Effect of seasonal changes on fertility parameters of Holstein dairy cows in subtropical climate of Taiwan

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Objective: The purpose of this retrospective study was to investigate the relationship between temperature–humidity index (THI), season, and conception rate (CR) of Holstein cows in central Taiwan.

Methods: The mean performance and number of observations were statistically evaluated for various parameters, including age at first service, number of days open, gestation length, CR, and calving interval for different parities.

Results: The results indicate that the mean age at first service was 493.2 days; the gestation length was similar across all cows of different parities, ranging from 275.1 to 280.7 days. The overall CR of all inseminations was significantly lower in multiparous cows (47.26%±0.22%) than in heifers (57.14%±0.11%) (p<0.05). At THI>72 and during the hot season (from June to November), CRs for multiparous cows were significantly reduced compared to that for heifers, while the ratio remained unchanged among heifers for all seasons.

Conclusion: To achieve a high CR, lactating cows should be bred in winter and spring (from December to May) from the start of the seasonal breeding program, whereas the heifer should be allowed to breed in summer and fall under the subtropical climate in Taiwan.

Keywords: Calving Interval; Dairy Cow; Fertility; Temperature–humidity Index; Heat Stress

INTRODUCTION

The economic return from individual cows is represented by the integration of several performance traits besides milk production. Specific traits such as the age at first service, age at first calving (AFC), number of days open, gestation length, conception rate (CR; pregnancy per artificial insemination (AI) service), calving interval for different parities, and length of herd life are important factors contributing to economic return and are partially determined by management policies. Lactating dairy cows prefer ambient temperatures (ATs) between –5°C and 25°C, which is known as the thermoneutral zone. Above this temperature, cows can no longer adequately cool themselves and experience heat stress [1]. Milk production leads to metabolic heat production because of the metabolism of large amounts of nutrients; thus, cows with high milk productivity are more vulnerable to heat stress compared to those with lower yields [2]. Heat stress, which is caused by a combination of seasonal influences such as air temperature, relative humidity (RH), solar radiation, and wind speed, depresses milk production and reproduction performance in lactating cows [3]. Heat stress is the main environmental factor responsible for the lower fertility of cattle, especially during the summer season in many warm areas of the world [4]. This worldwide problem inflicts considerable economic losses and affects about 60% of the world’s cattle population [5]. For the US dairy industry, annual economic losses caused by heat stress alone have been estimated to be about...
The climate of central Taiwan is defined as subtropical with concentrated rainfall during the hot season. Summers in Taiwan are extremely hot and humid, with temperatures and RH often exceeding 30°C (above 85°F) and 80% from June to November. Even though the environmental conditions suggest the possibility of the presence of heat stress, there has been no assessment of the influence of heat stress on the fertility of dairy cows in central Taiwan. The knowledge of these factors will make it easy to establish corrective measures to attain better fertility. In addition, AFC plays a critical role in achieving high profitability in dairy enterprises. Rearing replacement heifers needs large financial expenditure with no returns until the animals enter the milking herd [7]. An earlier AFC can save rearing costs due to decreased feed, labor, and rearing space. A previous study showed that reducing AFC from 25 months to 24 or 21 months could reduce rearing costs by 4.3% or 18%, respectively [7]. To maximize lactation performance and to reduce rearing costs, the mean AFC in Holstein heifers is recommended to be ≤24 months of age with a body weight of <560 kg [8]. A majority of dairy producers in the United Kingdom aim to start breeding Holstein Friesian heifers from around 14 to 15 months of age, and thus, the target AFC is generally 24 months on their farms [7]. No similar investigation has been conducted in central Taiwan. Therefore, the objective of the present study was to evaluate the effects of temperature, RH, and temperature–humidity index (THI) on the reproductive performance (AFC, number of days open, gestation length, CR, and calving interval) in Holstein cows of different parities. These results will help establish a management guide for dairy cattle in a subtropical region similar to central Taiwan.

MATERIALS AND METHODS

Animal housing and management

This study was conducted at the National Chung Hsing University (NCHU) Experimental Animal Farm in Taiwan (latitude and longitude is 24° 04’ N and 120° 38’ W, respectively). The herd consisted of Holstein heifers and cows, and the herd size was maintained at less than 110 animals. Animal health care was under the veterinary supervision. The animals were housed in groups in free-stall barns with slatted floors bedded with sand and equipped with overhead fans and a sprinkler system. Access to a shaded outdoor-exercise yard was also available for all lactating cows. Throughout the experimental period (from 2001 to 2013), cows were milked and fed twice daily with a diet of total mixed ration consisting of corn silage, sweet oats, chopped alfalfa, and Bermuda grass hay, as well as concentrate, minerals, and vitamins for lactating cows (Table 1). Fresh water was provided ad libitum. The mean milk yield for the herd was 8,700 kg for 305 days of lactation. The studied lactating cows (weighing 613 kg in average) were ranged from 2 year to 11 year in age and 1 to 8 in parities. The reproductive assessments included CR, which was the ratio of the number of pregnancies per AI, and parity, which measured the number of births within the total fertility of cows over their reproductive life.

Pregnancy diagnosis

Pregnancy was confirmed using transrectal real-time ultrasonography 30 days after AI by the herd veterinarians. Pregnancy was verified by the presence of uterine fluid and an embryo with its heartbeat. The dates on which fertile insemination was performed as well as the number of inseminations per conception were recorded. Cows that were observed in estrus more than 10 days after AI were assumed as nonpregnant and re-inseminated.

Meteorological data

Three different heat load indices are related to CR: mean THI, maximum THI, and minimum THI [5]. In this retrospective study, we aimed to investigate the relationship between THI and CR of Holstein cows in central Taiwan. In total, 13-year climatic records (from 2001 to 2013) were obtained from the official meteorological stations of the Taiwan Agricultural Research Institute, Wufeng, Taichung. The monthly and daily maximum temperatures and mean AT and RH were recorded throughout the year; the AT and RH data were used to calculate THI using the following equation: THI = [(1.8×AT+32) –[(0.55–0.0055×RH)×(1.8×AT–26)] [5]. The official meteorological station is approximately 10-kilometer away from the NCHU Experimental Animal Farm. Average temperatures

| Ingredients                  | Lactating cows (kg) | Dry cows (kg) |
|------------------------------|---------------------|---------------|
| Corn                         | 470.00              | 708.00        |
| Soybean meal                 | 150.00              | 185.00        |
| Full-fat soy flour           | 80.00               | 0.00          |
| Fish meal                    | 50.00               | 0.00          |
| Bran                         | 120.00              | 50.00         |
| Calcium carbonate            | 12.00               | 11.00         |
| Dicalcium phosphate          | 4.00                | 10.00         |
| Molasses                     | 40.00               | 20.00         |
| Salt                         | 8.00                | 10.00         |
| Saponification of fat powder | 50.00               | 0.00          |
| Sodium bicarbonate           | 13.00               | 0.00          |
| Vitamins                     | 1.00                | 2.00          |
| Minerals                     | 2.00                | 4.00          |
| Total                        | 1,000.00            | 1,000.00      |

1) Vitamin premix formula: vitamin A, 16,000,000 IU; vitamin D3, 6,000,000 IU; and vitamin E, 100,000 mg. The vitamin content (vitamins A, D3, and E) was no lower than 1.5 times of the National Research Council (NRC [18]) recommended content.

2) Mineral premix formula (per kg): ferrous sulfate, 60.00 g; manganese sulfate, 50.00 g; copper sulfate, 12.50 g; sodium selenite, 0.40 g; zinc sulfate, 50.00 g; and cobalt carbonate, 0.15 g. The mineral content (Co, Cu, Fe, Mn, S, Se, Na, and Mg) was no lower than 1.2 times of the NRC [18] recommended content.

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and humidity are similar for the two locations. However, the effects of the artificial cooling system in the barn were not considered in the study.

Statistical analyses
The date, age, parity, breed of semen-donor bull, season, date of estrus, names of AI technicians, and the time and date of AI were recorded. Raw data were collated using Microsoft Excel (Microsoft Corp., Redmond, WA, USA) and were subsequently transferred to SPSS analytical software (version 11.5; SPSS, Inc., Chicago, IL, USA) for multiple logistic regressions, whereas continuous variables (calving to first service interval, calving to conception interval, THI, CR, and different parities) were evaluated using the analysis of variance (PROC general linear model from SAS). The significance of differences for continuous variables was tested using Tukey’s test (least square means statement). Results were considered to be significant at p<0.05.

RESULTS
The effects of climate changes on fertility
The dataset contained 1,321 breeding records and associated pregnancy diagnoses from 607 dairy cows. The overall CR obtained was 48.5%. Minimum, maximum, and mean ATs during the study period were 12.2°C, 32.8°C, and 24.13°C, respectively, and mean RH during the study period was 80.08% (Table 2). Minimum, maximum, and mean THIs during the study period were 61.30, 80.39, and 72.19, respectively. THI showed seasonal fluctuations with lower monthly means (from 66.44 to 70.90) during cold climate conditions (from December to May) and higher monthly means (from 74.93 to 79.75) during hot climate conditions (from June to November) as shown in Table 3. Temporal trends of the evaluated THI are shown in Figure 1. THI was significantly affected by the season, with a monthly variation ranging between 60 and 80, although it did not vary significantly over the years. Table 3 shows that CRs were significantly affected by the seasons, particularly in dairy cows. Hot seasons (from June to November) significantly reduced CRs for multiparous cows (p<0.05), while CRs in heifers remained unchanged in all seasons. As shown in Table 4, at THI of >72, CR for multiparous cows was significantly reduced compared to that for heifers (p<0.05). CRs for multiparous cows were 43.84% and 50.68% at THIs of >72 and ≤72, respectively, over the 13-year study. For a THI<72, CR was high throughout the year, with no significant differences between the months or seasons.

Effect of different parities on conception rate, days open and gestation length
The reproductive efficiency of the herd is important to the economic success of the dairy operation. Table 5 shows that the number of required AI services differed across cows of different parities, where cows in parities 6 and 7 have higher CRs than those in parities 2, 3, 4, 5, and 8 (p<0.05). The overall CR for all inseminations was significantly lower in multiparous cows (47.26%±0.22%) than that in heifers (57.14%±0.11%) (p<0.05). Table 6 shows the time elapsed for getting pregnant (days open) of Holstein cows with different parities. A larger number of days open indicate a decline in fertility of cows. At the NCHU Experimental Animal Farm, significant differences in the number of days open indicate a decline in fertility of cows. At the NCHU Experimental Animal Farm, significant differences in the number of days open were found across between parity 7 to 8 cows and parity 1 to 2, parity 3 to 4 and parity 5 to 6, parity 6 to 7 cows. Table 7 shows that the length of the gestation periods varied from 252 days to 304 days across all cows of different parities. Most of the calves were born between the

| Seasons  | Mean temperature (°C) | Mean THI |
|----------|-----------------------|----------|
| Spring (from Mar. to May) | 23.72 | 70.90 |
| Summer (from Jun. to Aug.) | 28.63 | 79.75 |
| Fall (from Sep. to Nov.) | 25.53 | 74.93 |
| Winter (from Dec. to Feb.) | 18.98 | 66.44 |

CR: conception rate (pregnancy per artificial insemination service).

Means with different superscripts in the same row differ at p<0.05.
275th and 280th days of gestation, inclusively. No significant difference regarding the gestation lengths was found across all cows of different parities.

**DISCUSSION**

In Quebec, the AFC occurs, on an average, at 27 months, whereas the target is between 23 months and 24.5 months to maximize herd profitability [9]. The data show that the mean age at the first service and AFC in Holstein heifers at the NCHU Experimental Animal Farm are 493.2 days and 813.5 days (27.1 months), which are similar to that in the United Kingdom and Quebec, respectively [7,9] (Table 7). The normal gestation period for cows is between 275 days and 280 days [10]. At the NCHU Experimental Animal Farm, the mean gestation lengths based on gestation data were 275.1 days and 277.9 days for Holstein heifers and cows, respectively. Furthermore, the gestation lengths were similar across all cows of different parities. Three cows at this farm went into early labor (parity 1, on the 252nd day, parity 2 on the 262th day, and parity 3 on the 262th day), which may have been due to heat stress or illness, judging by the observation records. CR is commonly used as a critical indicator to evaluate the reproductive efficiency of a dairy farm. Although high CRs were observed on cows in parity 6 and 7 with unknown reason, probably due to too few sample size of cows in the records, our results suggest that in general multiparous cows have lower CRs than heifers (Table 5). Multiparous cows have been reported to have lower reproductive abilities, in which their embryos may die in the early stages of pregnancy, and the implantation of embryos become more difficult after multiple pregnancies [11,12]. In addition, lower values of days open were found on cows in parity 6 and 7,

![Figure 1](https://www.ajas.info)
which supported to the results of CRs in the same parities (Table 6). A higher value of days open and the increased culling rate typically decreased the profitability of dairy herds. The studied farm had 100 pregnant heifers; 30 of them were sold and 70 were studied. The culling rate of cows was 27.14% for parity 1 to 2, 15.69% for parity 2 to 3, 34.88% for parity 3 to 4, 50% for parity 4 to 5, 42.86% for parity 5 to 6, 25% for parity 6 to 7, and 50% for parity 7 to 8. Among these cows, parity 4 to 5 and 7 to 8 had the highest culling rates. After the fourth delivery, cows were culled due to reproductive disorders (37.66%) occurred during lactation or pregnancy or due to illnesses such as mastitis (18.18%), or other health problems including lameness, milk fever, abomasum dislocation, bovine ephemeral fever, tuberculosis, or death (44.16%). Our results suggest that the reproduction-related parameters should be weighted in the culling criteria for multiparous cows above 4 parties in Taiwan.

THI is used for assessing thermal stress, and high-producing dairy cows are adversely affected when THI exceeds 72 [13,14]. In the present study, THI was significantly affected by the season, with a monthly variation ranging between 60 and 80. Taiwan has an island climate, with the sea breeze blow-

Table 5. Statistics of artificial insemination in Holstein cows with different parities

| Variables                        | Parity 1 | Parity 2 | Parity 3 | Parity 4 | Parity 5 | Parity 6 | Parity 7 | Parity 8 |
|----------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|
|                                 | P (n)    | N (n)    | P (n)    | N (n)    | P (n)    | N (n)    | P (n)    | N (n)    |
| 2001                             | 1        | 0        | 0        | 0        | 0        | 0        | 0        | 0        |
| 2002                             | 1        | 0        | 0        | 1        | 0        | 0        | 0        | 0        |
| 2003                             | 0        | 1        | 1        | 1        | 1        | 1        | 1        | 1        |
| 2004                             | 0        | 2        | 2        | 0        | 0        | 0        | 0        | 0        |
| 2005                             | 5        | 1        | 3        | 4        | 4        | 4        | 4        | 4        |
| 2006                             | 5        | 5        | 4        | 5        | 4        | 4        | 4        | 4        |
| 2007                             | 6        | 8        | 4        | 4        | 6        | 4        | 4        | 4        |
| 2008                             | 11       | 5        | 1        | 5        | 4        | 3        | 4        | 1        |
| 2009                             | 18       | 11       | 5        | 14       | 17       | 3        | 4        | 0        |
| 2010                             | 12       | 5        | 9        | 5        | 5        | 1        | 0        | 1        |
| 2011                             | 15       | 10       | 9        | 8        | 12       | 11       | 4        | 7        |
| 2012                             | 11       | 14       | 8        | 5        | 7        | 1        | 4        | 5        |
| 2013                             | 15       | 7        | 6        | 8        | 3        | 5        | 6        | 4        |
| Number of cows with pregnancy   | 105      | 58       | 45       | 45       | 34       | 18       | 9        | 7        |
| Number of services per conception| 1.75±0.11a | 2.31±0.22b | 2.53±0.24b | 2.38±0.13a,b | 2.39±0.42a,b | 1.56±0.29a | 1.57±0.30a | 2.75±0.63a |
| CR (%)                          | 57.14±b | 43.29a   | 39.53a   | 40.02a   | 41.84a   | 64.10b   | 64.10b   | 36.36c   |

P, pregnancy; N, non-pregnancy; n, number of cows; CR, conception rate (pregnancy per artificial insemination service).

Table 6. Variations in the number of days open of Holstein cows with different parities

| Variables | Parity 1 to 2 | Parity 2 to 3 | Parity 3 to 4 | Parity 4 to 5 | Parity 5 to 6 | Parity 6 to 7 | Parity 7 to 8 |
|-----------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Number of cows | 51            | 43            | 27            | 14            | 8             | 6             | 3             |
| Days open (min, max) | 151±15ab | 182±17bc | 156±28ab | 178±40bc | 157±47ab | 158±32bc | 219±31bc |

Means with different superscripts in the same row differ at p < 0.05.

Table 7. Gestation length of Holstein cows with different parities

| Variables | Parity 11 | Parity 2 | Parity 3 | Parity 4 | Parity 5 | Parity 6 | Parity 7 | Parity 8 |
|-----------|-----------|----------|----------|----------|----------|----------|----------|----------|
| Number of cows | 70         | 51       | 43       | 28       | 14       | 8        | 6        | 3        |
| Gestation length | Mean (d) 275.1±6.5 | 277.8±6.28 | 276.8±5.4 | 279.1±6.4 | 275.4±6.2 | 277.4±4.0 | 278.2±5.0 | 280.7±2.9 |
|                | Min (d) 252 | 263      | 260      | 270      | 262      | 273      | 271      | 279      |
|                | Max (d) 294 | 297      | 289      | 304      | 283      | 285      | 286      | 284      |

11 The mean age at the first service and age at first calving in Holstein heifers are 493.2 days and 813.5 days (27.1 months), respectively.
In conclusion, our data shows that at THI of >72 and during the hot season (from June to November), CRs were significantly higher in heifers than in multiparous cows, although no significant differences were observed in the number of days open or gestation length on a dairy farm in a subtropical region in Taiwan. The contributions of physiological condition and genetic background will need to be included for further characterization of the relationship between stress response and reproductive performance in subtropical regions in Taiwan.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

ACKNOWLEDGMENTS

The authors are thankful to Professor Peng-Wen (Jacky) Chan for veterinary care and all facilities provided by Experimental Animal Farm, National Chung Hsing University to complete this project.

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