Arch. Tierz., Dummerstorf **47** (2004) 6, 537-549

Institut für Tierzucht und Tierhaltung der Christian-Albrechts-Universität zu Kiel[1], Germany, Eidgenössische Forschungsanstalt für Agrarwirtschaft und Landtechnik Tänikon, Schweiz[2]

JAN CHRISTOF BIELFELDT[1], RUTH BADERTSCHER[2], KARL-HEINZ TÖLLE[1] and JOACHIM KRIETER[1]

Influence of systematic effects on fertility traits in Swiss Brown cows

Dedicated to Prof. Dr. habil. Peter Glodek on the occasion of his 70th birthday

Abstract

The study was conducted to investigate the influence of systematic effects on fertility traits in Swiss Brown cows. Days to first service (DFS), days open (DO), calving interval (CI), non-return rate 90 (NRR90), and conception rate to first service (CRFS) were analysed. The data set included records from 82,755 cows out of 1,674 farms in Eastern and Central Switzerland. The observation period lasted from January 1988 to May 2002. Housing system, lactation number, region, zone, calving/insemination season, (all fixed), and 305-day milk yield (covariable) were tested significant at a level of $p < 0.05$. The random effect of herd*year accounted for between 5.2 and 16.9 % of the total variance. Improved fertility results were consistently investigated in loose housing systems. DFS (67.8 vs. 71.0 days), DO (86.3 vs. 96.0), and CI (378.7 vs. 386.7) were shorter, NRR90 (66 vs. 61 %) and CRFS (52 vs. 44 %) were higher in loose housing systems compared to tie-stall barns. Cows in the first lactation had longer time intervals and lower success rates compared to cows in the second and third lactation. In higher lactation numbers, the reproductive performance consistently decreased. Cows in Eastern Switzerland had the first service 1 day later (69.7 vs. 68.8) compared to animals in Central Switzerland, otherwise the time intervals (DFS –0.9 days; CI –0.8 days) as well as the success rates (NRR90 +3 %; FSCR +4 %) were better. NRR90 and FSCR were highest in the insemination season from April to June (67 and 52 %, resp.). FSCR was lowest from January to March (48 %) and NRR90 had the lowest values from October to December (60 %).

Key Words: Swiss Brown cattle, fertility traits, housing system, tie-stall barns, loose housing systems

Zusammenfassung

Titel der Arbeit: **Einfluss von systematischen Effekten auf Fruchtbarkeitsmerkmale bei Schweizer Braunviehkühen**

Die Arbeit wurde durchgeführt, um den Einfluss von systematischen Effekten auf verschiedene Fruchtbarkeitsmerkmale bei Schweizer Braunviehkühen zu untersuchen. Rastzeit, Güstzeit, Zwischenkalbezeit, Non-return Rate 90 und Konzeptionsrate wurden analysiert. Die Daten stammten von 82.775 Kühen aus 1.674 Betrieben in der Ost- bzw. Zentralschweiz. Der Erfassungszeitraum reichte von Januar 1988 bis Mai 2002. Das Haltungssystem, die Laktationsnummer, die Region, die Zone, die Kalbe- bzw. Besamungssaison (alle fix) und die 305-Tage Milchleistung (Kovariable) erwiesen sich als signifikant bei einem Niveau von $p < 0,05$. Der zufällige Effekt „Herde*Jahr“ erklärte zwischen 5,2 und 16,9 % der Gesamtvarianz. Bessere Fruchtbarkeitsresultate wurden durchgehend in Laufställen gefunden. Die Rastzeit (67,8 vs. 71,0 Tage), die Güstzeit (86,3 vs. 96,0 Tage) und die Zwischenkalbezeit (378,7 vs. 386,7 Tage) waren kürzer. Auch die Non-return Rate 90 (66 vs. 61 %) und die Konzeptionsrate bezogen auf die erste Besamung (52 vs. 44 %) waren höher im Vergleich zur Anbindehaltung. Kühe in der ersten Laktation hatten längere Zeitintervalle und niedrigere Befruchtungsraten als Kühe in der zweiten und dritten Laktation. In höheren Laktationen nahm die Fruchtbarkeitsleistung deutlich ab. Kühe aus der Ostschweiz hatten die erste Besamung zwar einen Tag später als Kühe in der Zentralschweiz, ansonsten waren sowohl Güst- (–0,9 Tage) und Zwischenkalbezeit (–0,8 Tage) als auch Non-return Rate 90 (+3 %) und Konzeptionsrate (+4 %) besser. Non-return Rate 90 und Konzeptionsrate waren für Besamungen von April bis Juni (67 % bzw. 52 %) am höchsten. Am geringsten war die Konzeptionsrate von Januar bis März (48 %) und die Non-return Rate 90 von Oktober bis Dezember (60 %).

Schlüsselwörter: Schweizer Braunvieh, Fruchtbarkeitsmerkmale, Haltungssystem, Anbindestall, Laufstall

Introduction

Deterioration in fertility of dairy cows has become a main problem in present milk production. In Swiss Brown cattle, the interval from calving to successful insemination rose from 108 days in 1984/85 up to 119 days in 2001/02 (SBZV, 2002). Culling due to low female fertility represents even about 25 % of all cullings in Swiss dairy production (AEBERHARD et al., 1997; STAERK et al., 1997). The economic losses due to poor fertility are costs of a prolonged calving interval, increased insemination costs, a reduced number of calves born, and replacement (ESSLEMONT et al., 2001). The most important culling reasons within the reproduction-complex are failure to conceive, absent or unobservable cycle, and embryonic loss (SCHNYDER and STRICKER, 2002). Fertility is not a single, it is a complex trait, that can be distinguished in two categories. On the one hand, there are fertility relevant time intervals like days to first service, days open, and calving interval. On the other hand, there are traits that correspond to fertilisation success, basically insemination index, conception rate, and non-return rate (PRYCE et al., 2000).

FOURICHON et al. (2000) and DISTL (2001) differentiated the effects influencing the reproductive performance in cow characteristics, climate and environment, herd characteristics, and herd management. An independent treatment of single factors is however not reasonable, because between the factors there are many interactions. The oestrus detection has, for example, major impact on the interval from calving to first service, and the milk yield is strongly affected by the feeding management, the lactation number, and the genetic merit (DISTL et al., 1998). The evaluation of the reproductive performance should therefore always be carried out by considering all possible influencing factors.

Especially time intervals largely underlie the farmer's reproduction management, i.e. the decision of the time of first insemination after calving and the efficiency of heat detection (BOICHARD and MANFREDI, 1994). In contrast, fertilisation success measures are less affected by farmer decisions, since success of an insemination is always desired.

The aim of this study was to analyse systematic effects on fertility traits of Swiss Brown cows in typical dairy production systems in Switzerland. Days to first service (DFS), days open (DO), and calving interval (CI) were investigated, representing continuously distributed traits. Non-return rate 90 (NRR90) and conception rate to first service (CRFS) corresponded to insemination success and were treated as binary distributed traits.

Material and Methods

Study design

The data was provided by the Swiss Brown Cattle Breeders' Association. The farm location was limited to 15 cantons in Eastern (mainly St. Gallen, Thurgau, Zurich, and Appenzell) and Central Switzerland (mainly Luzern, Schwyz, Zug). In Switzerland, farms are generally classified in zones to describe site altitude, local climate, traffic circumstance, and topography (SR, 1998). For this reason, farms out of three zones (valley, middle mountain, higher mountain) were considered. Additional farm requirements were a herd size greater than 10 cows and no alpine summer-pasturing of cows to avoid misclassification. The data recording was defined on the calving period from January 1988 to May 2002. Animal performance, insemination, and calving data were analysed from a total of 82,775 Swiss Brown cows out of 1,674 farms. Information about the housing system was additionally available. Tie-stall barns (T) and loose housing systems (L) were differentiated. When a farm changed the housing system from T to L, the exact point of conversion was almost not available. The only information was the type of barn presently existent on the farm: T, L, or T and L. In the case of T and L present side by side, the time interval from only T to only L was termed 'changing period' (C). C was considered as time span for both, the farmers and the cows, to adapt to the new environment. At the end of data recording, 1,045 farms had tie-stall barns and 629 farms were equipped with cubicles. During the period of data recording, 517 farms changed housing system from T to L. The median length of C was 891 days, ranging from 1 day to 7 years. The median number of cows in farms with T was 18.5 (range: 10 – 67 animals) and 26.0 (range: 10 – 74 animals) in farms with L. The random effect of herd*year considered in the statistical models accounted for different effects of environment and management, that varied over the years and were not documented systematically.

Definitions and data preparation

Days to first service (DFS) is defined as time interval between calving and the first subsequent insemination. Days open (DO) describes the time interval between calving and successful insemination. Both traits were checked for plausibility, following the requirements from PASMAN and REINHARDT (1998). Observations with DFS and DO, resp., less than 20 or greater than 200 days were excluded from analysis. Thus, 249,141 records were analysed concerning DFS and DO.

Calving interval (CI) is the time period between two consecutive calvings. It is only available for cows that conceive and calve again. The data was limited to between 260 and 600 days to eliminate outliners that may be due to early abortion or cows kept open for flushing to produce embryos for transfer (OLORI et al., 2002). Further on, the age at first calving had to be in the interval of 20 to 42 months (PASMAN and REINHARDT, 1998). The data file for investigating CI has only 161,253 records, excluding cows of lactation number 1.

Non-return rate 90 (NRR90) and conception rate to first service (CRFS) are binary distributed traits. NRR90 characterises the percentage of animals that are not reinseminated within 90 days after the first service. CRFS is defined as the percentage of successful inseminations from all first inseminations. An insemination was considered 'successful' when a calving followed within 270 to 305 days after this insemination. All previous inseminations during the same lactation were considered infertile. Finally, 82,775 records of heifers and 166,386 records of cows were analysed.

Statistical Analysis

DFS, DO, and CI represented continuously distributed traits and were analysed separately. In a first step, an F-test was conducted to obtain an indication about the importance (level of significance, p) of the fixed effects on each of the three traits. If p for a given factor was less than 0.05, this effect was included in the statistical analysis. The following linear mixed model was used, applying to the SAS-procedure MIXED (SAS, 2002). Least-Square-Means (LSM) and Standard Errors (SE) were derived. The Bonferroni-test indicated significant differences between the levels within each effect. Estimated b–values for the covariable of the 305-day milk yield give an indication about the relationship between the fertility traits and the milk yield. For all three traits a random effect of herd*year (σ^2_{hj}) was inserted in the statistical model in order to account for effects such as farm management and yearly variation. Variance parameters (σ^2) were calculated to get an indication about the proportion of the random effect on the total variance.

Model:

$$Y_{ijklmnop} = \mu + HS_i + LNR_j + RE_k + ZO_l + SE_m + my_n + hj_o + e_{ijklmnop}$$

with

$Y_{ijklmnop}$	=	observation value for DFS, DO, and CI, resp.	
μ	=	population mean	
HS_i	=	fixed effect of housing system	(T = tie-stall barn; C = "changing period"; L = loose housing)
LNR_j	=	fixed effect of lactation number	(Lactations 1; 2; 3; 4; 5; >5)
RE_k	=	fixed effect of region	(Eastern Switzerland; Central Switzerland)
ZO_l	=	fixed effect of zone	(valley; middle mountain; higher mountain)
SE_m	=	fixed effect of calving season	(January–March; April–June; July–September; October–December)
my_n	=	covariable 305-day milk yield	(current lactation)
hj_o	=	random effect of herd*year	(9 calving years: 1988–93; 94; 95; 96; 97; 98; 99; 2000; 2001–02; 1,674 herds) (o = 1, 2, ..., 15 066)
$e_{ijklmnop}$	=	random residual error	

Associations between fixed effects and the binary distributed traits (NRR90, CRFS) were tested in two steps. First, a χ^2-test was used to derive an indication about the importance (level of significance, p) of the fixed effects for each trait. If a factor was tested significant at a level of $p < 0.05$, a combined analysis was performed, applying to GLIMMIX (LITTELL et al., 1996), a SAS macro based on PROC MIXED. The macro uses iteratively reweighed likelihoods to fit the generalised linear mixed model. The macro calls PROC MIXED iteratively until convergence, which is determined by the relative deviation of the variance estimates. The random effect of herd*year (σ^2_{hj}) was also inserted in the statistical model. A Likelihood-ratio test was performed to test the hypothesis $\sigma^2_{hj} = 0$.

The model for investigating NRR90 and CRFS of the cows was a threshold model. The same effects as in the previously described model were considered. Due to a lower number of observations in higher lactations, the highest level of lactation number was >4. Additionally, the fixed effect of days to first service was included in the investigation with 4 levels (<50, 50–63, 64–77, >77 days).

NRR90 and CRFS of the heifers was also analysed with a threshold model. Region, zone, insemination season (all fixed), and herd*year (random) were consistently considered. Additionally the fixed effect of age at first insemination was tested significant, and therefore added to the model. Six classes were composed (<18, 18–

<20, 20–<22, 22–<24, 24–<26, ≥26 months). Information about the housing of the heifers was not available. Therefore, the fixed effect of housing system was withdrawn from the model. Further on, the covariable of 305-day milk yield was excluded.

Results

Data overview

In Table 1, characteristics of the data set are presented. The number of observations (n), means ($\bar{x}$), standard deviations (sd), minima (min), and maxima (max), for different animal and fertility traits are described for cows and heifers, separately. Non-return rate 90 and conception rate to first service are displayed in percentage.

Table 1
Characteristics of the data file concerning animal and performance parameters, and fertility traits for cows and heifers, separately

		n	$\bar{x}$	sd	min	max
Cows	305-day milk yield (kg)	249,141	5,861	1,392	1,010	16,688
	Lactation number	249,141	2.7	1.6	1	7
	Days to first service	249,141	69.5	25.6	20	200
	Days open	249,141	92.9	39.5	20	200
	Calving interval	161,253	384.5	51.9	298	600
	Non-return rate 90 (%)	166,368	62.1			
	Conception rate to first service (%)	166,368	47.2			
Heifers	Age at first service (months)	82,775	22.4	3.1	13	32
	Non-return rate 90 (%)	82,775	74.9			
	Conception rate to first service (%)	82,755	60.4			

Days to first service, days open, and calving interval

In Table 2, p-values (*p*), Least-Square-Means (LSM), and Standard Errors (SE) for the fixed effects and additionally variance parameters (σ^2) for the random effects, influencing DFS, DO, and CI, are presented. All single factors were approved to be significant at a level of $p < 0.01$. Two-way interactions were also included, but did not show any significant effects.

The random effect of herd*year accounted for 12.7 % of the total variance for days to first service (DFS). Concerning days open (DO), herd*year accounted for 5.8 % on total variance, and for calving interval (CI) herd*year explained 5.2 % of the total variance. The covariable 305-day milk yield of present lactation was also significant at a level of $p < 0.001$. The b-values of 0.003 and 0.007, resp., show the amount of the fertility traits with increasing milk yield.

The influence of housing system on the three analysed fertility relevant time intervals was similar, indicating that shortest intervals were realised in loose housing systems. Intervals were 3.2, 9.7, and 8.0 days shorter for DFS, DO, and CI, respectively, compared to tie-stall barns. During the changing period, all intervals lay in-between tie-stall barns and loose housing systems.

Table 2
Least-Square-Means (LSM) and Standard Errors (SE) for fixed effects and variance components (σ^2) of random effects on the fertility relevant time intervals days to first service (DFS), days open (DO), and calving interval (CI). The fixed effects and the covariable were significant at a level of $p < 0.01$. Different letters symbolise significant differences between classes ($p = 0.05$)

Influencing factors	Levels	Days to first service (DFS)[1)] LSM		Days to first service (DFS)[1)] SE	Days open (DO)[1)] LSM		Days open (DO)[1)] SE	Calving interval (CI)[2)] LSM		Calving interval (CI)[2)] SE
Housing system	Tie-stall barn (T)	71.0	c	0.12	96.0	c	0.15	386.7	b	0.20
	Changing period (C)	68.9	b	0.26	88.1	b	0.34	379.0	a	0.41
	Loose housing (L)	67.8	a	0.26	86.3	a	0.33	378.7	a	0.45
Lactation number	Lactation 1	72.6	a	0.17	94.1	a	0.23	388.4	a	0.28
	Lactation 2	69.5	b	0.17	89.5	c	0.23	381.9	b	0.30
	Lactation 3	68.6	c	0.18	88.5	d	0.25	379.9	c	0.33
	Lactation 4	68.2	d	0.20	88.3	d	0.28	378.6	d	0.38
	Lactation 5	68.2	d	0.23	89.4	c	0.33	380.0	c	0.47
	Lactation >5	68.3	d	0.22	91.1	b	0.31	380.1	c	0.51
Region	Eastern Switzerland	69.7	a	0.17	89.7	b	0.22	381.1	b	0.28
	Central Switzerland	68.8	b	0.18	90.6	a	0.23	381.9	a	0.29
Zone	Valley	67.4	b	0.14	89.4	b	0.18	380.8	b	0.23
	Middle mountain	70.3	a	0.23	91.1	a	0.29	382.4	a	0.36
	Higher mountain	69.9	a	0.26	90.0	b	0.33	381.2	b	0.41
Calving season	January – March	70.6	a	0.18	90.8	b	0.23	387.1	b	0.31
	April – June	70.6	a	0.19	93.1	a	0.27	393.3	a	0.34
	July – September	67.7	b	0.17	88.3	c	0.23	372.4	d	0.31
	October – December	68.0	b	0.17	88.3	c	0.22	373.1	c	0.29
305-day milk	b-value	0.0028			0.0068			0.0068		
Herd*year	σ^2 hj	0.83			0.92			0.96		
	σ^2 residual	5.69			15.0			17.4		

1) N = 249,141 2) N = 161,253

The longest intervals for all three traits were observed consistently in primiparous cows. The intervals declined to the cows in fourth lactation, and then increased slightly to the cows in higher than fifth lactation. Animals in Central Switzerland had the first service one day earlier, but both, DO and CI, were one day more in comparison with Eastern Switzerland. The analysis indicated that cows in middle mountain had the longest intervals for all three traits. Concerning DO and CI, valley and higher mountain did not show any difference.
Obvious tendencies were investigated for the effect of calving season on fertility. Longest intervals were consistently recognised in season April to June. January to March-season was only marginally better. Shorter intervals by far were observed in cows calving in the second half of the year. The differences between best and worst calving season accounted for 2.9 (DFS), 4.8 (DO), and 20.9 days (CI), respectively.

Non-return rate 90, conception rate to first service
Table 3 illustrates p-values, LSM and 95 % confidence limits for NRR90 and CRFS in cows. Variance components (σ^2) for the random effects are additionally presented.

Table 3
Retransformed Least-Square-Means (LSM) and Confidence limits (CL_L, CL_U) for fixed effects, estimated b–values of the covariable, and variance components (σ^2) of the random effects concerning non-return rate 90 (NRR90) and conception rate to first service (CRFS) of cows. The fixed effects and the covariable were significant at a level of $p < 0.05$.

Influencing Factors	Levels	Non-return rate 90 (NRR90)[1)] LSM	Non-return rate 90 (NRR90)[1)] CL_L– CL_U[2)]	Conception rate to first service (CRFS)[1)] LSM	Conception rate to first service (CRFS)[1)] CL_L– CL_U[2)]
Housing system	Tie-stall barn (T)	0.61	0.60–0.61	0.44	0.43–0.46
	Changing period (C)	0.67	0.65–0.68	0.55	0.53–0.57
	Loose housing (L)	0.66	0.65–0.68	0.52	0.51–0.54
Lactation number	Lactation 1	0.59	0.58–0.60	0.47	0.46–0.48
	Lactation 2	0.64	0.63–0.65	0.52	0.51–0.53
	Lactation 3	0.66	0.65–0.67	0.54	0.52–0.55
	Lactation 4	0.67	0.65–0.68	0.53	0.51–0.54
	Lactation >4	0.67	0.66–0.68	0.46	0.45–0.48
Region	Eastern Switzerland	0.66	0.65–0.67	0.52	0.51–0.53
	Central Switzerland	0.63	0.62–0.64	0.48	0.47–0.49
Zone	Valley	0.64	0.63–0.65	0.50	0.49–0.51
	Middle mountain	0.65	0.64–0.66	0.50	0.49–0.52
	Higher mountain	0.65	0.63–0.66	0.51	0.49–0.52
Insemination season	January – March	0.63	0.62–0.64	0.48	0.47–0.50
	April – June	0.67	0.66–0.68	0.52	0.51–0.53
	July – September	0.62	0.61–0.64	0.51	0.49–0.52
	October – December	0.60	0.58–0.61	0.50	0.49–0.51
Days to first service	< 50 days	0.53	0.51–0.54	0.38	0.36–0.39
	50 – 63 days	0.64	0.63–0.65	0.51	0.50–0.52
	64 – 77 days	0.69	0.67–0.70	0.55	0.54–0.57
	> 77 days	0.72	0.71–0.73	0.57	0.56–0.58
305-d milk yield	b–values	–0.00027		–0.00031	
Herd*year	σ^2 hj	0.109		0.136	
	σ^2 residual	0.975		0.972	

1) N = 166,368 2) CL_L, CL_U: lower, upper confidence limit, p = 0.05

The random effect of herd*year explained about 10.1 % of the total variance in NRR90 and about 12.3 % of the total variance in CRFS.

Both, NRR90 and CRFS were highest within the changing period (0.67 and 0.55) and slightly lower in loose housing (0.66 and 0.52). In tie-stall barns, NRR90 and CRFS were significantly lower (0.61 and 0.44).

Concerning lactation number, NRR90 and CRFS had varying trends: NRR90 increased continuously from lactation number 1 (0.59) until lactation greater than 4 (0.67). In contrast, CRFS increased to the maximum in the third lactation (0.54) and declined to the lowest level in lactation number > 4 (0.46).

In Eastern Switzerland, NRR90 was 3 % and CRFS was 4 % higher compared to Central Switzerland. Regarding the zones, NRR90 and FSCR varied only marginally.

Obvious differences were identified between the insemination seasons. NRR90 was highest for inseminations from April to June (0.67), approximately 5 % higher compared to other seasons. CRFS differed in a range of 4 %, with best values for cows inseminated in spring (0.52) and summer (0.51).

A major impact on NRR90 and CRFS was analysed for the effect of days to first service. When the first insemination was practised until day 50 of the current lactation, the fertility results were lowest by far. NRR90 and CRFS were 11 and 13 %, resp., higher if the cows were inseminated in the interval from 50–63 days. The best NRR90 and CRFS were realised when the inseminations were terminated later than 77 days post partum.

In Table 4, LSM and confidence limits of NRR90 and CRFS as well as variance components for the random effects are displayed for the heifers.

Table 4
Retransformed Least-Square-Means (LSM) and Confidence limits (CL_L, CL_U) for the fixed effects and variance components (σ^2) of the random effects concerning non-return rate 90 (NRR90) and conception rate to first service (CRFS) of heifers. The fixed effects were significant at a level of $p < 0.05$

Influencing Factors		Non-return rate 90 (NRR90)[1]		Conception rate to first service (CRFS)[1]	
	Levels	LSM	CL_L– CL_U[2]	LSM	CL_L– CL_U[2]
Region	Eastern Switzerland	0.80	0.78–0.81	0.61	0.60–0.61
	Central Switzerland	0.79	0.78–0.80	0.59	0.58–0.59
Zone	Valley	0.79	0.78–0.80	0.61	0.60–0.61
	Middle mountain	0.80	0.79–0.81	0.59	0.59–0.60
	Higher mountain	0.79	0.78–0.80	0.59	0.58–0.60
Insemination season	January – March	0.76	0.75–0.77	0.61	0.60–0.61
	April – June	0.82	0.81–0.84	0.59	0.59–0.60
	July – September	0.81	0.80–0.83	0.60	0.59–0.61
	October – December	0.72	0.71–0.74	0.59	0.58–0.60
Age at first service	< 18 months	0.87	0.85–0.88	0.57	0.56–0.58
	18 –< 20 months	0.84	0.82–0.85	0.58	0.57–0.59
	20 –< 22 months	0.81	0.80–0.82	0.59	0.58–0.60
	22 –< 24 months	0.75	0.74–0.76	0.60	0.59–0.61
	24 –< 26 months	0.70	0.69–0.72	0.62	0.61–0.63
	≥ 26 months	0.64	0.62–0.65	0.61	0.60–0.63
Herd*year	σ^2 hj	0.192		0.064	
	σ^2 residual	0.944		0.984	

[1]N = 82,775 [2]CL_L, CL_U: lower, upper confidence limit, p = 0.05

The random effect of herd*year explained 16.9 % of the total variance in NRR90 and only 6.1 % of the total variance in CRFS.

The differences between regions and zones in NRR90 and CRFS were only marginal.

NRR90 was highest if heifers were inseminated from April to June (0.82), and from July to September (0.81). Lowest NRR90 was observed in the service season October to December (0.72). CRFS ranged between 59 % (April–June; October–December) and 61 % (January–March).

The age at first service significantly influenced both, NRR90 and CRFS, but in different ways: Highest NRR90 was identified in very young heifers (0.87), declining stepwise until the group of the oldest heifers (0.64). In contrast, CRFS slightly increased with age at first service.

Discussion

There are many parameters to describe the reproductive performance of dairy cows. Time intervals on the one hand and measures referring to insemination success on the other hand were commonly used for quantifying the fertility situation of dairy cows. Moreover, interrelations between animal factors and management tools are frequently observed, for example the farmer’s decision in the age at first service or the voluntary waiting period after calving. FOURICHON et al. (2000) defined 4 complexes (climate and environment, herd management, herd characteristics, and cow characteristics) that basically summarised the single effects.

The main topic of this study was to compare the influence of tie-stall barns versus loose housing systems on fertility in Swiss Brown cows. Several single factors, such as exercise and space, animal contact, lighting conditions, hygiene etc. influence cow fertility. In the present study, housing system was taken as superior term representing these numerous single factors due to missing information. For all three time intervals (DFS, DO, and CI) as well as for NRR90 and CRFS, better results were found for cows in loose housing systems compared to animals in tie-stall barns. DÜRING (1987) investigated a high significant effect of the housing system on different fertility parameters. In agreement, better fertility results were found for loose-housed cows. The difference between tie-stall barns and cubicles in days open was 15.6 days and in calving interval 6.0 days. The predominance of the free stall became approved by the investigation of VALDE et al. (1997). They found a significant better fertility status index, generated out of non-return rate, insemination index and days open, for cows in cubicles. The authors explained that oestrus detection was much easier in free stalls. In the study of RATNAYAKE et al. (1998), days to first service and days open were 3.3 and 11.2 days, resp., shorter for cows housed in loose barns. Distinct oestrus symptoms and therefore a better date of artificial insemination explained this fact. In addition, the authors suggested that daily exercise after calving had a positive effect on oestrus cycle, what led to an earlier insemination. This assumption was confirmed by REHN et al. (2000), who mentioned a positive effect of exercise and animal contact on the reproduction performance. They calculated that the interval from calving to successful insemination was 13 days shorter for loose-housed cows. It becomes apparent that due to exercise and better animal contact, oestrus symptoms can be detected more precise in loose housing systems, and therefore the reproductive performance was better.

Sexual maturity is determined by the genetic disposition associated with the feeding regime of the farmer. In the present study, the age at first calving had strong impact on NRR90. JANSON (1980) indicated that within heifers, the age had no significant effect on fertility. Only if heifers were inseminated so early in life that some of them had not reached sexual maturity, fertility was lower (PLATEN et al., 1999). This is in accordance with the results of HYPPÄNEN and JUGA (1997), who detected highest non-return rates in heifers between 20 and 30 months at first service. Younger heifers less than 20 months showed 4 % lower non-return rates. In this study, the heifers had obviously reached sexual maturity, proved by NRR90 highest in young heifers < 18 months. According to this, DÜRING (1987) found a tendency towards better subsequent fertility results when the age at first calving was lower. The author suggested that increasing adiposis of reproduction organs might explain the decrease in fertility with inclining age.

The 305-day milk yield was significant on all fertility traits at a level of $p < 0.001$. With increasing milk yield, fertility results declined. Numerous studies also indicated an antagonistic relationship between higher milk yield and reproductive performance (NEBEL and McGILLIARD, 1993; SEELAND and HENZE, 2003). FAUST et al. (1988) derived that each 1000 kg increase in FCM resulted in markedly decreased fertility results. There were 2.1 to 2.7 more days to first service, 7.5 to 8.5 % lower CRFS, and 0.25 more inseminations per conception. NEBEL and McGILLIARD (1993) reported that selection for milk yield has increased blood concentrations of somatotropin and prolactin, stimulators of lactation, and decreased insulin, a hormone that is antagonistic to lactation and may be important for normal follicular development. These changes in hormone concentrations promote higher milk yield but may be potentially detrimental to other physiological functions, such as reproduction. A management factor strongly associated with milk yield is feeding and energy supply of dairy cows in the postpartum, or rather service period. The level of negative energy balance alters hypothalamic secretion of GnRH and its effect on gonadotropin secretion, and therefore, ovarian secretion of progesterone. Progesterone on his part affects oestrus expression and supports the uterus during early pregnancy.

The lactation number is of special interest concerning fertility results. Basically, fertility intervals and rates were worse in primiparous cows. This observation is in accordance with other studies, reporting lower fertility observed in first parity compared with second and third parity cows (LUCY et al., 1992; HYPPÄNEN and JUGA, 1997). LUCY et al. (1992) confirmed that lower energy balance in first lactation cows was associated with delayed intervals to first ovulation. ROCHE et al. (2000) pointed out that the nutritional management of cows in the periparturient and the early postpartum period is a main factor contributing to a high reproductive efficiency. In this study, NRR90 was at a constant level regarding rising lactation number, whereas CRFS declined. In a large sample of Holstein cows in France, BOICHARD and MANFREDI (1994) evaluated a continuous decline in CRFS from 54 % in first to 38 % in seventh lactation. They suggested a true age effect and a selection of cows on production as reasons for this trend. MARTI and FUNK (1994) suggested that older cows had more DO because of more reproductive diseases and stress associated with high yield. It becomes quite evident that today’s high yielding dairy cows must be fed adapted optimally to their age, to their production level, and to their body condition, both in pre- and in postpartum period.

The herd*year effect, representing the overall reproductive management program on each farm, was considered as a main factor influencing fertility (EVERETT and BEAN, 1986). In their analysis, conception rate differed by ± 8.3 % from herd to herd. NEBEL and McGILLIARD (1993) concluded that two daily management decisions had the most impact on an efficient reproductive performance, heat detection on the one, and voluntary waiting period until insemination on the other hand. Heat detection routines have been considered to be the major management procedure affecting fertility relevant interval parameters. Insemination management, i.e. decision of insemination yes/no, and subsequent insemination supports good fertility. Many studies have dealt with this first point, mainly expressed by the variable ‘days to first service’. The present investigation pointed out a strong relationship between DFS and NRR90 and CRFS, resp., indicated by inclining values with DFS. After BOICHARD and MANFREDI (1994) conception rate to first service is mainly influenced by the

calving-insemination interval. Conception rate to first service was very low just after calving, arising rapidly to 60–70 days p.p. This level was stable up to 100 days p.p. and further on, gradually declining. The authors confirmed that less fertile cows, either high yielding or having short and silence oestrus, were inseminated later. Non-return rates were also strongly affected by calving-insemination interval (HYPPÄNEN and JUGA, 1997). There was a linear influence with non-return rate increasing when interval lengthened. COLEMAN et al. (1985) found that days open was least in high-producing herds. Days to first service increased with production of the individual cow. The authors assumed that herd managers intentionally delayed first service of high-producing cows. MARTI and FUNK (1994) discussed producers' intentional delays in breeding the high producing cow.
Besides management, there are several natural factors contributing to 'environment'. The influence of regions or zones on fertility traits was controversially discussed in previous studies. JANSON (1980) suggested that it is difficult to compare fertility parameters between different geographical locations due to varying seasonal risk factors. Besides the level of nutrition and exercise, photoperiodism and temperature were the main factors responsible for seasonal variation in fertility. Increasing daylight seemed to have a stimulating effect on conception, indicated by shortest fertility relevant time intervals for calving in the summer months. Similar results were evaluated by BOICHARD and MANFREDI (1994). NRR90 was best in the insemination period April–June and worst in October–December. HYPPÄNEN and JUGA (1997) also found best non-return rates during the pasture period. Results were decreased in autumn and poorest during winter and spring months. REURINK et al. (1990) analysed lowest NRR in the winter season (November–February) and highest in late spring season (May–June). COLEMAN et al. (1985) observed that cows calving in spring had first oestrus nine days later than cows in other seasons. During warmer summer months, cyclic reproductive activity was reduced. EVERETT and BEAN (1986) found highest conception rate in June (53.8 %), and lowest rates in January (51.6 %) and the summer months (July, 51.6%, August, 50.1 %, September, 51.9 %). The authors supposed that both, high and low temperatures, had negative effect on reproductive performance. FAUST et al. (1988) observed in primiparous Holsteins a wide variation in fertility traits across months. The interval from parturition to first insemination was shortest in February (72.4 days) and longest in May and June (81.2 days each). First service conception rate was highest and number of services was lowest in calving December (56.7 %, 1.80 services). Possible reasons in that study were heat stress during summer and the shortage of labour and time of the producers.

Acknowledgement

The authors thank the Swiss Brown Cattle Breeders' Association for providing the data and the Swiss Research Station for Agricultural Economics and Engineering of Tänikon for the financial support.

References

AEBERHARD, K.; BRUCKMAIER, R.; BLUM, J.:
Hochleistungskühe in der Schweiz. Schweiz. Agrarforschung **4** (1997), 277–280
BOICHARD, D.; MANFREDI, E.:
Genetic analysis of conception rate in the French Holstein cattle. Acta Agric. Scand. **44** (1994), 138–145

COLEMAN, D. A.; THAYNE, W. V.; DAILEY, R. A.:
Factors affecting reproductive performance in dairy cows. J. Dairy Sci. **68** (1985), 1793–1803
DISTL, O.; STENSKE, M.; SEELAND, G.:
Schätzung von Kreuzungsparametern für Fruchtbarkeitsmerkmale beim Milchrind. Arch. Tierz., Dummerstorf **41** (1998), 5–13
DISTL, O.:
Die Bedeutung von Gesundheitsmerkmalen in der Zucht von Milchrindern. Arch. Tierz., Dummerstorf **44** (2001), 365–380
DÜRING, F.:
Untersuchungen zur Gesundheitssituation in Schleswig-Holsteinischen Milchviehherden. Schriftenreihe des Institutes für Tierzucht und Tierhaltung der Christian-Albrechts-Universität zu Kiel, Heft **35** (1987)
ESSLEMONT, R.J.; KOSSAIBATI, M.A.; ALLCOCK, J.:
Economics of fertility in dairy cows. In: Fertility in the High–Producing Dairy Cow. M.G. DISKIN, ed. British Society of Animal Science, Occasional Publication **26** (2001), Edinburgh, Scotland
EVERETT, R. W.; BEAN, B.:
Semen fertility – An evaluation system for artificial insemination sires, technicians, herds, and systematic effects. J. Dairy Sci. **69** (1986), 1630–1641
FAUST, M. A.; McDANIEL, B. T.; ROBINSON, O. W.; BRITT, J. H.:
Environmental and yield effects on reproduction im primiparous Holsteins. J. Dairy Sci. **71** (1988), 3092–3099
FOURICHON, C.; SEEGERS, H.; MAHLER, X.:
Effect of disease on reproduction in the dairy cow: a meta-analysis. Theriogenology 53 (2000), 1729–1759
HYPPÄNEN, K.; JUGA, J.:
Environmental and genetic effects on the 60-day nonreturn rate in Finnish AI bulls. Interbull Bulletin, Grub, Germany, **18** (1997), 91–98
JANSON, L.:
Studies on fertility traits in Swedish dairy cattle. Acta Agric. Scand. **30** (1980), 109–124
LITTELL, R. C.; MILLEKEN, G. A.; STROUP, W. W.; WOLFINGER, R. D.:
SAS System for Mixed Models. SAS Institute Inc., Cary, NC (1996)
LUCY, M. C.; STAPLES, C. R.; THATCHER, W. W.; ERICKSON, P. S.; CLEALE, R. M.; FIRKINS, J. L.; CLARK, J. H.; MURPHY, M. R.; BRODIE, B. O.:
Influence of diet composition, dry-matter intake, milk production and energy balance on time of post-partum ovulation and fertility in dairy cows. Anim. Prod. **54** (1992), 323–331
MARTI, C. F.; FUNK, D. A.:
Relationship between production and days open at different levels of herd production. J. Dairy Sci. **77** (1994), 1682–1690
NEBEL, R. L.; McGILLIARD, M. L.:
Interactions of high milk yield and reproductive performance in dairy cows. J. Dairy Sci. **76** (1993), 3257–3268
OLORI, V.E.; MEUWISSEN, T.H.E.; VEERKAMP, R.F.:
Calving interval and survival breeding values as measure of cow fertility in a pasture-based production system with seasonal calving. J. Dairy Sci. **85** (2002), 689–696
PASMAN, E.; REINHARDT, F.:
Beschreibung der Zuchtwertschätzverfahren für Fruchtbarkeit und Abkalbemerkmale im VIT bei Schwarzbunt, Rotbunt und Rotvieh. DGfZ-Schriftenreihe, Heft **11** (1998)
PLATEN, M.; KROCKER, M.; LINDEMANN, E.; GROSS, U.:
Einfluss des Erstkalbealters auf Fruchtbarkeit und Leistung bei Milchkühen. Arch. Tierz., Dummerstorf **42** (1999), 417–429
PRYCE, J. E.; ROYAL, M. D.; GARNSWORTHY, P. C.; MAO, I. L.:
Fertility in the high producing dairy cow. 51st Annual Meeting of the EAAP, The Hague, The Netherlands (2000)
RATNAYAKE, D. R. T. G.; BERGLUND, B.; BERTILSSON, J.; FORSBERG, M.; GUSTAFSSON, H.:
Fertility in dairy cows managed for calving intervals of 12, 15 and 18 months. Acta Vet. Scand. **39** (1998), 215–228
REHN, H.; BERGLUND, B.; PHILIPSSON, J.; EMANUELSON, U.; TENGROTH, G.:
Breed and management interaction for production and reproduction in Swedish dairy cows. Acta Agric. Scand. **50** (2000), 137–145
REURINK, A.; DEN DAAS, J. H. G.; WILMINK, J. B. M.:
Effects of AI sires and technicians on non-return rates in the Netherlands. Livest. Prod. Sci. **26** (1990), 107–118
ROCHE, J. F.; MACKEY, D.; DISKIN, M. D.:

Reproductive management of postpartum cows. Anim. Reprod. Sci. **60–61** (2000), 703–712

SAS:
SAS/STAT User's Guide, Version 8, first edition, Cary, NC, USA (2002)

SBZV:
Swiss Brown Cattle Breeders' Association, Annual Report 2002.

SCHNYDER, U.; STRICKER, C.:
Genetic evaluation for female fertility in Switzerland. Proceedings of the 2002 Interbull Meeting in Interlaken, Switzerland, May 26-27, Bulletin **29** (2002), 138–141

SEELAND, G.; HENZE, C.:
Beziehungen zwischen Milchleistung und Fruchtbarkeit in einer Schwarzbuntpopulation nach intensiver Steigerung der Milchleistung. Arch. Tierz., Dummerstorf **46** (2003), 103–112

SR:
Verordnung über die landwirtschaftlichen Produktionskataster und die Ausscheidung von Zonen. http://www.admin.ch/ch/d/sr/c912_1.html (1998)

STAERK, K.; FREI-STAEHELI, C.; FREI, P.; PFEIFFER, D.; DANUSER, J.; AUDIGE, L.; NICOLET, J.; STRASSER, M.; GOTTSCHEIN, B.; KIHM, U.:
Incidence and costs of health problems in Swiss dairy cattle and their calves [1993-1994]. Schweiz. Arch. Tierheilk. **139** (1997), 343–352

VALDE, J. P.; HIRD, D. W.; THURMOND, M. C.; ØSTERÅS, O.:
Comparison of ketosis, clinical mastitis, somatic cell count, and reproductive performance between free stall and tie-stall barns in Norwegian dairy herds with automatic feeding. Acta Vet. Scand. **38** (1997), 181–192

Received: 2004-09-01

Accepted: 2004-09-27

Author's address
JAN CHRISTOF BIELFELDT, Dr. KARL-HEINZ TÖLLE , Prof. Dr. JOACHIM KRIETER
Institut für Tierzucht und Tierhaltung der Christian-Albrechts-Universität zu Kiel
Olshausenstr. 40
D-24098 Kiel
Germany

Dr. RUTH BADERTSCHER
Eidgenössische Forschungsanstalt für Agrarwirtschaft und Landtechnik
Tänikon
CH-8356 Ettenhausen
Switzerland