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Association of Some Physiological Factors and Milk Performance in Chinese Holstein

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ABSTRACT

In an effort to determine the effect of physiological factors on milk production, a total of 13889 lactation records for 10544 Chinese Holstein cows from 2005-2011 year were collected for association analysis. Physiological information included age at first calving (AFC), milk peak day (MPD), calving interval (CI), calving season (CS) and parity (P). After the statistical comparison, it was concluded that all factors can significantly affect the level of 305-d milk production ($p<0.05$) with the exception of age at first calving. In addition, our data suggested that the 2nd and 3rd parity, calving in winter, reaching the milk peak at 60-80 day postpartum, calving for the first time at the age of 24-27 month and a 360-390 day calving interval are optimum for best milk performance in dairy cattle.

Key words: Physiological factor, calving interval, milk production, cow

INTRODUCTION

As the most important economic trait for dairy cattle, milk production was of great concern in years. Researchers have paid much attention to the relationship between milk production and various factors. Generally, high milk production depends on the breed of cow (Cole and Null, 2009) and genetic factors primarily. Currently, numerous researchers have conducted studies on genetic evaluation for milk production traits (Nicolazzi *et al*., 2011; Hammami *et al*., 2008; Szyda *et al*., 2005). The impact of management, especially nutritional regulation is also significant in affecting milk performance. Cows must be fed appropriately to produce high yields. So far, there have been several nutritional models, e.g., CNCPS (cornell net carbohydrate and protein system for cattle) (Fox *et al*., 1992; Russell *et al*., 1992) and DVE/OEB system (the Dutch protein evaluation system) (Tamminga *et al*., 1994; NRC, 2001), to calculate dairy nutrient requirement for specific performance criteria.

Production performance of dairy cows is also affected by some other factors including reproduction, body condition and environment and so on. Among these factors, good physiological condition is very important to improve lifetime productivity. Investigating physiological factors influencing milk performance may be helpful in determining areas of improvement in milk yield by regulating the relevant factors in practice. Nilforooshan and Edriss (2004) estimated the effect of age at first calving on productive life in Iranian Holsteins and concluded that reduction of age at first calving to 24 month of age could be an effective management practice. Moreover, there were still some other studies referring to the impact of disease (Green *et al*., 2002; Fleischer *et al*., 2001), calving ease (Eaglen *et al*., 2011) and herd management (Bach *et al*., 2008; Srairi *et al*., 2009) on milk performance.

The dairy herd improvement program (DHI) is a valuable tool that helps to evaluate the progress of herd's milk production. DHI can be defined as a complete recording system for dairy production performance, including cattle pedigree, birth and calving records, daily milk yield, constituent and similar parameters (Schmidt and Smith, 1986). Dairy farmers can keep close examination of herd performance and determine whether veterinary, breeding or nutrient attention is required in order to increase economic return associated with production testing records (McCaffree *et al*., 1974; Schmidt and Smith, 1986). Taking into account the difference in genetic background and management systems involved, the aim of the current study was to investigate some physiological factors affecting milk performance and their effects on 305 days milk yield in Chinese Holstein cows, to serve as baseline information for the improvement of dairy herd management.

MATERIALS AND METHODS

Data collection: A total of 13889 lactation records from 10544 Holstein dairy cows belonging to 48 dairy herds from 2005-2011 year were collected from Dairy Cattle Center, Shandong Academy of Agricultural Sciences and Shandong OX Biotech Co. Ltd. All cows were from DHI herds in Shandong Province, China. The collected data included age at first calving, milk peak day, calving interval, parity, calving season and milk yield. The records that matched the following criteria were retained: Age at first calving between 20 and 43 month (mo), milk peak day between 15 and 200 days, calving interval between 240 and 700 days, yield (305 days) of milk between 1000 and 18000 kg.

Classification of records: All records were classified into several groups based on the following factors: Age at First Calving (AFC), Milk Peak Day (MPD), Calving Interval (CI), Calving Season (CS) and Parity (P). Each parameter was classified as shown in Table 1.

Statistical analysis: Statistical analysis was undertaken by Least Square Mean (LSMs) of SAS statistical package version 8.2. Least Square model was applied to 305 days milk yield:

$$y_{ijklmno} = \mu + H_i + AFC_j + MPD_k + CI_l + CS_m + P_n + e_{ijklmno}$$

where, $y_{ijklmno}$ is the observation; μ is overall mean; H_i is fixed effect of ith herd; AFC_j is treatment effect of jth level of age at first calving (AFC); MPD_k is treatment effect of kth level of Milk Peak Day (MPD); CI_l is treatment effect of lth level of Calving Interval (CI); CSm is treatment effect of

Table 1: Data classifications

Parameter	Classifications					
P	1	2	3	4	5	≥6
CS	Spring	Summer	Autumn	Winter		
MPD (days)	15-40	41-60	61-80	81-100	101-200	
CI (days)	240-360	361-390	391-420	421-450	451-480	481-700
AFC (months)	20-25	25-28	28-31	31-34	34-37	37-43

P: Parity, CS: Calving season, MPD: Milk peak day, CI: Calving interval, AFC: Age at first calving mth level of Calving Season (CS); P_n is treatment effect of nth level of parity (P); $e_{ijklmno}$ is random error term. A value of $p<0.05$ was regarded as significant.

RESULTS AND DISCUSSION

The result of least square analysis and significance test suggested that, all factors can affect milk yield significantly ($p<0.05$) except for AFC. Table 2 showed the results of variance analysis by GLM procedure.

There was a tendency for 305 days milk yield to increase firstly and then decrease with advancing parity (Table 3). Cows at the 2nd and 3rd parity produced higher yields (6818.3 and 6688.4 kg on average, respectively) than other parity groups.

As can be seen from Table 4, cows calving in winter produced highest 305 days milk yields (6855.2 kg on average), yet lowest in summer (5741.1 kg on average).

Results in Table 5 revealed that cows reaching their peak milk production 60 to 100 days after calving produced highest yields.

Table 2: Effects of different factors on 305 days milk yield

Factors	df	Type III sum of squares	Mean square	F-value	Pr>F
Parity	5	1003326072	200665214	46.87	<0.0001
Calving season	3	2175187364	725062455	169.36	<0.0001
Milk peak day	4	1919794506	479948626	112.11	<0.0001
Calving interval	5	300175001	60035000	13.08	<0.0001
Age at first calving	5	22134758	4426952	1.45	0.2020

Table 3: Multiple comparison of least square means of 305 days milk yield among cows at different parity

Parity	No. of records	305 days milk yield LSM (kg)
1	4275	6454.8^b
2	3957	6818.3^a
3	2753	6688.4^a
4	1657	6400.9^b
5	755	5845.9^c
≥6	492	5801.2^c

Means in the same column with different lowercase differ significantly ($p<0.05$), LSM: least square means

Table 4: Multiple comparison of least square means of 305 days milk yield among cows in different calving season

Calving season	No. of records	305 days milk yield LSM (kg)
Spring	2437	6449.0^b
Summer	3563	5741.1^d
Autumn	3990	6294.3^c
Winter	3899	6855.2^a

Means in the same column with different lowercase differ significantly ($p<0.05$)

Table 5: Multiple comparison of least square means of 305 days milk yield among cows with different milk peak day

Milk peak day (day)	No. of records	305 days milk yield LSM (kg)
15-40	5810	5717.1^d
41-60	2534	6250.1^c
61-80	1887	6573.0^a
81-100	1222	6694.6^a
101-200	2436	6439.8^b

Means in the same column with different lowercase differ significantly ($p<0.05$)

Table 6: Multiple comparison of least square means of 305 days milk yield among cows with different calving interval

Calving interval (day)	No. of records	305 days milk yield LSM (kg)
240-360	2423	5997.5[b]
361-390	1731	6287.5[a]
391-420	1289	6329.4[a]
421-450	961	6461.1[a]
451-480	801	6477.1[a]
481-700	2409	6435.2[a]

Means in the same column with different lowercase differ significantly ($p<0.05$)

Table 7: Means of somatic cell count in raw milk by parity and testing year

	Means ($\times10^3$ cells mL^{-1})					
Parity	2006	2007	2008	2009	2010	2011
1	298.57	123.13	346.52	502.05	554.70	525.62
2	436.82	152.57	426.90	573.81	621.72	659.69
3	497.05	274.08	505.66	706.58	762.48	658.79
4	607.18	347.92	590.91	678.99	899.67	764.42
5	693.15	387.51	699.55	700.89	840.03	875.91
≥6	631.13	467.73	699.53	873.74	1050.34	931.08

According to Table 6, an extension of calving interval may lead to an increase in 305 days milk yield. But no significant differences were observed among groups for cows with calving intervals of longer than 360 days.

Number of parity: The effect of parity on milk production was related to the development of mammary gland and body condition. Generally, mammary glands for heifers were not fully developed and performed imperfect secretory function, thus, milk yields were low for primiparous cows.

Cows at the 2nd and 3rd parity produced higher yields than other parity groups, which was inconsistent with the finding obtained by Cai (1998) who indicated that there was a maximum output for cows in 4-5th parity. According to the statistical results from DHI laboratory, Dairy Cattle Center, Shandong Academy of Agricultural Sciences, we learned the mean Somatic Cell Count (SCC) in raw milk from cows of different parity between 2006 and 2011 as presented in Table 7. SCC in milk increased with increasing parity. And then, increased SCC caused very high milk yield losses in the Chinese Holstein population (Guo *et al*., 2010). In addition, alfalfa, the most productive and highest quality forage species (Dennis and Bowman, 1993), was absent in more than 50% dairy farms investigated. However, diets containing alfalfa elicited great dry matter intake (DMI) and milk yield (West *et al*., 1997). Consequently, dairy cows cannot give full play to lactation potential after reaching adulthood owing to decreasing body condition for lack of high-quality alfalfa. For these reasons above, the difference between research results may be partly caused by poor nutrition supply and veterinary attention for cows investigated. Therefore, mastitis prevention and comprehensive nutrition supply should be enhanced for cows to reach their maximum secretion potential.

Calving season: Calving season has an effect on 305 days milk production. Knight (2001) observed that lactation persistency can be improved by calving in the winter rather than in the summer. And this was in accordance with the current study. There were other studies which came to similar conclusions (Ye *et al*., 2011; Akcay *et al*., 2007). One of the reasons for a less quantity of 305 days milk for cows calving in summer than those in autumn and winter may be the high temperature (Ujica and Maciuc, 2000) which diminishes the cows' appetite and reduces the forage consumption during the ascendant and plateau of lactation's curve. Thus, preferring winter as calving season will be beneficial. And dairy farmers should adjust breeding date to keep cows away from calving in summer as far as possible.

Milk peak day: Milk peak day can significantly influence lactation yields. Pollott (2000) analyzed the lactation curve with day of peak yield as a model parameter, giving the evidence that MPD is important to determine cow's milk yield. In the current study, cows reaching a peak production at 60-100 days after calving may produce high 305 days milk yields. Our figures were slightly higher than those reported by Rowlands *et al*. (1982) who found that peak yields for heifers occurred on average at approximately 10 weeks post calving and 7 weeks for cows and Knight (2001) who indicated that daily milk yield increased to reach a peak at about 8 weeks postpartum. Actually, a good lactation is characterized by achieving peak yields in time and reasonable production being maintained for longer. Ferris *et al*. (1985) and Muir *et al*. (2004) found persistent lactation tend to be correlated with low peak yields and later time to peak, which indicated less severe negative energy balance (Ferris *et al*., 1985). Thus, milk peak duration may be the key to the total lactation milk production. It could be speculated that cows with early MPD (<40 day) may not reach due peak because of inadequate energy reserves during perinatal period, poor body condition and some other reasons. For cows with MPD delay, the peak yields may be of shortened duration. In view of the significance of peak yields and durability on the whole lactation milk yield, we concluded that the regulation of MPD in 60-80 days postpartum could be an effective management practice.

Calving interval: Calving interval is a critical factor affecting milk production traits. Nieuwhof *et al*. (1989) examined calving intervals ranging from 393 days following second parity to 405 days following sixth for Holsteins in the United States from 1966 to 1986.

In the present study, cows calving within 360 day interval produced low milk yields, which was similar to the results from previous studies that pregnancy soon after calving may decrease persistency (Dobson *et al*., 2007). Arbel *et al*. (2001) found in their study that an extension of 60 days open contributed to increase of economic profit in high-yielding cows. Calving interval depends on time of insemination and pregnancy rates per insemination primarily. There is evidence showing that pregnancy rates per insemination in later lactation are equivalent or better than those soon after calving. And that, the economic value of persistency almost triples when calving interval increases from 12 to 13 months (Dekkers *et al*., 1998). Therefore, calving interval should be kept beyond 360 days. However, lactation potential can remain for 10 months after delivery for most cows with milk yield being reduced substantially after that. Thus, the extension of non-pregnancy may increase the cost of management and breeding. Allowing for lifetime productivity, calving interval should be kept within 390 days.

Age at first calving: Milk production for primiparous cows was unaffected by AFC (Table 8). Similarly, there is evidence in the literature indicating that AFC has little correlation with milk production during the first lactation provided that age is above 22 month (Hoffman and Funk, 1992), although Losinger and Heinrichs (1996) reported a negative effect of AFC on future milk

Table 8: Multiple comparison of least square means of 305 days milk yield among cows with different age at first calving

Age at first calving (month)	No. of records	305 days milk yield LSM (kg)
20-25	1303	6451.3[a]
25-28	1593	6494.3[a]
28-31	670	6610.9[a]
31-34	321	6351.2[a]
34-37	179	6300.3[a]
37-43	209	6532.1[a]

Means in the same column with different lowercase differ significantly ($p<0.05$)

production when AFC was beyond 27 month. Nilforooshan and Edriss (2004) reported a positive effect of reducing age at first calving on milk yield and productive life, although reducing age at first calving to 21 month of age had a negative effect on yields of milk for Iranian Holsteins of the Isfahan province. These observations could agree with the report by Bach *et al*. (2008) who got a negative relationship between AFC and milk yield.

According to the examination conducted by Hare *et al*. (2006), the mean calving age for first parity was 26.9 month for Holsteins from 1980 to 2004. In the current study, there was little relationship between AFC and first-lactation yields. Generally, the effect of AFC on milk production can be interpreted from the reasons below: on the one hand, mammary gland may develop immaturely for cows calving too early in first parity (<24 month), so physical development of cows can be blocked; on the other hand, calving too late in first parity may reduce the number of calves born all life and milk yield, so as to reduce lifetime productivity. Therefore, age at first calving should be kept between 24 and 27 month referring to studies above.

CONCLUSIONS

Physiological factors are closely related with milk performance for Holsteins. Optimum parameters for age at first calving, milk peak day, calving interval, calving season and parity obtained in this study will be helpful for the improvement of milk production in dairy cows.

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