Analysis of non-genetic factors affecting calving difficulty in the Czech Holstein population

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ABSTRACT: The objective of this study was to analyze the effects of non-genetic factors affecting calving difficulty in the Holstein population of the Czech Republic for subsequent compilation of the model for genetic evaluation as well as for herd management practice. Calving difficulty recorded in 1997–2006 was assessed in three categories: 1 = normal, 2 = hard pull, 3 = complicated. The original observations were transformed to an underlying normal scale. A data set containing 409 255 records was analysed by a linear model with fixed effects of season, parity of dam, sex of calf and Holstein gene proportion. All these effects were significant, and their appropriate categorization was considered. Analyses of additional factors such as gestation length, age at first calving and preceding calving interval were performed. The results revealed that gestation length was in a non-linear relationship with calving difficulty. A higher risk of difficult calving was associated with short or long gestation and with a prolonged preceding calving interval in multiparous cows. Calving difficulty should be adjusted for these factors. A decreased risk of difficult calving could be achieved by an altering of calving interval and age at first calving as a management tool.

Keywords: calving process; gestation length; age at first calving; preceding calving interval; dairy cattle

Fertility related traits as cost reducing factors are of increasing concern to Holstein breeders. Dystocia and stillbirth represent important economic costs either direct (loss of calf, death of dam, veterinary assistance and labour) or long-term (culling rate, milk yield and fertility) ones (Meijering, 1984). In spite of low heritability (Kemp et al., 1988, h^2 = 0.06; McGuirk et al., 1999, h^2 = 0.05; Junge et al., 2003, h^2 = 0.05 and 0.06, direct and maternal, respectively; Jamrozik et al., 2005, h^2 = 0.14; Fuerst and Fuerst-Waltl, 2006, h^2 = 0.02 to 0.09), an effort to reduce the incidence of difficult calvings and the stillbirth rate in dairy herds is made by a selective use of sires over females at risk (mainly heifers). Several factors have an evident impact on calving performance, e.g. parity or dam age, sex of calf, gestation length, and season of calving being the most important (Meijering, 1984). Adjustments for such non-genetic factors are made in genetic evaluations (Berger, 1994; McGuirk et al., 1999; Fuerst and Egger-Danner, 2003).

The incidence of dystocia and stillbirths tends to be population specific because of genetic factors and a range of non-genetic factors (Berry et al., 2007). The Czech Holstein population is specific in its development (conversion from the original Czech Fleckvieh cattle by upgrading crossing with Black and White and Holstein bulls) and in management conditions in herds. In the Czech Republic, data on the course of deliveries on farms have been recorded by breeders for more than ten years, but they have not been used for the genetic evaluation of calving traits yet. A model for the estimation of breeding value of calving difficulty in populations

Supported by the Ministry of Agriculture of the Czech Republic (Project No. MZe 0002701402)

of Czech dairy cattle breeds is being prepared at present. The objective of this paper was to analyze the effects of non-genetic factors affecting calving difficulty in the Holstein population of the Czech Republic. Furthermore, the knowledge of the investigated effects might also be applied in herd management practice.

MATERIAL AND METHODS

Records of calving difficulty in the Holstein breed gathered in Central Bohemia and in the Highland regions in 1997–2006 were used in this study. Calving difficulty was assessed by farmers in three categories: 1 = normal, with the assistance of maximally two persons without complications, 2 = hard pull, with the assistance of three or more persons, with vaginal or neck contusions, 3 = complicated, with serious difficulties and veterinary assistance required. Multiple births were omitted. Together with the calving score, the sex of the calf born was recorded but not in stillbirths. In such a case, sex was designated as class unknown. Records with parity higher than six were omitted for their rapidly decreasing frequency. Cows sharing less than 50% of Holstein genes were excluded. Breed groups were divided according to the Holstein or Red Holstein gene proportion: 1 = 89–100%, 2 = 76–88%, 3 = 50 to 75%. The edited data resulted in 409 255 records.

In the data set considered for the analyses, 94.14% of calvings were recorded as normal, 4.98% as presenting difficulties, and 0.84% as seriously complicated. Comparing the raw frequencies between regions during the observed period, there were obvious differences that could have been caused by slight deviations from the actual scale based on the subjectivity of scoring. Therefore, calving scores were transformed by means of their frequencies into a standardized normal distribution within the year of calving and the region. The frequencies were calculated for each stratum (year × region) and converted to class means on an underlying normal scale which enables the combination of different scales used in region and time. The transformed values were used instead of the original observations.

Analyses undertaken to identify non-genetic sources of variation used the GLM procedure of SAS (2003) for the multivariate least-squares method. Factors included in the initial analysis were the month of calving, parity of the dam, sex of the calf born, and the percentage of Holstein genes. Additional models were compiled for investigating the possible structure of these factors or for adding others (gestation length, age at first calving, preceding calving interval). The following linear models were used:

$$TCD_{ijklmp} = \mu + S_i + P_j + SC_k + BG_l + \mathrm{GL_m} + e_{ijklmp}$$

$$TCD_{ijklp} = \mu + S_i + P_j + SC_k + BG_l + a_1GL_{ijklp} + a_2GL_{ijklp}^2 + e_{ijklp}$$

for gestation length;

$$TCD_{iklnp} = \mu + S_i + SC_k + BG_l + AFC_n + e_{iklnp}$$

$$TCD_{iklp} = \mu + S_i + SC_k + BG_l + b_1AFC_{iklp} + b_2AFC_{iklp}^2 + e_{iklp}$$

for age at first calving;

$$TCD_{iklop} = \mu + S_i + SC_k + BG_l + PCI_o + e_{iklop}$$

$$TCD_{iklp} = \mu + S_i + SC_k + BG_l + c_1PCI_{iklp} + e_{iklp}$$

for preceding calving interval

where:

- *TCD* = the transformed value of calving difficulty
- μ = overall mean
- *S* = season; *i* = winter, spring, summer, autumn
- *P* = parity; *j* = 1, 2+
- *SC* = sex of calf; *k* = male, female, unknown
- *BG* = breed group; *l* = H89-100, H76-88, H50-75
- *GL* = gestation length; *m* = 1 to 8, intervals of five days
- a_1, a_2 = regression coefficients
- *AFC* = age at first calving; *n* = 1 to 6, intervals of four months
- b_1, b_2 = regression coefficients
- *PCI* = preceding calving interval, *o* = 1 to 6 (330 to 359, 360 to 389, 390 to 449, 450 to 539, 540 to 629, 630 to 750 days)
- c_1 = regression coefficient
- *e* = residual error

The estimated effects of the investigated factors are shown in Figures 1–7 and are parameterised as $\Sigma\alpha_i = 0$, in general.

RESULTS AND DISCUSSION

Initial analysis of significant factors affecting calving difficulty

The initial linear model included the effects which Hradecká (2002) found to be significant (month of calving, parity, sex of calf and breed group); they

Table 1. Incidence of difficult calvings (%) categorized within effects

Effect	Number of observations	Calving difficulty score		
		1	2	3
Month of calving				
January	39 130	93.74	5.38	0.88
February	33 745	93.70	5.27	1.03
March	34 961	93.81	5.22	0.97
April	32 851	93.90	5.16	0.94
May	33 314	93.98	5.12	0.90
June	33 847	94.27	4.82	0.91
July	36 581	94.29	4.81	0.90
August	34 552	94.37	4.79	0.84
September	29 887	94.34	4.83	0.83
October	31 106	94.72	4.57	0.71
November	33 408	94.48	4.72	0.80
December	35 873	94.14	4.96	0.90
Parity				
1	158 192	91.12	7.56	1.32
2	105 266	96.20	3.25	0.55
3	69 712	96.05	3.33	0.62
4	41 931	95.90	3.46	0.64
5	22 798	95.87	3.43	0.70
6	11 356	95.33	3.90	0.77
Sex of calf				
Male	192 535	96.81	2.76	0.43
Female	188 582	97.50	2.21	0.29
Unknown	28 138	53.27	38.70	8.03
Breed group				
H89-100	246 683	93.34	5.63	1.03
H76-88	89 408	94.94	4.30	0.76
H50-75	73 164	95.82	3.61	0.57

Table 2. Initial analysis of variance

Source of variation	*df*	SS
Month of calving	11	8.503
Parity	5	167.515
Sex of calf	2	21 492.74
Breed group	2	6.898
Error	409 234	76 526.758
R^2		22.85%

explained 0.009, 0.169, 21.67 and 0.007% of the total variability, respectively. Frequencies in classes of calving difficulty by effect levels are presented in Table 1. A summary of the initial analysis of variance is given in Table 2. It can be assumed that a great amount of variability explained by the sex of calf (21.67%) is evoked by the class of stillbirths with unknown sex.

Month of calving. The spring months were associated with more difficult calvings, whereas the autumn months with slightly easier ones, as shown in Figure 1. There is, however, hardly any possibility of generalizing the differences in calving performance based on the month of calving. Meijering (1984) pointed out the inconsistent results of studies on this effect. McGuirk (1999) reported more difficulties in winter months in contrast to summer time. Fuerst and Egger-Danner (2003) suggested slightly easier calvings in late summer and autumn to be a

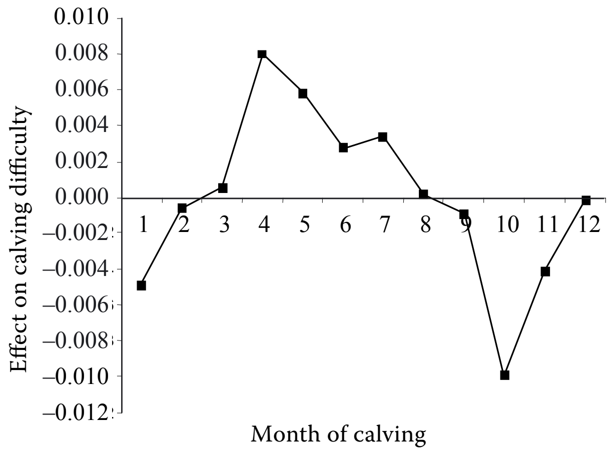

Figure 1. Estimated effects of months on calving difficulty

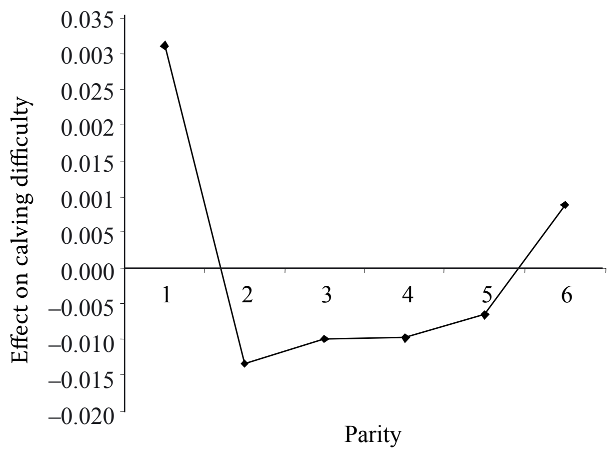

Figure 2. Estimated effects of parities on calving difficulty

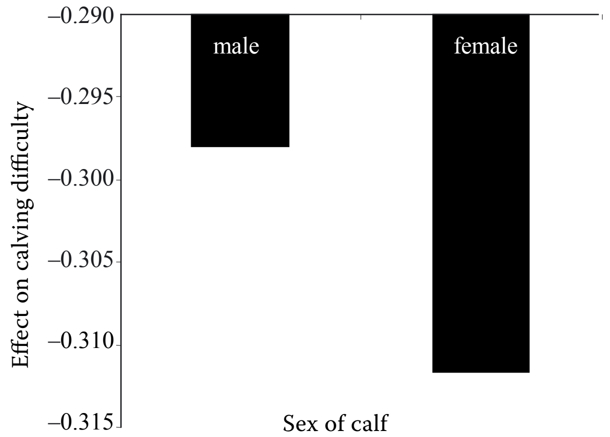

Figure 3. Estimated effects of calf sex (groups of known sex only) on calving difficulty

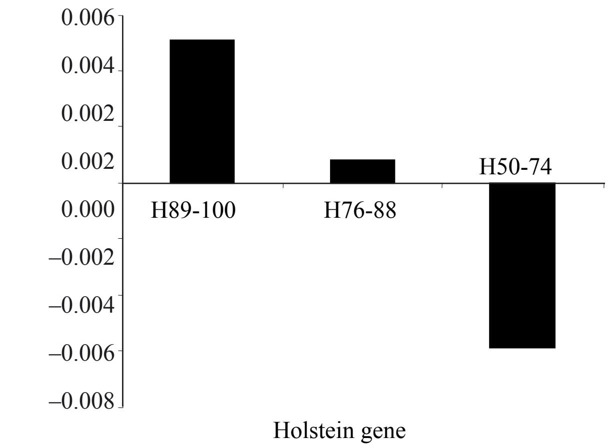

Figure 4. Estimated effects of breed group on calving difficulty

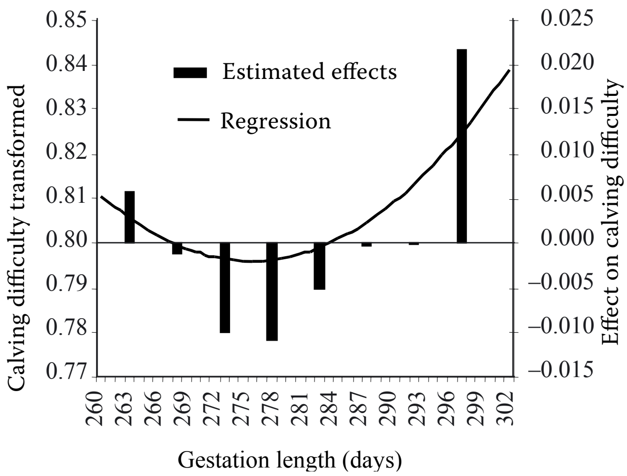

Figure 5. Relationship between gestation length and calving difficulty

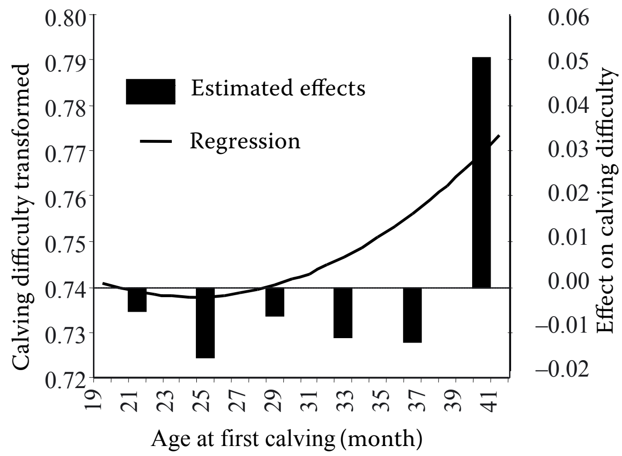

Figure 6. Relationship between age at first calving and calving difficulty

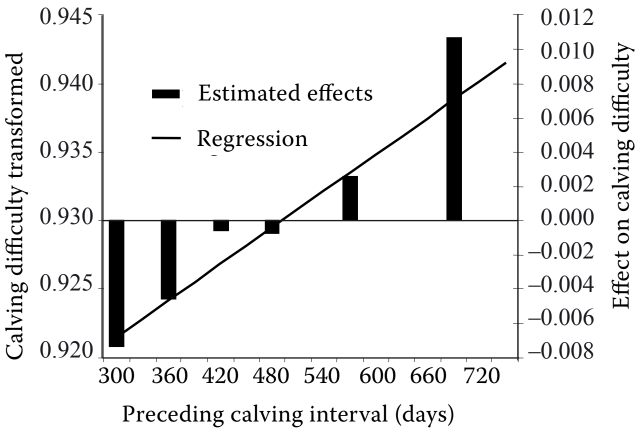

Figure 7. Relationship between preceding calving interval and calving difficulty

result of pasturing activity and better condition of heifers/cows. Nevertheless, calving performance significantly changes during the year, and adjustments for this factor are necessary. A few differences between consecutive months were found in this study. Therefore, they were joined together, and seasons of three months were compiled (winter = December to February, spring = March to May, summer = June to August, and autumn = September to November).

Parity. Parity was fitted as a six-level factor, according to the lactation number. Calving difficulty in primiparous cows significantly differed from that in cows in all other parities. The estimated effect of parity 1 was the highest, which means the highest frequency of difficult calvings, whereas the fewest difficulties were in parity 2, and after that calving difficulty rose until parity 6 (significantly different from others, including parity 1). The estimated effects of parities are presented in Figure 2. Delivery problems are mainly caused by foeto-pelvic incompatibility (discrepancy between the size of the calf and the pelvic dimensions of the dam) (Meijering, 1984; Nogalski, 2003). Primiparous cows have not achieved their full development and mature body size yet (Kratochvílová et al., 2002), and the pelvic inlet area might relatively increase till maturity (Meijering, 1984). The size of the calf expressed either by birth weight (Přibyl et al., 2003) or calf size score (McGuirk et al., 1999) is usually included in the genetic evaluation as an additional trait describing calving performance. The size of the calf as a factor affecting calving difficulty has to be evaluated with respect to the parity group, as parity affects birth weight and dystocia inversely – heifers deliver calves with lower birth weights than do older cows (Johanson and Berger, 2003; Přibyl et al., 2003), but show a higher rate of dystocia. Delivery progress in the first parity seems to be controlled by more or slightly different factors than in other parities. With regard to this, the number of lactation groups could be reduced to two (parities 1 and 2+) or calving traits could be distinguished as different for the first and later parities. Both of these approaches are used in current National Genetic Evaluation Systems (2007, www-interbull.slu.se).

Sex of calf. The Czech recording system does not require to record the sex of the calf if it is stillborn. This is a crucial point for problems with the correct assessment of the calf sex effect. Sex was classified into three categories: male, female and unknown, with frequencies of 0.47, 0.46 and 0.07, respectively. In this case, a balanced sex ratio in the group with unknown sex has to be presumed. The sex of the calf born was the strongest effect in the model. Raw frequencies in Table 1 show a great difference between known and unknown calf sex groups. Figure 3 presents the estimated effects of groups with known sex. Male calves were delivered with more difficult calvings. There is a general agreement that the sex of the calf is a major source of variability (Meijering, 1984; McGuirk et al., 1999; Fuerst and Egger-Danner, 2003).

Breed group. Purebred Holstein cows tended to have more difficulties with delivery, whereas cows sharing genes of other breeds (mainly dual-purpose Czech Fleckvieh or rarely beef breeds) calved more easily. The estimated effects of breed groups are given in Figure 4. No comparative study of calving difficulty of Holstein and Czech Fleckvieh breeds has been done until now. However, a comparison of different beef breeds by Pilarczyk and Wójcik (2007) revealed that large-sized breeds were also

Table 3. Simple statistics of gestation length, age at first calving and preceding calving interval

	No. of observations	Mean	SD	No. of categories	Frequency
Gestation length	314 627	280.0	5.51	8	0.011, 0.029, 0.142, 0.354, 0.323, 0.113, 0.021, 0.007
Age at first calving	158 052	831.9	95.70	6	0.027, 0.507, 0.342, 0.096, 0.023, 0.005
Preceding calving interval	199 359	414.2	75.02	6	0.259, 0.214, 0.272, 0.180, 0.057, 0.018

large at birth and had a higher risk of difficult calvings. Nogalski (2003) reported correlations between calving difficulty and birth weight (0.27) or measurements of calves (0.24–0.77); the body dimensions seem to be more relevant than the body weight of the calves born. We could presume that the increased share of breeds other than Holstein would be accompanied by more or less difficult calvings, but the breed effect in this study can conceal other factors: e.g. the breed group with 50–75% of Holstein genes has been excluded from the Holstein population in 2002; in previous years fewer difficulties were recorded because of less precise recording; and not last, pure Holstein herds arising in the 1990's were often kept separately with particular management and extra care. The results correspond to those given by Hradecká (2002) in her previous research of the Czech Holstein population. She determined an association between dam breed group and herd-year-season effect.

Analysis of other factors affecting calving difficulty

The effect categorization from the initial model was used for the following analyses that introduced gestation length, age at first calving and preceding calving interval as covariates or as fixed categorized effects. Simple statistics in all the factors are given in Table 3.

Gestation length. Gestation length is often analysed as a calving trait. Hansen et al. (2004) presented a weak genetic correlation between gestation length and calving difficulty, and thus the benefit of using gestation length as a trait correlated with calving characteristics in a genetic evaluation was found to be limited. However, Table 4 presents a phenotypic significant non-linear relationship between calving difficulty and gestation length. More difficulties are associated with short or long gestation periods, as shown in Figure 5. The figure indicates that the intermediate value that minimizes the risk of calving difficulty is 275.8 days, which is shorter than the average value of 280 days. In shorter gestation, Johanson and Berger (2003) found a higher incidence of perinatal mortality that could cause an earlier onset of parturition and more difficulties during calving. Long gestation represented a higher incidence of difficult calvings that are probably associated with higher birth weight and size of the calf, as Strapák et al. (2000) reported an essential relationship between birth weight and the calving process. If gestation length or birth weight were not evaluated separately, then gestation length seems to be of such importance that it could be included in the model for genetic evaluation.

Age at first calving. Prospective causes of higher incidence of dystocia encountered when heifers calve at a relatively young or old age were reviewed by Meijering (1984). They can be attributed to the poor pelvic development, not fully compensated for by a smaller calf, or to a reduction in the elasticity of the pelvis and accumulation of fat in the pelvic region, but substantial evidence is missing. The results of this study are not conclusive either. Figure 6 represents a non-linear relationship between calving difficulty and age at first calving but neither of the regression terms (linear or quadratic) was significant (Table 4). This corresponds to the fluctuating mean values of calving difficulty in groups according to age. Moreover, the frequencies in groups of months of age rapidly decreased after 36 months. The first calving at less than 22 months of age indicates a mating age of less than 13 months, which is a matter of error rather than a deliberate service at that age. Similarly, the first calving at more than 36 months of age indicates problems with conception or inadequate herd management. In accordance with the Description of National Genetic Evaluation Systems (2007, available at http://www-interbull.slu.se), records of extreme age at first calving are excluded from the evaluation. For example in NL/BE, records are omitted when

Table 4. Regression coefficients of gestation length, age at first calving and preceding calving interval on calving difficulty

	Regression coefficients					
	linear	SE	*P*	quadratic	SE	*P*
Gestation length	-3.21×10^{-2}	8.42×10^{-3}	0.0001	5.81×10^{-5}	1.502×10^{-5}	0.0001
Age at first calving	-1.79×10^{-4}	1.528×10^{-4}	0.2425	1.21×10^{-7}	0.9×10^{-7}	0.1574
Preceding calving interval	4.44×10^{-5}	1.145×10^{-5}	0.0001	–	–	–

the age at first calving is < 640 or > 1 074 days, whereas in DE/AT, data are excluded when the age at first calving is < 20 or > 40 months. Based on this analysis, it is recommended to omit records with age at first calving of < 22 or > 36 months.

Preceding calving interval. This trait is a useful characteristic of cow fertility. It combines at least two important aspects; first, the ability to return to the reproduction cycle, and second, the ability to confront the positive energy balance at the end of lactation and during the dry period and to prepare for parturition. Table 4 gives the results of regression analysis, and Figure 7 represents the linear relationship between the length of the preceding calving interval and difficulties during subsequent parturition, together with the estimated effects of classes according to lengths of calving intervals on calving difficulty. The risk of difficult calving, which increases with prolonged calving interval, can be minimized by mating policy and by avoiding late services, which is a matter of herd management. Similarly to higher age at first calving, a long calving interval is also accompanied by the accumulation of fat and consequently by a higher risk of difficult calving. However, Berry et al. (2007) did not identify any significant relationship between body condition score at calving and dystocia likely as a result of very few over-conditioned cows. There are a few studies investigating the effect of pre-calving characteristics (body condition score, drying off, dry period, etc.) on calving traits. The preceding calving interval could be introduced as a covariate into the model for genetic evaluation of calving difficulty in multiparous cows.

CONCLUSIONS

As the course of delivery is a subjectively assessed trait, the crucial point in trying to improve calving performance is precision of data recording and reducing the influence of many non-genetic factors. The analysis of these effects showed significant effects of gestation length and preceding calving interval as well. Therefore, calving difficulty should be adjusted for these factors. An altered calving interval and age at first calving could be used as a management tool for decreasing the risk of difficult calvings, and these should be considered in a mating strategy.

Acknowledgement

The authors greatly thank the Czech-Moravian Breeders' Association for supplying data, particularly Mgr. Václav Čermák for discussion about the data editing, and Mr. Arnold Harbers, NRS, Arnhem, the Netherlands, for valuable help and discussion about the transformation of the observed data to an underlying normal scale.

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Received: 2008–01–31
Accepted after corrections: 2008–04–11

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