pressure-reducing valve is fully open, the now only minimum pressure difference is not capable of covering the aerodynamic losses in the pressure-reducing valve and the vacuum falls below the adjusted level. Regarding the fact that all air flows through the pressure-reducing valve, the aerodynamic losses are increasing with the increasing air flow rate. This shows in the graph in such a way that the horizontal distance of the passive branch

and the vacuum pump characteristic increases with the increasing air flow rate. The aerodynamic losses in the pressure-reducing valve and in the whole control unit result in the vacuum pump operation with the vacuum higher than that on the entrance into the pressure-reducing valve; more precisely said – than that in the point of measurement V_r. Regarding the fact that it is actually all air sucked off by the vacuum pump that has to pass through the pressure-reducing valve at the stabilized regime on the passive branch, the instantaneous values of pump efficiency and air flow rate through the pressure-reducing valve are equal. We can define the actual working point of the pump for a random point on the passive branch by running a vertical (straight line of constant air flow rate) through a selected point on the passive branch; the point of intersection with the vacuum pump characteristic represents the actual working point of the pump. Pressure loss due to the pressure-reducing valve or – more precisely said – caused by the whole control unit can be read as a vertical distance of the passive branch and the pump characteristic. As the transition from the control branch into the passive branch in the control unit with pressure-reducing valve means a transition from the controlled opening of the pressure-reducing valve up to the maximum opening at a simultaneous pressure decrease in the big air chamber, the transition is continuous and does not exhibit any bend.

It unambiguously follows out from the graph in Fig. 3 that in the control branch of the control valve with weight there is a pronounced vacuum level fluctuation in dependence on air volume Q_s entering into the vacuum system. In this case it is from 50.5 kPa at the entirely closed flowmeter up to 43.0 kPa at the air flow rate 8.5 dm³/s, the moment of bend on the characteristic and hence the moment of transition into the passive branch. Total fluctuation within the entire range of the control branch was 7.5 kPa. Even if we take into account the fact that the control branch was shifted into the area of higher air flow rates due to decreased vacuum and thus increased efficiency of the vacuum pump, and will do a comparison of vacuum values at air flow rates up to 6.8 dm³/s when all control valves are still in the control branch in order to achieve unbiased results, the vacuum will range from 50.5 kPa to 44.0 kPa, i.e. the fluctuation is ranging about 6.5 kPa.

Should we assess the diaphragm-operated control servo-valve and the control unit with pressure-reducing valve, we can make a statement that the results are comparable with the vacuum controlled by the diaphragm-operated control valve ranging from 49.8 kPa at the entirely closed flowmeter up to 49.2 kPa at the air flow rate 6.8 dm³/s, which is a vacuum drop by 0.6 kPa. Similarly, the vacuum in the control unit with pressure-reducing valve ranged from 50.3 kPa at the entirely closed flowmeter up to 49.5 kPa at the air flow rate 6.8 dm³/s, which represents a vacuum drop by 0.8 kPa.

The laboratory measurements demonstrated that the control unit with pressure-reducing valve is in terms of vacuum level regulation at changing air flow rate fully

comparable with the modern control servo-valves. Nevertheless, we point out that the vacuum levels were measured at the stabilized air flow rate and therefore the measurements do not capture dynamic properties of the compared methods of vacuum control in milking machines.

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Porovnání činností regulačních ventilů dojicích strojů a navrženého regulačního zařízení s redukčním ventilem z hlediska úrovně podtlaku

ABSTRAKT: Jedním ze základních požadavků na dojicí stroje je udržování konstantní úrovně podtlaku při změnách spotřeby vzduchu dojicím strojem. To by mělo být zabezpečeno regulačním ventilem. Autor příspěvku navrhl zařízení pro regulaci úrovně podtlaku s redukčním ventilem při současném řízení chodu vývěvy, což umožňuje snížit spotřebu elektrické energie. Příspěvek se zabývá porovnáním činnosti běžně používaných regulačních ventilů s navrženým zařízením pro regulaci podtlaku. Provedeným měřením hodnoty podtlaku při různých průtocích vzduchu a následným statistickým vyhodnocením výsledků bylo prokázáno, že funkce navrženého regulačního zařízení je srovnatelná s nejlepšími používanými regulačními ventily. Je však třeba uvést, že měření hodnoty podtlaku bylo prováděno v ustáleném stavu průtoku vzduchu a že tedy tato měření nepostihují dynamické vlastnosti porovnávaných způsobů regulace podtlaku dojicích strojů.

Klíčová slova: dojicí stroj; regulace podtlaku; regulační ventil; stabilita podtlaku

Corresponding author:

Ing. JIŘÍ FRYČ, CSc., Mendelova zemědělská a lesnická univerzita, Agronomická fakulta, Zemědělská 1, 613 00 Brno, Česká republika
tel.: + 420 5 45 13 21 05, fax: + 420 5 45 13 29 14, e-mail: fryc@mendelu.cz

Different methods of cropstand establishment within the system of winter oilseed rape cultivation

O. ŠAŘEC, P. ŠAŘEC, M. KAVKA

Czech University of Agriculture, Prague, Czech Republic

ABSTRACT: The aim of the study is to assess various technologies of winter oilseed rape cropstand establishment, and to choose those which bring advantages to farmers. In order to check up different alternatives, field trials have been carried out in Opařany since 1998. The technologies in question are divided into three groups: traditional technologies (ploughing & drilling), minimized technologies (soil loosening & drilling), and finally non-tillage technologies (drilling straight into stubble). The technologies are assessed with respect to direct costs, seed yields and revenues. According to the results, the ploughing operation can apparently be substituted by reduced soil-treatment techniques in the system of oilseed rape cultivation.

Keywords: winter oilseed rape; cropstand establishment; yield; direct cost; minimized technology; direct drilling

When compared with other crops in the Czech Republic, oilseed rape brings relatively high financial revenues to the farmers in these days. Over the few past years, the acreage of oilseed rape has surpassed 10% of the Czech Republic's arable land. This is the reason why this crop, and more precisely the ways of soil cultivation and sowing, are in our focus. High energy demand of the traditional tillage which includes ploughing is reflected in the costs of tilling operations, and consequently in the costs per production unit. Moreover, this soil cultivation is time demanding, and therefore inconvenient when considering the relatively early term of winter rape sowing.

The traditional tillage is based on a quality shallow ploughing to about 10 cm of depth that should be carried out straight after a preceding crop's harvest. Broken up soil can be then treated by rolling and harrowing if need is. A pre-sowing medium ploughing comes next with the possible application of phosphor and nitrogen fertilizers, and manure. Advantage can be taken by putting together the ploughing with a ploughed-field treatment, and a soil compactness improvement. In order to perform a pre-sowing soil preparation, tillers, compactors, or rotary harrows can be employed. The latter ones can be put together to a drilling machine. Reduced soil treatment methods presume that the manure application is shifted towards the preceding crop. Due to a short break period, leaving out ploughing enables to adhere to the sowing in demanded term. Soil's shallow ploughing to 10 to up to 15 cm of depth performed by a disk plough, or by a field tiller is one option. In the case of a disk plough, double soil loosening with two direction transects is required.

When establishing a cropstand of winter rape, saving technologies that combine shallow soil cultivation to the drilling depth and drilling can find their place. These minimized technologies as well as the technology of direct drilling into non-cultivated soil, i.e. into

stubble, should be firstly checked up in a smaller range. Non-ploughing methods, and direct drilling in particular, cannot generally manage without previous herbicide application. The protection against field voles and slugs may be required as well. In this case, higher nitrogen rates are very often as a rule.

Cereals or forage crops are the most common preceding crops, in the majority of fields sowed with rape. That is why it would be appropriate, in order to get correct results which reflect reality, to set the experimental lots in the fields where cereals were grown just before.

CONCLUSION OBJECTIVE

The purpose is to outline optimum systems of selected field cropstand establishment in terms of production, economy and ecology.

FIELD TRIAL METHODOLOGY

Field trials have been carried out as semi-operational in Opařany since 1998. Currently, the results from the previous three years are at disposal. The farm is situated in the rye and potato growing region at the elevation above sea level of more than 450 m. Experimental lot acreages varied around approximately 2 hectares, and individual variants were divided by two-meter strips. In each year, winter wheat had been grown in the field where the experiment was set afterwards. Due to a considerable livestock production in Opařany, manure is applied regularly.

The methodology of the field trials was designed in the manner enabling the comparison of different methods of soil cultivation and sowing in the system of winter oilseed rape production. Major evaluation criteria were the direct costs of the variants, their seed yields, and finally their financial yields. Individual experimen-

Table 1. Variants of winter rape cropstand establishment in Opařany 1998–1999

Variant (lot) No.	Variants' characteristics (rolling came after sowing with all the variants)
1	Tillage 3×: 1× disk coulters, 2× A-hoes, Drilling: Horsch CO 6.25
2	Tillage 3× (see Variant No. 1), Drilling: Horsch SE 3.25
3	Tillage 3× (see Variant No. 1), Drilling: Horsch CO 6.25 & additional fertilization
4	Direct drilling: John Deere 750 A
5	Direct drilling: Horsch SE 3.25
6	Tillage 2×: disk coulters (Cífer), Rolling 1×, Drilling: Horsch CO 6.25
7	Tillage 2× (see Variant No. 6), Rolling 1×, Drilling: Horsch SE 3.25
8	Tillage 2× (see Variant No. 6), Rolling 1×, Drilling: JD 750 A
9	Ploughing, Dragging & Harrowing 2×, Drilling: combine drill Maschio & Pneusej 4.5 m

tal variants differed only in soil cultivation operations, and in different drilling machines used. The other operations such as the application of chemicals and fertilizers, the quantity of seed sown, a rape variety etc. were the same for all the variants in a particular year. The costs of every operation were monitored.

Each variant is described in more detail further bellow. Generally, they can be divided into three groups as follows:

– traditional technologies (ploughing & drilling) acting as a control,
– minimized technologies (soil loosening & drilling),
– non-tillage technologies (drilling straight into stubble).

The experimental lot was observed in the time of sowing in August, in autumn after germination had taken place, in spring when the winter rape was coming out of dormancy, and during the period of harvest as well. Various measures were investigated, e.g. sowing depth, soil moisture and compaction, plants population density, cropstand height before harvest, and of course seed yield, oil content, germination power etc.

RESULTS

Three years of field trials have been accomplished so far with the variants belonging to the three major groups described above. Over the last two years, another sowing technology was examined in addition, i.e. direct drilling during the harvest of the preceding crops. These technological variants were planted in another field than the others. Thus they can not be assessed together.

Opařany: 1998–1999

Nine variants (Table 1) were started off on August 17–18 1998.

– With all the variants, the variety of winter oilseed rape sown was Capitol, the quantity of seed sown was 5 kg/ha, and spraying was carried out within three days after sowing.
– On March 16, regenerative fertilization by 150 kg/ha of LAV 27% was applied $\Rightarrow$ 41 kg of pure nitrogen per hectare.
– On April 2, liquid fertilizer DAM 390 in the rate of 200 kg/ha ($\Rightarrow$ 66 kg of pure nitrogen per hectare) & Nurelle D 0.6 l/ha (insecticide) were applied.

Table 2. Yields and costs in Opařany 1998–1999

Variant No.	Yield at 8% (t/ha)	Cropstand establishment costs		Market revenue (CZK/ha)	Total direct costs (CZK/ha)	Financial yield (CZK/ha)	Profitability
		(CZK/ha)	(CZK/t)				
1	2.73	2,425	888	16,380	10,381	5,999	8
2	3.14	2,445	778	18,840	10,401	8,439	6
3	2.79	2,435	872	16,740	10,591	6,149	7
4	1.22	1,250	1,024	7,320	9,206	−1,886	9
5	3.31	1,320	398	19,860	9,276	10,584	3
6	3.43	2,160	629	20,580	10,116	10,464	4
7	3.43	2,180	635	20,580	10,136	10,444	5
8	3.49	2,110	604	20,940	10,066	10,874	2
9	**3.78**	**3,210**	**849**	**22,680**	**11,166**	**11,514**	**1**

Comments: Calculated farm price 6,000 CZK/t, and lend rent cost 600 CZK/ha
 – Establishment costs (CZK/t) = Establishment costs (CZK/ha) / Yield at 8% (t/ha)
 – Market revenue (CZK/ha) = Farm price (CZK/t) × Yield at 8% (t/ha)
 – Financial yield (CZK/ha) = Market revenue (CZK/ha) – Total direct costs (CZK/ha)
Source: Calculations of the author with the use of prices and tariffs stated in KAVKA et al. (2000)
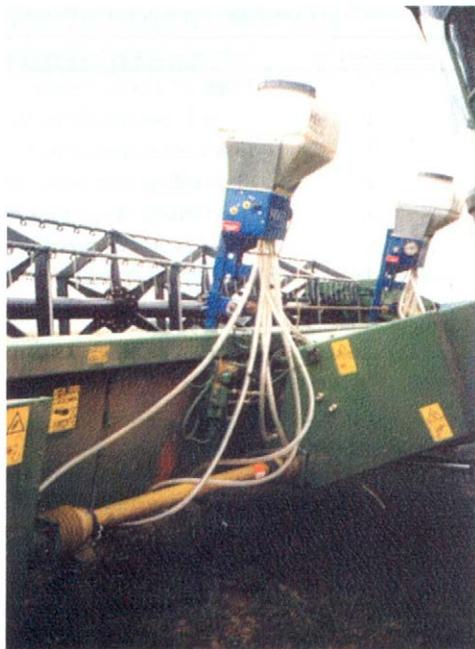
Fig. 1. Direct drilling during the preceding crop harvest (John Deere CTS)

- On April 28, liquid fertilizer DAM 390 at the rate of 100 kg/ha ($\Rightarrow$ 33 kg of pure nitrogen per hectare) & Vaztak 10 EC 0.15 l/ha (insecticide) were applied.
- On July 26, harvest was effectuated by the combine harvester Massey Ferguson (adapted to the oilseed rape harvest).

The autumn of the year 1998 was distinctive by the eminent presence of field voles. This affected seriously the field trial's results (Table 2). The seed yields of reduced soil treatment variants were considerably lower than the one of the Variant No. 9 (i.e. traditional technology). Especially the Variant No. 4 was stricken.

Table 3. Variants of winter rape cropstand establishment in Opařany 1999–2000

Variant (lot) No.	Variants' characteristics (rolling came after sowing with all the variants)
1	Direct drilling: John Deere 750 A
2	Direct drilling: Horsch CO 6.25
3	Direct drilling: Howard – Semavátor 3 m
4	Tillage 2×: disk coulters, Drilling: John Deere 750 A
5	Tillage 2× (see Variant No. 4), Drilling: Horsch CO 6.25
6	Tillage 2× (see Variant No. 4), Drilling: Howard – Semavátor 3 m
7	Tillage 2× (see Variant No. 4), Drilling: combine drill Maschio & Pneusej 4.5 m
8	Ploughing, Drilling: combine drill Maschio & Pneusej 4.5 m
9	
10	
11	
12	The Variants No. 9 to 16 are analogous to the Variants No. 1 to 8 (i.e. 9 = 1, 10 = 2…), only deep
13	soil loosening (PP1-039) by a chisel plow to up to 50 cm of depth was integrated into the technological process
14	
15	
16	
17	Direct drilling during the winter wheat harvest on August 27 (sowing drill was fastened onto the combine harvester's cutterbar, the quantity of seed sown was 6 kg/ha), Shallow ploughing, Rolling

Table 4. Yields and costs in Opařany 1999–2000

Variant No.	Yield at 8% (t/ha)	Cropstand establishment costs (CZK/ha)	(CZK/t)	Market revenue (CZK/ha)	Total direct costs (CZK/ha)	Financial yield (CZK/ha)	Profitability
1	2.60	1,200	462	15,600	10,271	5,329	15
2	2.99	1,250	418	17,940	10,321	7,619	8
3	3.17	1,270	401	19,020	10,341	8,679	4
4	3.20	2,060	644	19,200	11,131	8,069	7
5	2.96	2,110	713	17,760	11,181	6,579	11
6	3.00	2,130	710	18,000	11,201	6,799	10
7	3.24	2,100	648	19,440	11,171	8,269	5
8	3.06	2,360	771	18,360	11,431	6,929	9
9	3.23	2,100	308	19,380	11,171	8,209	6
10	2.41	2,150	892	14,460	11,221	3,239	17
11	3.37	2,170	644	20,220	11,241	8,979	2
12	3.46	2,960	855	20,760	12,031	8,729	3
13	3.06	3,010	984	18,360	12,081	6,279	13
14	3.11	3,030	974	18,660	12,101	6,559	12
15	**3.84**	**3,000**	**781**	**23,040**	**12,071**	**10,969**	**1**
16	3.06	3,260	1,065	18,360	12,331	6,029	14
17	2.30	995	433	13,800	10,066	3,734	16

Comments: Calculated farm price 6,000 CZK/t, and lend rent cost 600 CZK/ha
 – Establishment costs (CZK/t) = Establishment costs (CZK/ha) / Yield at 8% (t/ha)
 – Market revenue (CZK/ha) = Farm price (CZK/t) × Yield at 8% (t/ha)
 – Financial yield (CZK/ha) = Market revenue (CZK/ha) – Total direct costs (CZK/ha)
Source: Calculations of the author with the use of prices and tariffs stated in KAVKA et al. (2000)

Dixon Test for Extreme Deviations proved that the seed yield of the Variant No. 4 is a distant observation (significance level $\alpha = 0.05$, $K_2 = 0.5898 > K_{2,\ 1-0.05} = 0.437$). This variant was therefore excluded from all subsequent analyses and evaluations.

Each variant is assigned profitability according to its financial yield. The poor outcomes of the first three variants were partly caused by the additional cost of the third tillage.

Opařany: 1999–2000

In the business year 1999–2000, the field trials continued with seventeen variants (Table 3). The Variant No. 17 was planted in another field which could be considered of inferior quality. Its result should not be therefore compared with the others.

– With all the variants, the variety named Apex was sown on August 20, the quantity of seed sown was 4 kg/ha (except the Variant No. 17).

Table 5. Variants of winter rape cropstand establishment in Opařany 2000–2001

Variant (lot) No.	Variants' characteristics
1	Direct drilling: John Deere 750 A
2	Direct drilling: Horsch SE 3.25
3	Direct drilling: Horsch CO 6.25
4	Tillage 2×: disk coulters, Drilling: Horsch CO 6.25
5	Tillage 2× (see Variant No. 4), Drilling: Horsch SE 3.25
6	Tillage 2× (see Variant No. 4), Drilling: John Deere 750 A
7	Tillage 2× (see Variant No. 4), Drilling: combine drill Maschio & Pneusej 4.5 m
8	Ploughing, Drilling: combine drill Maschio & Pneusej 4.5 m
9	Direct drilling during the winter wheat harvest (sowing drill was fastened onto the combine harvester's cutterbar), Disk ploughing as shallow as possible
10	Direct drilling during the winter wheat harvest, No other treatment

Comments: Because of an eminent rainfall, there was no need for rolling to be carried out

Table 6. Yields and costs in Opařany 2000–2001

Variant No.	Yield at 8% (t/ha)	Cropstand establishment costs (CZK/ha)	(CZK/t)	Market revenue (CZK/ha)	Total direct costs (CZK/ha)	Financial yield (CZK/ha)	Profitability
1	3.52	955	271	24,640	9,504	15,136	7
2	3.24	1,005	310	22,680	9,554	13,126	8
3	3.71	975	263	25,970	9,524	16,446	4
4	4	1,865	466	28,000	10,414	17,586	2
5	3.91	1,895	485	27,370	10,444	16,926	3
6	**4**	**1,815**	**454**	**28,000**	**10,364**	**17,636**	**1**
7	3.82	1,855	486	26,740	10,404	16,336	6
8	3.91	2,475	633	27,370	11,024	16,346	5
9	3.12	1,075	344	21,840	9,624	12,216	9
10	2.55	630	247	17,850	9,179	8,671	10

Comments: Calculated farm price 7,000 CZK/t, and lend rent cost 600 CZK/ha
— Establishment costs (CZK/t) = Establishment costs (CZK/ha) / Yield at 8% (t/ha)
— Market revenue (CZK/ha) = Farm price (CZK/t) × Yield at 8% (t/ha)
— Financial yield (CZK/ha) = Market revenue (CZK/ha) – Total direct costs. (CZK/ha)
Source: Calculations of the author with the use of prices and tariffs stated in KAVKA et al. (2000)

- Spraying with Butisan (2.0 l/ha) & Command (0.1 l/ha) (both are herbicides) was carried out straight after the sowing.
- On September 13, spraying with Targa (1.0 l/ha) against waste seeds was performed.
- On March 23, regenerative fertilization by 200 kg/ha of LAV 27% was performed ⇒ 55 kg of pure nitrogen per hectare.
- On April 8, liquid fertilizer DAM 390 in the rate of 200 kg/ha (⇒ 66 kg of pure nitrogen per hectare) & Talstar 0.1 l/ha (insecticide) were applied.
- On April 24 once more, liquid fertilizer DAM 390 in the rate of 100 kg/ha (⇒ 33 kg of pure nitrogen per hectare) & Vaztak 0.12 l/ha (insecticide) were applied.
- Subsequent harvest was effectuated by the combine harvester John Deer CTS which was equipped with

the DGPS for yield mapping (extended cutterbar table, lateral knife, cutting width of 7.6 m).
During the business year 1999–2000, nothing unusual occurred. Thus the results (Table 4) may bee regarded as credible.

Opařany: 2000–2001

In the business year 1999–2000, eight variants (Table 5) were set up, which were similar to the first eight variants of the year 1999–2000. Further two variants were established to follow up with the Variant No. 17 from the year 1999–2000. The latter two were planted in another field likewise the Variant No. 17 from the previous year.
- With all the variants, the variety named Bristol was sown on August 20, the quantity of seed sown was

seed yield reduced-tradit. traditional

Index differences of aggregated seed yields of reduced technologies to traditional technology

■ non-tillage
▨ minimization

0.2
0.1
0.1   0.10
0.0   0.01   0.01   traditional
-0.1   0.01   -0.02   technology
-0.1   -0.05
-0.2   -0.11
-0.2   -0.12
        -0.16

Opařany 1998/99   Opařany 1999/00-no deep loosening   Opařany 1999/00-deep loosening   Opařany 2000/01
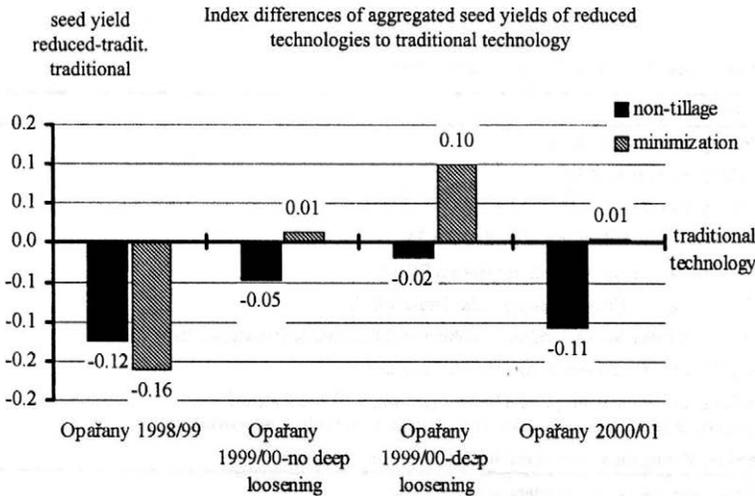
Fig. 2. Seed yields' comparison of the separate technological groups in Opařany
Comments: The Variants No. 4 from the year 1998–1999, No. 17 from the year 1999–2000, and No. 9 and 10 from the year 2000–2001 are not calculated with

finan. yield
reduced-tradit.
traditional

Index differences of aggregated finantial yields of reduced
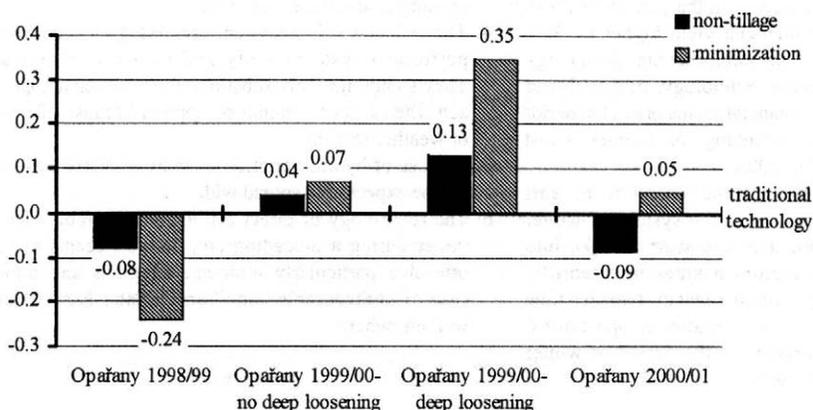technologies to traditional technology

Fig. 3. Financial yields' comparison of the separate technological groups in Opařany
Comments: The Variants No. 4 from the year 1998–1999, No. 17 from the year 1999–2000, and No. 9 and 10 from the year 2000–2001 are not calculated with

lower again, i.e. 3.5 kg/ha (except the Variants No. 9 and 10).
– On August 22, spraying with Lasso (4.5 l/ha) & Command (0.1 l/ha) (both are herbicides) was carried out.
– On August 29, Galant Super was applied with the rate of 1.25 l/ha.
– On September 27, spraying with Lontrel (0.4 l/ha) was performed.
– On March 7, regenerative fertilization by 200 kg/ha of LAV 27% was performed ⇒ 55 kg of pure nitrogen per hectare.
– On April 3, liquid fertilizer DAM 390 in the rate of 200 kg/ha (⇒ 66 kg of pure nitrogen per hectare) & Nurelle 0.6 l/ha (insecticide) were applied.
– On April 30, liquid fertilizer DAM 390 in the rate of 200 kg/ha (⇒ 66 kg of pure nitrogen per hectare) & Vaztak 0.1 l/ha (insecticide) were applied.
– Subsequent harvest was effectuated by the combine harvester Massey Ferguson (adapted to the oilseed rape harvest).
The Variants No. 9 and 10 were sown on August 12–13. The quantity of seed sown (variety named Stela) was increased to 10 kg/ha.
The Variants No. 9 and10 were seriously damaged by a hailstorm short before the harvest. Losses caused by this adversity were estimated to amount to 25% to up to 30%. The other variants were not affected.

ASSESSMENT

As was already mentioned above, the Variant No. 4 from the business year 1998–1999 and all the techno-

logical variants of the drilling straight into stubble-field were left out from further assessment. Although the direct drilling during the pre-crop harvest was either applied in a inferior quality field or damaged by a hailstorm, the outcomes suggest that in some cases, this technology is justified.
The question is what method of soil treatment and sowing within the system of winter oilseed rape production is convenient. In order to illustrate the comparison between the reduced soil treatment technologies and the traditional technology including ploughing, the average yields of minimized and non-tillage technologies were put in proportion to the traditional technology's yield in each year.
The average **seed yields** per hectare (Fig. 2) of the non-tillage variants were during all the three years lower than those of the traditional technology (the most by 16%). Concerning the minimized technologies, the figures were worse (by 12%) compared to the traditional technology only in the business year 1998–1999. That year was for the sake of the abundance of field-voles hazardous regarding the reduced soil-treatment technologies. In the following years, the minimized technologies manifested better results then the traditional one, especially in the case of the integration of deep soil loosening (a chisel plow) into technological process.
Both reduced soil treatment technology's groups achieved worse average **financial yields** per hectare (Fig. 3) than the traditional technology solely in the business year 1998–1999. In the case of the minimized variants, the difference amounted even to 24% (the Variants No. 1–3 included three times performed shallow ploughing which increased the costs). In the following

years, the financial yields favoured the reduced soil treatment methods, particularly when the shallow soil loosening (shallow ploughing) was involved. This is the most evident in the case of the minimized technologies with the deep soil loosening in the year 1999–2000, which reached average financial yield higher by 35% than the Variant No. 16 (deep soil loosening, ploughing). Concerning the non-tillage technology, despite lower seed yields in each year, financial yields proved superior to those of the traditional technology on account of cost reduction in the year 1999–2000.

When assessing different technologies of soil treatment and of sowing within the system of winter oilseed rape production, it is necessary to take into account as well other factors besides profitability. One of them is a higher overall capacity (smaller time required) of the reduced soil-treatment operations, which is of major importance in the period of winter rape's cropstand establishment.

CONCLUSIONS

1. Within the system of winter oilseed rape cultivation, ploughing can be substituted by reduced soil treatment methods, considering naturally all the known risks.
2. A combination of traditional and reduced technologies seems the most favourable, always with respect

to farm's, and particularly field's conditions, and to their forecast for the future.
3. In the case of an eminent soil compaction (e.g. in the tyre tracks), it is desirable to carry out a deep soil loosening (subsurface ploughing).
4. The reduced soil treatment technologies should be performed systematically and in optimum terms. They should not only substitute the traditional approach when this one cannot be applied because of time or weather reasons.
5. The use of hybrid varieties sown by accurate seeders can be expected to spread wide.
6. The technology of direct drilling by a combine harvester during a preceding crop harvest seems to be utilizable, particularly in mountain regions, and in the case of unfavourable conditions (a later harvest) as well elsewhere.

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Zhodnocení různých způsobů zakládání porostů řepky ozimé

ABSTRAKT: Cílem práce je zjistit, které technologie zakládání porostu řepky ozimé jsou technicky a ekonomicky výhodné. Za účelem ověření různých postupů jsou od roku 1998 prováděny poloprovozní a provozní pokusy v ZD Opařany. Zkoušené technologie jsou roztříděny do tří skupin: tradiční technologie (orba + setí), minimalizační technologie (podmítka + setí), bezorebné technologie (setí přímo do strniště). Jednotlivé technologie jsou hodnoceny podle přímých nákladů, výnosu semen a finančního výnosu. Podle výsledků je v systému pěstování řepky ozimé orba nahraditelná postupy s redukovaným zpracováním půdy.

Klíčová slova: řepka ozimá; technologie zakládání porostu; výnos; přímé náklady; minimalizace; přímý výsev

Corresponding author:

Doc. Ing. ONDŘEJ ŠAŘEC, CSc., Česká zemědělská univerzita, Technická fakulta, 165 21 Praha 6-Suchdol, Česká republika
tel.: + 420 2 24 38 31 46, fax: + 420 2 20 92 13 61, e-mail: sarec@tf.czu.cz

Sample rate selection for oscilloscopic diagnostics of alternator and starter

J. POŠTA, R. PAVLÍČEK

Czech University of Agriculture, Prague, Czech Republic

ABSTRACT: The selection of the sample rate is essential for oscilloscopic measurements of dynamic quantities. Too low sample rate may distort the measured signal's waveform and in consequence even result in mistakes. Too high sample rate may increase the information noise level and thereby decrease the measurement sensitivity for certain purpose. Using high sample rate leads to rapid increase of data volumes and oscilloscope's memory requirements, or shortens the possible lenght of the measured waveform. For every dynamic process measurement, where an oscilloscope is put to use, it is necessary to determine the optimal sample rate (sample rate span). This paper focuses on general principles for the optimal sample rate selection.

Keywords: diagnostics; oscilloscope; sample rate; alternator; starter

Productive manufacturing of any kind is possible only with high-productive and economic machines and machine aggregates. As the development of machine construction progresses, more sophisticated functions are implemented. This is made possible by improvements in the construction, which on the other hand mean significant increase in purchase prices and losses in case of failure. Therefore the importance of preventive maintenance in the field of machine operation is growing.

As the complexity and price of machines and manufacturing equipment increases, the task structure and workload of maintenance workers are changing. The workers, mechanics – repairmen, become specialists who focus on searching for machine's malfunction sources, detection of emerging failures' symptoms and failure prevention. These activities are called diagnostics and are main goals of diagnostics itself.

As we understand the term diagnostics in this way, we still can see significant progress – the prevention and anticipating failure caused operation problems are emphasized even more (BALOG 1999). These trends consequently bring changes in methods of proceeding diagnostics – the progress aiming from simple searching for apparent failures' sources to periodic preventive diagnostics checking, inspections or revisions towards permanent automated monitoring of the operational and functional state of the machine and its main parts.

Common methods of operational parameters' measuring used for machine construction and development do not meet the requirements for the above mentioned purposes. The disassembling methods are not suitable for operational diagnostics and can not be used for onboard diagnostics at all. The methods of dynamic diagnostics which implement recording and analyzing of diagnostic signals' waveforms within short periods of time or during induced or natural transition processes meet the requirements (FLEISCHHANS 2000). A storage oscilloscope with memory is suitable for monitoring and visualization of waveforms during such rapid processes. The essential problem of oscilloscopic measurements is the sample rate selection. Optimal sample rate has to be set before every single measurement. This paper focuses on general principles for the optimal sample rate selection. Experimental verification for automobile alternator, combustion chamber and starter of combustion engine has been carried out.

MATERIAL AND METHOD

For every monitored variable the characteristic frequency of its waveform variation can be determined according to the operation conditions. This characteristic frequency determines the optimal sample rate selection (POŠTA, PAVLÍČEK 1999). For oscilloscopic measurements the sample rate selection is important. Too low sample rate may distort the measured signal's waveform and in consequence even result in mistakes. Too high sample rate may increase the information noise level and thereby decrease the measurement sensitivity for certain purpose. Using high sample rate leads to rapid increase of data volumes and oscilloscope's memory requirements, or shortens the possible lenght of the measured waveform. Fig. 1 demonstrates the possible cases.

Besides the sample rate, the measured signal's period stability is also important for the characteristic waveform's sufficient representation without distortion. In case the period is unstable this fact has to be considered in the minimal sample rate selection process.

The phase of characteristic signal and phase of sampling should be synchronized for the waveform's clear representation without distortion. Modern oscilloscopes are able to start the sampling process in extreme level (minimum or maximum) of the waveform (FLEISCHHANS 2000). Thus this function allows user to
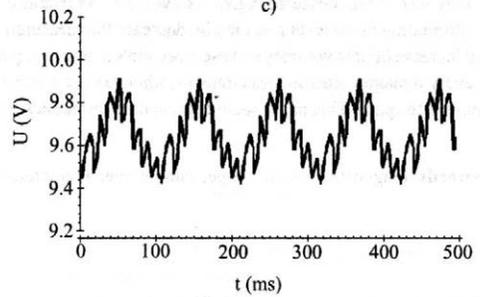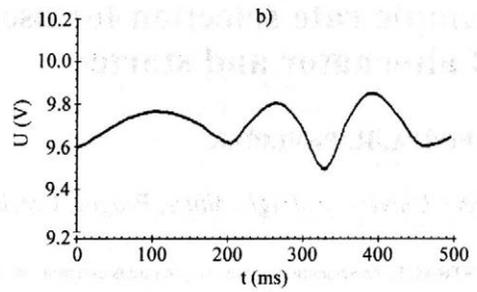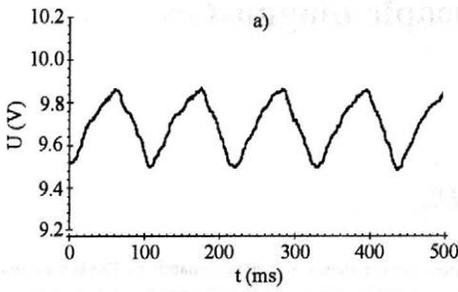
Fig. 1. Waveform of identical signal according to selected sample rate
a) correct display of the waveform, optimal sample rate
b) distorted waveform, too low sample rate
c) noisy waveform, too high sample rate

choose $b = 2$ samples per one period of the characteristic signal's waveform, but in case of unstable period of the characteristic signal the measurement might be totally devaluated as depicted in Fig. 2b.

The monitored signal's waveform may be a component of a multidimensional signal which is generated by multiple simultaneously affecting factors. These factors are related to the construction of the machine and to present operation conditions of the machine (POŠTA t al. 2000). Each of these factors generates different characteristic frequency, these frequencies make up resulting signal. If the characteristic frequencies generated by these factors differ significantly, the suitable sample (or display) rate selection can emphasize chosen characteristic frequency.
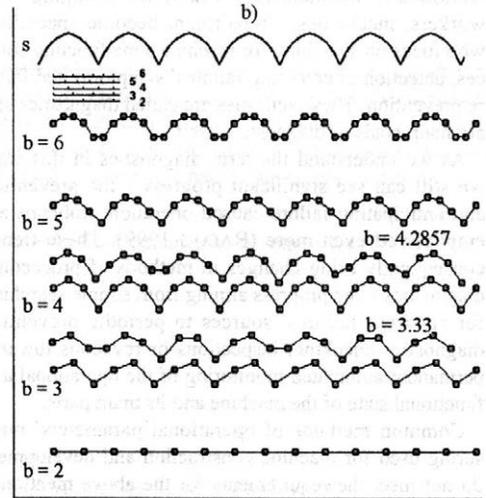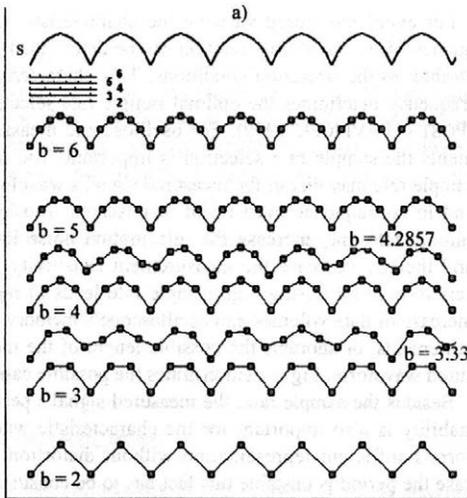

Fig. 2. Waveform of identical signal according to phase synchronization to the sampling process
S – measured waveform, b – number of samples per one period
a) various number of samples per one period of the characteristic signal waveform and phase synchronization of the measured waveform and sampling process
b) various number of samples per one period of the characteristic signal waveform and phase shift between the measured waveform and sampling process
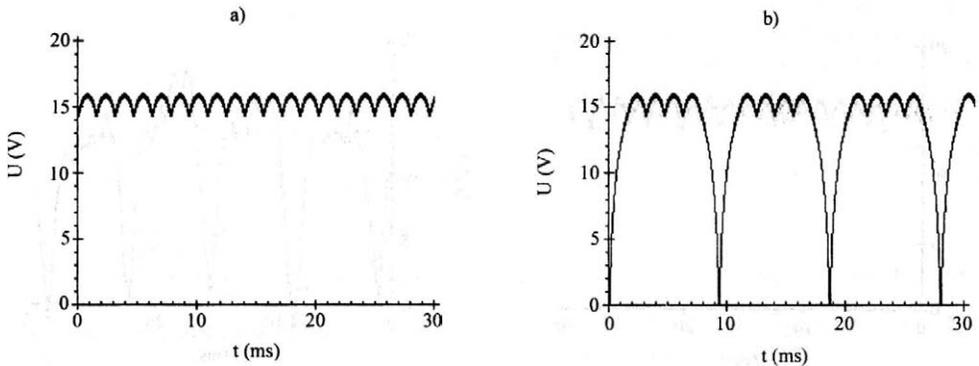
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Fig. 3. Expected (theoretic) alternator output voltage waveform (1,700 rpm)
a) faultless alternator
b) one main diode interrupted

For every dynamic measurement the optimal sample rate (or sampling frequency bandwidth) selection is consequently needed. That enables to display the main monitored variable's waveform and reduce noise without significant distortion of the waveform. The optimal sample rate selection also saves memory capacity and thereby allows to record longer period of time and increases the probability of rarely occurring irregularities' detection (POŠTA, PAVLÍČEK 2001).

Provided that sufficient memory capacity is at disposal for data recording, e.g. the measurement is not limited by the capacity of the memory, choosing the sample rate as high as possible is very useful, especially in case of multidimensional signals. The data can be adjusted (suitable process of filtration can be applied) later when visualized so the characteristic waveform of the monitored signal is represented without distortion (Fig. 1a).

For experimental verification of the above explained ideas the 2-channel digital oscilloscope, realized by oscilloscopic converting card PCX-1230 located in a personal computer, was used. Such a system allows direct data transfer to the computer and subsequent processing and visualization of the data using appropriate software (POŠTA, PAVLÍČEK 1999). Microsoft Excell was used for acquired data processing.

The converting card PCX-1230 is a component of the Precision Serie kit, which is used especially for laboratory and industrial measurements with very high requirements for accuracy, sample rate and multichannel inputs. The device is based on Analog Devices A/D converters and thanks to its circuits' construction reaches required parameters. The PCX-1230 card features:

– 3 separated input channels (amplifier + A/D converter + data memory),
– programmable synchronization logic for detecting external events,
– control logic with recording before and after event,
– multicard master/slave logic for synchronizing all PC cards in the system,

– enables using 3 data inputs on the same time base,
– analog inputs:
  – number of inputs 3
  – input impedance 100 kΩ
  – input voltage range ±1 V,
– A/D converter:
  – type AD9220 (Analog Devices)
  – resolution 12 bit
  – working frequency 10 MHz (internal oscillator),
– data memory:
  – memory capacity 3×256 kB (expandable to 3× 1,024 kB).

RESULTS

ALTERNATOR

The instantaneous output voltage of the alternator was measured under controlled steady external conditions (rpm, load, field current) and factitious failures (interruption and short circuit of the rectifier's main diode). Fig. 3 shows expected (theoretic) output voltage waveform of faultless alternator and output voltage waveform in case of interruption in one main diode.

Fig. 4 shows actual output voltage waveform recorded using mentioned sample rate. Various sample rates were applied and results were compared to find out the minimal necessary number of samples recorded within one period of the characteristic waveform.

STARTER AND COMBUSTION CHAMBER OF THE ENGINE

The instantaneous terminal voltage of the starter was measured during the combustion engine's starting process.

The waveform can be affected by varying mechanical resistance (caused for example by forces of compression pressures in engine cylinders) or by additional mechani-
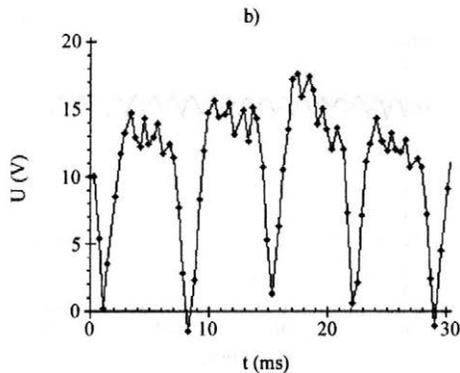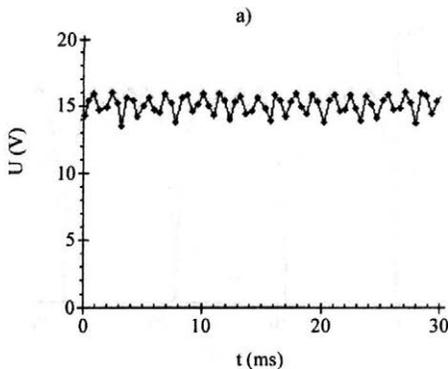
Fig. 4. The real (measured) alternator output voltage waveform 1,700 rpm, sample rate 2.441 kHz, on-load current 5 A, alternator 14 V, 35 A
a) faultless alternator
b) one main diode interrupted

cal resistances (such as damaged pinion gearing of the starter, damaged flywheel gear ring) or also "electrical" failures of the starter (caused by the circuits' contact resistances or brush contact resistance) (POŠTA, PAVLÍČEK 2001).

The premised hypothesis, that selection of suitable sample rate might at least partly eliminate the monitored signal's distortion caused by other simultaneously affecting factors, was tested.

Fig. 1a shows the results of the measurements, which were aimed to test the relative tightness of combustion engine cylinders. Mentioned results were obtained using optimal sample rate, the measurement examined a four cylinder engine with good tightness of all cylinders. The parameters of the measurement: $n_{ms} = 272$ rpm, characteristic frequency $f_1 = 9.066$ Hz, used sample rate $f_v = 2.441$ kHz.

Fig. 1c demonstrates measurement results for the same engine but significantly higher sample rate. The influence of damage of the starter's pinion gearing to the waveform is apparent.

DISCUSSION

The comparison of Figs. 3 and 4 shows that the measured waveforms correspond to the theoretic expectations and therefore the selected sample rate was correct.

It can be concluded that the minimal sample rate for alternator dynamic diagnostics can be determined as follows:

$$f_{mA} = \frac{b \cdot n \cdot v \cdot p}{60} \quad (1)$$

where: f_{mA} – minimal sample rate (Hz),
   b – number of samples per one period of the characteristic signal (1),
   n – alternator armature speed (rpm),
   v – number of stator winding phases (1),
   p – number of armature's magnetic poles (1).

Suitable sample rate for combustion chamber tightness diagnostics and starter diagnostics can be obtained from following idea.

1. Characteristic frequency of sensed signal is generated by overcoming the compression pressures in the engine cylinders. Minimal sample rate can be obtained by calculation:

$$f_{m1} = b \cdot f_{S1} = \frac{b \cdot n_{ms} \cdot z \cdot p_k}{60} \quad (2)$$

where: f_{m1} – minimal sample rate (Hz),
   f_{S1} – characteristic frequency (Hz),
   b – number of samples per one period of the characteristic signal waveform (1),
   n_{ms} – crankshaft rpm during the engine start (rpm),
   z – number of cylinders (1),
   p_k – compression cycle number per one crankshaft revolution (1), (four-cycle engine $pk = 0.5$, two-cycle engine $pk = 1$).

2. Characteristic frequency of sensed signal is generated by damaged tooth of the pinion or by deformed hinge of the starter pinion. Minimal sample rate can be obtained from:

$$f_{m2} = b \cdot f_{S2} = \frac{b \cdot n_{ms}}{i_s \cdot 60} \quad (3)$$

where: f_{m2} – minimal sample rate (Hz),
   f_{S2} – characteristic frequency (Hz),
   n_{ms} – crankshaft rpm during the engine start (rpm),
   i_s – transmission ratio between the crankshaft and the starter pinion (1).

3. Sensed signal's characteristic frequency is generated by increased brush contact resistance during the transition between separated commutator bars. Minimal sample rate fm3 can be obtained from:

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$$f_{m3} = b \cdot f_{S3} = \frac{b \cdot n_{ms} \cdot p_k \cdot p_{pk}}{i_s \cdot i_{vs} \cdot 60} \qquad (4)$$

where: f_{m3} – minimal sample rate (Hz),

f_{S3} – characteristic frequency (Hz),

n_{ms} – crankshaft rpm during the engine start (rpm),

p_k – number of the commutator bars (1),

p_{pk} – number of brushes couples connected in parallel (1),

i_s – transmission ratio between the crankshaft and the starter pinion (1),

i_{vs} – transmission ratio between the armature and the starter pinion (1).

For above mentioned cases the following expression is valid:

$$f_1 < f_2 < f_3 \qquad (5)$$

CONCLUSIONS

The analysis of waste number of waveforms recorded under identical external conditions and various sample rates leads to the following recommendation:

The sample rate should be selected three (or more) times higher then the frequency of the characteristic signal.

From the discussion of mentioned results the following conclusion can be drawn:

In case the characteristic frequencies generated by various components of the system are significantly different, suitable sample rate selection can emphasize chosen characteristic frequency.

Generally speaking, the sample rate selection is very important. Inadequate sample rate can cause serious problems or consequently lead a false diagnosis.

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Volba vzorkovací frekvence pro osciloskopickou diagnostiku alternátoru a spouštěče

ABSTRAKT: Pro měření dynamických veličin pomocí osciloskopu je důležitá volba vzorkovací frekvence. Příliš nízká vzorkovací frekvence může způsobit zkreslení průběhu snímané veličiny a tím vést k omylům. Příliš vysoká vzorkovací frekvence může zvýšit informační šum a tím snížit citlivost měření pro daný účel. Při vysoké vzorkovací frekvenci rychle roste objem dat, a tedy se buď pronikavě zvyšují nároky na paměť, nebo se zkracuje délka zaznamenaného průběhu snímané veličiny. Pro každé měření dynamického děje pomocí osciloskopu je proto třeba stanovit optimální vzorkovací frekvenci. Příspěvek se zabývá obecnými zásadami pro volbu optimální vzorkovací frekvence při dynamické diagnostice alternátoru a spouštěče.

Klíčová slova: diagnostika; osciloskop; vzorkovací frekvence; alternátor; spouštěč

Corresponding author:

Doc. Ing. JOSEF POŠTA, CSc., Česká zemědělská univerzita, Technická fakulta, 165 21 Praha 6-Suchdol, Česká republika

tel.: + 420 2 24 38 32 66, fax: + 420 2 20 92 13 61, e-mail: posta@tf.czu.cz

Low temperature pumping characteristics of biodegradable chainsaw oils

R. KLVAČ[1], C. KANALI[2], A. SKOUPÝ[1]

[1]Mendel University of Agriculture and Forestry, Faculty of Forestry and Wood Technology, Brno, Czech Republic
[2]University College Dublin, Agricultural and Food Engineering Department, Dublin, Ireland

ABSTRACT: The use of biodegradable oils for timber harvesting operations poses several technical problems (viz. temperature intolerance, hysteresis), and imparts negatively on operator health. This paper investigates low temperature pumping characteristics of biodegradable oils used in power chainsaws. Eleven different types of oils were studied (viz. one mineral oil, one mixture of a mineral and a biodegradable oil, and nine biodegradable oils). The results of the study classified the oils into four different groups, based on established temperature thresholds for the pumpability of the oils at low temperatures. The results also showed that bio-degradable oils are more suitable for use in timber harvesting operations at low temperatures than mineral oils.

Keywords: biodegradable oil; chainsaw; low temperatures; lubricating; pumping characteristics

The use of only vegetable based biodegradable oils for loss-making lubrication (i.e. an open lubrication system in which oil is employed as a cooling and lubricating agent then dispersed into nature without returning it into the system) for forest operation has been a requirement since 1996 in the Czech Republic (Law No. 289/1995). Currently, several biodegradable oils with some characteristics that are similar or better than those of mineral oils are available on the market (LAUHANEN et al. 2000). The approval for use of these oils is based on such factors as price, lubrication characteristics, accessibility, shelflife, adhesive properties and low temperature pumping characteristics.

In spite of there being a prohibition, the use of mineral or other types of oils (viz. used gear, hydraulic and kitchen oils) for timber harvesting operations still continues. HARTWEG and KEILEN (1989) calculated that the annual consumption of oils for logging in Germany exceeded the volume sold by a two million litres, implying that applied oils that are considered to be toxic might have been used. In their study, ATHANASSIADIS et al. (1999) found that a mean value of 35 litres per cubic metre under bark of chainsaw oil for single grip harvester is required during mechanized timber felling and crosscutting operations.

Although biodegradable oils have been found to be better lubricants than mineral oils, and they degrade faster than mineral oils (LAUHANEN et al. 2000), these oils still pose several fundamental problems. For example, thin layers of rapeseed oil easily oxidize when exposed to air. An oxidized rapeseed oil is sticky, and when left on a machine part, such as the chain of a chainsaw, it may result in the ceasing of the chain. This may subsequently cause difficulties in the removal of grease residual from the chain. Oxidized oil residuals may also restrict piston movement during oil pumping, resulting in damaging of the drive wheels of the transmission system. In addition, since oil is usually dispersed by air, a mixture of impurities in the air (such as dust particles) and oil may settle on cylinder walls, leading to poor engine cooling, and if not checked may lead to engine seizure. Thus, many users disapprove of the use of biodegradable oils in vehicles, based on loss-making lubrication properties (SKOUPÝ et al. 1995).

GULKO (1970) investigated the effect of friction caused by the cutting mechanism of a power chainsaw. The guide bar had six channels for oil application, and six thermal points for measuring the temperature of the guide bar during operation. Satisfactory performance was achieved when the chainsaw operated at a rate of 200 g/h, a speed of 8 to 20 m/s, and when the oil was added from the top or bottom of the guide bar. Previous studies show that increase in the rate of flow of lubrication oils (up to 200 cm³/hour) decreased the temperature of the guide bar. However, the use of more than 200 cm³/hour of oil had little or no significant influence on the temperature of the guide bar (SZEPESI 1968). NAVRÁTIL (1995) studied the wear of cutting parts of chainsaws and established 5 ml per 60 seconds to be the minimum amount of oil required for sufficient guide bar lubrication.

Studies on the effect of lubrication oils on the environment show that about 60% of chain lubricant end up in subsurface water systems (BUBLINEC, ŠIMEK 1989), while approximately 25% of all oil lubricant settle on the soil surface (SKOUPÝ et al. 1990; SKOUPÝ, ULRICH 1994). The remaining oil settles on stumps, logs, operator clothes, or on sawdust. In their study, LAUHANEN et al. (2000) found that both biodegradable and mineral oils imparted negatively on the health of the operator, and that mineral oils were more toxic to plants than biodegradable oils.

The suitability of oils for use in chainsaws requires constant pumping of specified amounts of oil to the grooves of the guide bar at low temperatures, as the oil attributes change. The minimum temperature required to pump oils depends on complex physical attributes of the oil. These attributes may result in either different rates of freezing or temperature hysteresis (which occurs when the oil happens to have different melting and freezing points). The complexity of the attributes may also affect the pumping characteristics of the oils, especially at low temperatures. The objective of this study was to characterize oils used as lubricants in chainsaws for timber harvesting, based on their low temperature pumping characteristics.

MATERIALS AND METHODS

The equipment shown in Fig. 1 was designed by SKOUPÝ et al. (1995) and employed in acquiring data for the establishment of low temperature pumping characteristics of biodegradable oils used in chainsaws. It consists of a beaker for holding the oil sample, a suction tube (2.5 mm inner diameter), a measuring cylinder for determining the volume of the oil sample, a pressure gauge for displaying the suction pressure, a suction pump, digital thermometer, and connecting tubes. The digital thermometer was chosen, since it does not require inserting in a freezer as is normally done with conventional mercury thermometers in order to maintain its temperature to that of the oil sample.

The beaker was placed in a freezer for at least 24 hours at −25°C after being filled with 150 cm^3 of the oil sample, and after inserting the suction tube in the oil. It was then removed from the freezer and immediately wrapped with polystyrene insulating material for slow warming up. Thereafter, the suction tube was connected to the rest of the apparatus as presented in Fig. 1, and the suction pump started. Data collection involved recording: oil temperatures in the beaker in time when the oil entered and exited the measuring cylinder, and suction time (time taken to fill the 5 cm^3 measuring cylinder with oil − time was measured by stopwatch). The suction pressure of 13.0 ± 10% kPa utilized corresponded to the pressure normally employed in pumping oil in chainsaws (SKOUPÝ et al. 1995). The temperature of the oil in the beaker was kept uniform by frequently stirring the oil during data acquisition. The measurement was repeated as much as possible with rise temperature. Eleven different types of oil were studied (viz. one mineral oil, one mixture of a mineral and a biodegradable oil, and nine biodegradable oils).

Five samples for each type of oil were tested, and the data collected were utilized to draw graphs relating mean oil temperature (θ_{mean}) and suction time (t) for each measurement. The temperature θ_{mean} corresponded to the average of the oil temperatures in the beaker at the oil inlet and outlet of the measuring cylinder. Regression analysis was performed on the data relating θ_{mean} and t. Equations obtained were used to compute a temperature (θ_{60}) corresponding to a suction time of 60 s, which defined the lower limit for the pumpability of oil for use in chainsaws (SKOUPÝ 1990; SKOUPÝ, PŘIBYL 1991). Pumpability is defined as the low temperature, low shear stress-shear rate viscosity characteristics of an oil that permit satisfactory flow to and from the engine oil pump and subsequent lubrication of moving components (ANONYMOUS 2001).

RESULTS

The different types of oil studied included Biomil P35, Biomil P70, Bipol, Biosol, Clear-refined Oil, Ekolube Cut 80P/1 (a mixture of mineral and vegetable oil), Ekolube Cut 80P/2 (a biodegradable oil), Husqvarna Veg Oil, Lespol, OA M6A and Shell Kettensägenöl
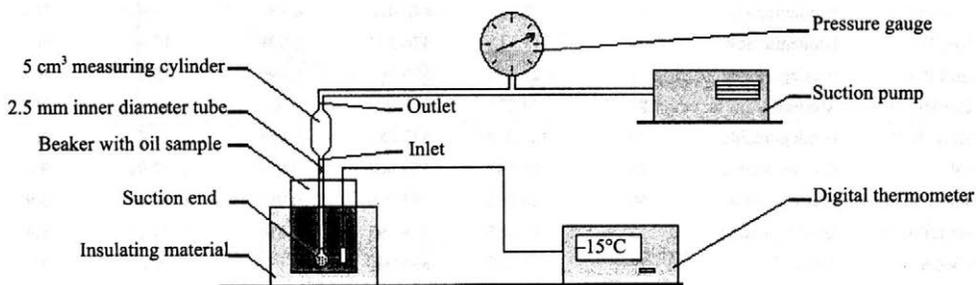

Fig. 1. Schematic of the system used for establishment of oil pumpability

Table 1. Physical information of the oils (arranged alphabetically)

Oil name	Density (kg/m³)	Viscosity (mm²/s) (at 40°C)	Viscosity (mm²/s) (at 100°C)	Flash point (°C)	Melting point (°C)	Biodegradability (%/21 days)
Biomil P35	N	35–45	N	240	N	92
Biomil P70	N	74–84	N	240	–20	92
Bipol	912	41	9.3	278	–33	97.1
Biosol	918	68	17	270	–28	99
E. Cut 80 P/1	900	72–75	12–14	205	–35	53
E. Cut 80 P/2	910	74–76	15–19	215	–23	85
H. Veg Oil	985	68	N	> 200	–33	> 95
Lespol	921	> 75	N	310	–19	96.6
OA M6A	N	N	10–12	220	–25	N
Shell K. S. B.	925	90	20.6	250	–36	N

N – not given; biodegradability – according to CEC L-33-A-93

Super Bio (Shell chainsaw oil super bio). More detailed information are shown in Table 1. Note: Two different oils with the same trade name Ekolube Cut 80P were produced, therefore were distinguished by indexes 1 and 2 in this study.

The total number of data collected for each of the eleven different types of oil tested ranged between 47 and 98. These data were utilized to draw graphs relating mean oil temperature and suction time, in order to establish lower temperature limits for pumpability of the oils. Fig. 2 shows the results for one of the oils, Husqvarna Veg Oil. In general, the relationship between θ_{mean} and t for all the oils was as shown in the figure. Regression analysis performed on the data gave the relationship shown in equation (1), where a and b are regression constants. The values for the constants a and b, and the corresponding correlation coefficients (R) for each oil are present in Table 2. The temperature (θ_{60}),

also shown in Table 2, corresponding to a suction time of 60 s that defined the lower limit for the pumpability of oil for use in chainsaws was computed based on equation (1) and the constants a and b.

$$\Theta_{mean} = a + \frac{b}{t} \tag{1}$$

At the freezer temperature of –25°C under which the oils were kept for 24 hours, all the oils were in a liquid state except Bipol, Biomil P35, Clear-refined and Lespol oils. Mean values of measured melting temperatures for Bipol, Biomil P35, Clear-refined and Lespol oils are shown in Table 1. As these oils had higher melting points than the –25°C utilized at the start of each test, less data was acquired for them as compared to the other oils. Since the melting and freezing temperatures for these oils are not equal, temperature hysteresis exists. In addition, since the θ_{60} values (shown in brackets in Ta-

Table 2. Regression analysis results for the pumpability test (arranged by θ_{60})

Oil name	Type of oil	No. of data	Regression coefficient a	Regression coefficient b	R	θ_{60} (°C)	$\theta_{melting}$ (°C)
Biosol	Biodegradable	97	–27.489	516.316	0.976	–18.9	N
E. Cut 80 P/2	Biodegradable	95	–25.316	442.426	0.986	–17.9	N
H. Veg Oil	Biodegradable	98	–25.716	476.373	0.979	–17.8	N
Biomil P70	Biodegradable	85	–22.353	396.766	0.990	–15.7	N
E. Cut 80 P/1	Mixture	84	–24.233	590.007	0.981	–14.4	N
Shell K. S. B.	Biodegradable	78	–22.229	532.483	0.933	–13.4	N
Bipol	Biodegradable	73	–15.537	158.504	0.959	(–12.9)	–9.0
Biomil P35	Biodegradable	60	–20.583	193.266	0.961	(–17.4)	–8.9
Clear-refined oil	Biodegradable	52	–17.865	218.393	0.864	(–14.2)	–8.4
OA M6A	Mineral	76	–21.219	894.940	0.989	–6.3	N
Lespol	Biodegradable	47	–7.0891	281.140	0.945	–2.4	–7.9

R – correlation coefficient; θ_{60} – temperature corresponding to the lower limit for oil pumpability; $\theta_{melting}$ – melting point; mixture – mixture of mineral and vegetable oil; N – not found out
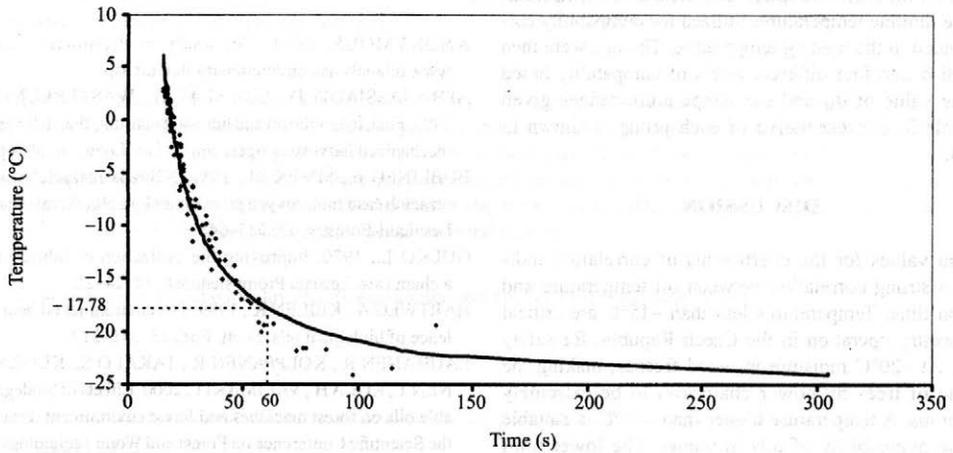
Fig. 2. Relationship between suction time and oil temperature for Husquarna Veg Oil

Table 3. Different pumpability levels for oils

Group 1	Group 2	Group 3	Group 4
$-15°C > \theta_{60}$	$-15°C \leq \theta_{60} < -10°C$	$-10°C < \theta_{60} < -8°C$	$-8°C < \theta_{60}$
Biomil P70	Ekolube Cut 80 P/1	Biomil P35	Lespol
Biosol	Shell Kettensägenöl Super Bio	Bipol	OA M6A
Ekolube Cut 80 P/2		Clear-refined Oil	
Husqvarna Veg Oil			

- ▲ Biomil P35   - × - OA M6A   —— E. Cut 80 P/1   - ○ - E. Cut 80 P/2
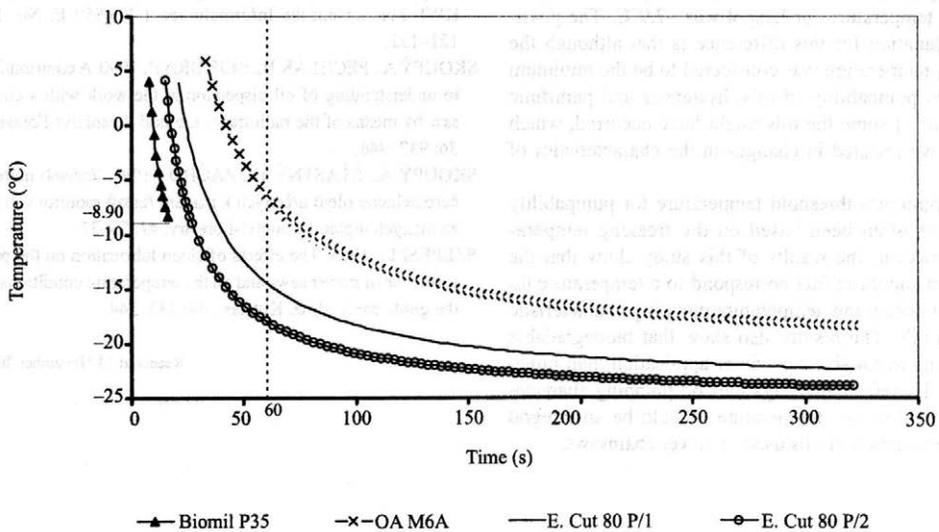
Fig. 3. Relationship between suction time and oil temperature for representative oils from each group of pumpability level

ble 2) for these oils are lower than the melting temperatures the limiting temperatures utilized for pumpability corresponded to the melting temperature. The oils were then classified into four different levels of pumpability based on the value of θ_{60} and the temperature ranges given in Table 3. Representative of each group is shown in Fig. 3.

DISCUSSION

High values for the coefficients of correlation indicates a strong correlation between oil temperature and suction time. Temperatures less than $-15°C$ are critical for forestry operation in the Czech Republic for safety work. At $-20°C$ moisture in wood freezes, making the cutting of trees by power chainsaws to be extremely dangerous. A temperature higher than $-10°C$ is suitable for the pumpability of oils in winter. The lower limit normally provided for pumpability of mineral oils is $-8°C$. Therefore, the oils in Groups 1 and 2 with θ_{60} values less than $-10°C$ can satisfactorily be utilized for timber harvesting operations in winter. The oils in Groups 3 and 4 are suitable for use only in frost-free conditions. However, the oils in Group 3 can be pumped soon after melting. They have pumpability thresholds lower than that for mineral oils.

Oil producers often consider the freezing temperature to be the lower limit for pumpability of oils. Some of the oils studied, for example Bipol and Lespol, had assigned pumpability temperature values far lower than measured values. Bipol producers normally indicate a temperature of $-32°C$ as the freezing point of the oil. However, in this study Bipol was solid at $-25°C$ and it melted at $-9°C$. Similarly, labels for Lespol oil indicate a freezing temperature of $-19°C$. In this study the measured melting temperature for Lespol was $-7.9°C$. The possible explanation for this difference is that although the freezing temperature was considered to be the minimum threshold pumpability of oils, hysteresis and paraffinic behaviour of some the oils might have occurred, which could have resulted in changes in the characteristics of the oils.

The minimum threshold temperature for pumpability of oil has often been based on the freezing temperature. However, the results of this study show that the threshold should in fact correspond to a temperature θ_{60} obtained during low temperature pumping characteristic tests on oils. The results also show that biodegradable oils are more suitable for winter application than mineral oils. Therefore, investigations on pumping characteristics of oil at low temperatures should be an integral part of evaluation of oils used in power chainsaws.

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Čerpatelnost biologicky odbouratelných olejů při nízkých teplotách používaných k mazání řetězových motorových pil

ABSTRAKT: Použitelnost biologicky odbouratelných olejů při těžbě dřeva působí mnohé technické problémy (teplotní intolerance, hystereze) a má negativní vliv na zdraví operátora. Práce hodnotí čerpatelnost olejů používaných k mazání řetězů řetězových motorových pil při nízkých teplotách. Celkem bylo hodnoceno 11 druhů olejů (jeden minerální, jeden míchaný a devět biologicky odbouratelných olejů). Výsledkem studie je klasifikace olejů do čtyř skupin založených na čerpatelnosti olejů při nízkých teplotách. Výsledky při porovnání s minerálním olejem ukazují na vyšší využitelnost biologicky odbouratelných olejů (na bázi řepkových olejů) při nízkých teplotách než minerálního oleje.

Klíčová slova: biologicky odbouratelný olej; řetězová motorová pila; nízká teplota; čerpatelnost

Corresponding author:

Ing. RADOMÍR KLVAČ, Mendelova zemědělská a lesnická univerzita, Lesnická a dřevařská fakulta, Lesnická 37, 613 00 Brno, Česká republika
tel.: + 420 5 45 13 41 52, fax: + 420 5 45 21 14 22, e-mail: rklvac@mendelu.cz

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