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# Evaluation of Heifer Management Criteria for Improved Lactation and Reduced Dystocia: A Systematic Analysis of Body Weight, Average Daily Gain, and Age

Research Article

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## ABSTRACT

Decisive heifer management for improved lactation and reduced dystocia requires a systematic analysis of age, body weight (BW), and average daily gain (ADG) using an adequately large sample size. The objective of this study was to determine effects of BW and age at first breeding and ADG until pregnancy on yields of milk, milk fat, and milk protein in the first lactation and the occurrence of dystocia in Holstein heifers. Production, reproduction, and growth data for 3208 heifers from three large Holstein herds were recorded and used. Heifers were divided to four groups based on ADG including 1) < 700 g/d, 2) 700-750 g/d, 3) 750-800 g/d, and 4) > 800 g/d. Based on BW at the commencement of pregnancy, heifers were divided to three groups of 1) < 350 kg, 2) 350-380 kg, and 3) > 380 kg. Based on age at the start of pregnancy, heifers were divided to three groups of 1) < 14 mo, 2) 14-15 mo, and 3) > 15 mo. Results demonstrated that weight and age at first breeding affected (P<0.05) milk production in the first lactation, such that heifers with > 380 kg body weight (11499 kg milk) and > 15 mo age (11430 kg milk) at breeding had the highest milk production. Heifers with > 800 g/d ADG tended (P<0.10) to have higher milk and milk protein production during the first lactation compared to other ADG groups. Heifers with 700-750 g/d ADG had the highest milk fat production among ADG groups. Heifers with > 380 kg BW at first breeding had higher milk fat production (349 kg) in their first lactation compared to heifers with > 350 kg BW (334 kg) and 350-380 kg BW (336 kg). Heifers with > 800 g/d ADG (24.4%) had higher (P<0.05) occurrence of dystocia compared to heifers with ADG of < 700 g/d (14.2%), 700-750 g/d (11.3%), and 750-800 g/d (20%). Heifers with < 350 kg BW at first breeding had higher occurrence of dystocia than did the other BW groups (P<0.05). In conclusion, greater heifer BW (>380 kg) and age (>15 mo) at first breeding were associated with greater productive performance during the first lactation, but heifers with the age of < 23 mo at first calving had decreased milk production and increased occurrence of dystocia. Thus, ADG prior to conception and BW and age at first breeding all affect production performance in the first lactation and dystocia incidence rate at first calving.

KEY WORDS dystocia, heifer, milk production, pregnancy age.

## INTRODUCTION

Replacement heifer management represents a significant investment in modern dairy farming (Nikkhah, 2015).

Heifer productivity and health has large impacts on profitability of the global dairy industry (Bouska *et al.* 2007; Nikkhah *et al.* 2011). Successful transitioning of replacement heifers into production phase as a lactating cow is critical for the profitability of modern dairy herds (Hoffman and Funk, 1992; Curran *et al.* 2013). Growing replacement heifers from birth until calving and entering the lactating herd represents 10-15% of total cost on modern dairies and is second to total feed cost for lactating herds (Pirlo *et al.* 2000; Do *et al.* 2013). Reproductive management of heifers has always been challenging. On one hand, minimal body weight (BW) and height criteria must be met before the first insemination and commencement of pregnancy to maximize milk production in the first lactation (Jessica *et al.* 2013). On the other hand, there is interest in decreasing the age at first calving by increasing average daily gain (ADG). Thus, to optimally decrease the age at first calving, minimal BW and height must be reached at earlier ages to allow for earlier insemination. However, the earlier calving would be desired only if the first lactation milk production improved and the likelihood of reproductive challenges such as dystocia do not increase (Macdonald *et al.* 2005; Lammers *et al.* 1999).

Delaying the first calving could considerably increase production costs (Macdonald *et al.* 2005). Too early insemination and calving could, on the other hand, negatively affect milk production, health, and productive life (Hare *et al.* 2006). Hence, finding the optimal age and BW for the first insemination and commencement of pregnancy is crucial in shaping the future lactation performance and health of the dairy herd. Optimizing the first calving age has been an interesting subject of research (Ettema and Santos, 2004; Meyer *et al.* 2004; Radcliff *et al.* 2000). Conclusive data, however, are lacking. No research has reported the effects of different management criterial such as age and BW at first breeding and ADG prior to conception altogether in a multifaceted, integrated study on milk production in the first lactation and dystocia at first calving. It was hypothesized that the age, BW, and ADG of heifers at first breeding and calving are important factors which impact the likelihood for dystocia and first lactation milk yield. Therefore, the objective of this study was to determine effects of age, BW, and ADG at first breeding on dystocia and first lactation yield of milk, fat and protein.

## MATERIALS AND METHODS

### Heifer management and data collection

The data including body weight (BW) at first insemination, ADG prior to conception (g/d), and age at first breeding were documented and obtained from three large dairy herds during three consecutive years (Ferdows Pars Agriculture and Livestock Holding Co., Tehran, Iran) (Table 1). Insemination and calving data were recorded for 3208 Holstein heifers from March 2016 through July 2018. The participating farms were operated under similar management conditions including regular veterinary services, estrus synchronization protocols, artificial insemination, lactation records, and vaccination. All heifers were raised under intensive production systems in free-stall barns and fed balanced total mixed rations with a similar forage to concentrate ratio. The main dietary feed ingredients were corn silage, alfalfa hay, dehydrated beet pulp, ground barley and corn grains, soybean meal, canola meal, cottonseeds, cottonseed meal, corn gluten meal, extruded soybean, fish meal, protected fat powder, and minor supplements such as sodium bicarbonate, salt, macro- and micro-minerals, vitamins, and feed additives. Body weights were recorded for individual heifers at birth, weaning, and breeding (commencement of pregnancy). The weaning and first-breeding BW measurements were made after 12 h of overnight feed withdrawal. Dystocia was described if two people were required to aid in parturition. Heifers experiencing dystocia were assigned a score of 1 and those with calving ease were assigned a score of 0. For analyzing milk production, actual 305-d milk yield data were used. Milk yield was recorded monthly and regularly during the first lactation.

Heifers were divided to three groups based on BW at first breeding including 1) < 350 kg (n=1253), 2) 350-380 kg (n=1109), 3) > 380 kg (n=846). The heifers were divided to four groups based on ADG prior to conception including 1) < 700 g/d (n=719), 2) 700-750 g/d (n=818), 3) 750-800 g/d (n=957) and 4) > 800 g/d (n=714). The heifers were divided to three groups based on age at first breeding including 1) < 14 mo (n=1292), 2) 14-15 mo (n=1380), and 3) > 15 mo (n=536) (Table 2).

### Statistical analysis

A linear mixed model using PROC MIXED of SAS Program (SAS, 2004) was used to analyze production performance with class statements for herd, calving year and season, sex of calf, dystocia and dependent variables. The statistical model used for analyses was:

$$y_{ijklmnopqrs} = \mu + Herd_i + Cyear_j + Season_k + Dys_l + \beta(\overline{Preg_m} - Preg) + AFP_n + FWP_o + GR_p + FWP_o \times AFP_n + AFP_n \times GR_q + Anim_r + e_{ijklmnopqrs}$$

Where:
$y_{ijklmnopqrs}$: dependent variable (milk production traits).
$\mu$: overall mean.
$Herd_i$: fixed effect of herd i.
$Cyear_j$: fixed effect of jth year of calving.
$Season_k$: fixed effect of kth season of calving.
$Dys_l$: fixed effect of the year of dystocia at calving (2 categories; normal calving = 0 and difficult calving=1).
$\beta$: regression coefficient of observations on Preg as a covariate.
$Preg_m$: month of pregnancy.
$AFP_n$: fixed effect of pth age at first pregnancy.
FWPq: fixed effect of qth weight in first breed.

GRr: fixed effect of rth group of gain before breed; the random effect of animal.
$Anim_r$: random effect of animal.
$e_{ijklmnopqrs}$: random residual effect with mean 0 and homogenous variance σ2.

Nonlinear regressions (Proc Logistic) were utilized to analyze different management group effects on the occurrence of dystocia using the following model:

$$Logit(\pi)= \alpha + Herd_i + Cyear_j + Season_k + Sex + \beta_l (Preg_n-\overline{Preg}) + AFP_o + FWP_p + GR_q + FWP_p \times AFP_o + AFP_o \times GR_q + Anim_s + e_{ijklmnopqrs}$$

Significance was declared at P < 0.05 and tendencies for significance were declared at P ≤ 0.10.

## RESULTS AND DISCUSSION

The highest (49.4%) and lowest (0.2%) number of inseminations (breeding) occurred for 13 and 19 mo old heifers, respectively. The breeding frequencies (% of total of 3208 heifers) were 11.7%, 49.4%, 25.3%, 8.9%, 2.1%, 1.6%, 0.8%, and 0.2% for heifers of 12, 13, 14, 15, 16, 17, 18, and 19 months of age, respectively. Average daily gain prior to conception tended (P<0.10) to affect milk production in the first lactation (Table 3). Heifers with > 800 g ADG tended (P<0.10) to have higher milk production than other groups. The ADG prior to conception affected milk fat production in the first lactation, such that heifers with 700 to 800 g/d ADG had higher (P<0.05) milk fat production than did heifers with > 800 g/d and < 700 g/d ADG (Table 3). Milk protein production during the first lactation tended (P=0.10) to be affected by ADG prior to conception. Heifers with > 800 g/d ADG tended to have higher (P<0.10) milk protein production than did heifers with < 700 g/d ADG (338 *vs.* 328 kg).

Body weight at first breeding had significant effects (P<0.05) on production performance in the first lactation (Table 4). Heifers with > 380 kg BW at first breeding had higher milk production in their first lactation, when compared to heifers with < 350 kg and 350-380 kg BW (11499 vs. 11059 and 11027 kg milk, respectively). Heifers with > 380 kg BW tended (P<0.10) to produce greater milk fat in their first lactation than did heifers with lower BW (Table 4). Also, heifers with > 380 kg BW at first breeding produced greater (P<0.05) milk protein than did heifers with < 350 kg BW (P<0.05; 345 *vs.* 326 kg).

Heifers at > 15 mo of age at first breeding had higher (P<0.05) milk production than did heifers at 14-15 and < 14 mo of age, respectively (11430 *vs.* 11199 and 10956 kg). Milk fat production in the first lactation tended to be greater (P=0.10) for heifers at > 14 mo of age than for heifers at < 14 mo of age at first breeding (346 *vs.* 329 kg; P=0.10).

Milk protein production in the first lactation tended to be greater (P=0.10) for heifers becoming pregnant at > 15 mo of age than for heifers becoming pregnant at lower ages (Table 5).

The three herds were different (P<0.05) in the incidence rate of dystocia (Table 6). The highest and lowest incidence rates of dystocia were respectively 32.4% and 5.5%. Calving year affected (P<0.05) dystocia occurrence. The years 2018 and 2016 had the highest (23.5%) and lowest (16.2%) dystocia incidence rates, respectively. Dystocia occurred most frequently in spring (21.8%) and least frequently in summer (13.5%) (OR=1 *vs.* OR=0.24; P<0.05). Moreover, dystocia occurred > 2 times more frequently (P<0.05) for male calves than for female calves.

Heifers with > 800 g/d ADG tended (P<0.10) to have higher dystocia incidence rate compared to heifers with lower ADG. Heifers with > 800 g/d (24.4%) and 700-750 g/d (11.3%) ADG had the highest and lowest dystocia incidence rate, respectively. Body weight at first breeding affected (P<0.05) dystocia incidence rate. Heifers with < 350 kg BW had higher (P<0.05) dystocia incidence rate at first calving, when compared to heifers with 350-380 and > 380 kg BW (22.2 *vs.* 17.7 and 15.1, respectively).

This study provides newly synthesized systematic and integrated insights using an adequately large sample size on how three different management criteria in heifer management including age and BW at first breeding and ADG prior to conception impact milk production in the first lactation and dystocia incidence rate at first calving. Optimal heifer age at first breeding (insemination) is an important decision in dairy cow physiology and health management, which depends on breed and the environment. The environment concerns with heifer rearing conditions including nutrition, health, welfare, and climate. Likely ideally, Holstein heifer's first parturition occurs at 24 mo of age, which means that the first insemination (start of pregnancy) occurs at 15 mo of age (Sadek *et al.* 2014). However, it has been reported that the first insemination in Swedish heifers may occur at 19-20 mo of age. Some researchers did not find any relationships between ADG and first lactation production performance in heifers (Cooke *et al.* 2013). Sadek *et al.* (2014), however, reported that heifers with 850-900 g/d ADG had higher milk production than did heifers with lower ADG. In contrast, a negative relationship between ADG until pregnancy and the first lactation milk production has been reported (Bayram *et al.* 2009). This negative relationship was reasoned to be likely because of postponed mammary development in heifers that became pregnant too early.

**Table 1** Production and reproduction properties of the first-calf Holstein heifers in three herds (total number of heifers=3208)

| Variable | Herd | | | Mean |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| Milk yield 305-d (kg) | 10983 | 11003 | 11142 | 11042 |
| Milk fat (%) | 3.15 | 3.16 | 3.12 | 3.14 |
| Milk protein (%) | 3.09 | 3.11 | 3.08 | 3.09 |
| Body weight at the start of pregnancy (kg) | 347.0 | 355.1 | 376.9 | 358.5 |
| Age at the start of pregnancy (d) | 434.7 | 422.8 | 426.6 | 429.0 |
| Average daily gain (g) | 713.3 | 754.1 | 792.3 | 748.6 |
| Pregnancy length (d) | 275.6 | 274.3 | 275.9 | 275.4 |
| Dystocia incidence (%) | 12.5 | 5.5 | 32.4 | 16.9 |

**Table 2** Heifer categories/groups and numbers for different management criteria

| Management criterion | Group | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Body weight at first insemination (kg) | < 350 (n=1253) | 350-380 (n=1109) | > 380 (n=846) | - |
| Average daily gain until pregnancy (g/d) | < 700 (n=719) | 700-750 (n=818) | 750-800 (n=957) | > 800 (n=714) |
| Age at first insemination (mo) | < 14 (n=1292) | 14-15 (n=1380) | > 15 (n=536) | - |

**Table 3** Effect of average daily gain (ADG) until first insemination (g/d) on 305 d yield (Mean±SE) of milk, fat and protein during the first lactation

| Variables | ADG group (g/d) | | | | P-value |
|---|---|---|---|---|---|
| | < 700 | 700-750 | 750-800 | > 800 | |
| Milk (kg) | 11201±136.1 | 11192±81.8 | 11113±90.7 | 11273±99.3 | 0.09 |
| Fat (kg) | 339.9±11.8[ab] | 354.8±7.1[a] | 341.5±7. 8[a] | 323.9±11.1[b] | 0.04 |
| Protein (kg) | 328.1±10.1 | 331.7±6.5 | 335.6±6.7 | 338.4±15.1 | 0.10 |

**Table 4** The 305 d yield (Mean±SE) of milk, fat and protein of first lactation of Holstein heifers differing in body weight at first insemination

| Variables | Body weight group (kg) | | | P-value |
|---|---|---|---|---|
| | < 350 | 350-380 | > 380 | |
| Milk (kg) | 11027±90.9[b] | 11059±88.8[b] | 11499±90.7[a] | 0.001 |
| Fat (kg) | 334.4±7.8 | 336.2±7.6 | 349.5±7.8 | 0.070 |
| Protein (kg) | 326.4±6.7[b] | 333.4±6.4[ab] | 344.6±6.9[a] | 0.008 |

**Table 5** The 305 d yield (Mean±SE) of milk, fat and protein of the first lactation of Holstein heifers differing in age at first insemination

| Variables | Age group (mo) | | | P-value |
|---|---|---|---|---|
| | < 14 | 14-15 | > 15 | |
| Milk (kg) | 10956±109.3[c] | 11199±73.4[b] | 11430±73.4[a] | 0.001 |
| Fat (kg) | 328.9±9.4 | 345.9±6.4 | 345.3±14.2 | 0.10 |
| Protein (kg) | 321.7±8.3 | 334.71±5.6 | 348.0±12.6 | 0.10 |

The BW data were conceptually in agreement with the results of other studies (Ettema and Santos, 2004; Meyer *et al.* 2004; Handcock *et al.* 2019), indicating that heifers with greater BW at first insemination had greater milk production in their first lactation, when compared to heifers with lower BW. However, putting much pressure on heifers for too high ADG to decrease the first parturition age increases feed costs and may jeopardize milk production performance.

Lowering heifer insemination age may adversely affect the first lactation performance (Meyer *et al.* 2004; Cock *et al.* 2013). Ettema and Santos (2004) reported that heifers at 25.9 mo of age at first parturition produced greater milk compared with those that calved at < 22 mo of age at first parturition.

Moreover, Teke and Murat (2013) reported that heifers with > 23 mo of age at first calving produced greater milk than did heifers with lower ages at first calving. These results are in agreement with the findings of the current study. The results of the present study specifically suggest that heifers with > 24 mo of age at calving can have superior production performance over heifers with < 23 mo of age at calving.

The finding that male *vs.* female calf birth was associated with higher dystocia would be convincing since male calves are usually larger and heavier than female calves (Mee, 2008).

Average daily gain and BW at first breeding affected (P<0.05) dystocia incidence rate (Table 6). Literature on the effect of BW at first breeding on dystocia is scarce.

**Table 6** Estimated odds ratios (95% CI) for the effects of herd, calving year, calving season, calf sex, average daily gain and body weight (BW) at first breeding on dystocia incidence rates of Holstein heifers

| Variable | Calving No. | Dystocia incidence (%) | Odds ratio (95% CI) | P-value |
|---|---|---|---|---|
| **Herd** | | | | |
| 1 | 1369 | 12.49 | Reference | 0.001 |
| 2 | 832 | 5.53 | 0.43 (0.30-0.62) | |
| 3 | 1007 | 32.37 | 5.2 (3.84-7.69) | |
| **Calving year** | | | | |
| 2016 | 476 | 16.19 | Reference | 0.001 |
| 2017 | 1971 | 17.43 | 1.35 (0.99-1.83) | |
| 2018 | 761 | 23.46 | 3.13 (1.91-5.15) | |
| **Calving season** | | | | |
| Spring | 619 | 21.81 | Reference | 0.02 |
| Summer | 968 | 13.53 | 0.24 (0.16-2.16) | |
| Autumn | 867 | 15.57 | 0.37 (0.16-5.22) | |
| Winter | 754 | 18.83 | 0.46 (0.15-8.94) | |
| **Calf sex** | | | | |
| Female | 1687 | 12.51 | Reference | 0.001 |
| Male | 1521 | 21.83 | 2.34 (1.91-2.87) | |
| **Average daily gain** | | | | |
| < 700 g/d | 719 | 14.18 | Reference | 0.08 |
| 700-750 g/d | 818 | 11.27 | 0.79 (0.57-1.10) | |
| 750-800 g/d | 957 | 19.97 | 1.04 (0.72-1.49) | |
| > 800 g/d | 714 | 24.37 | 1.38 (0.96-2.08) | |
| **Body weight at first breeding** | | | | |
| < 350 kg | 1353 | 22.18 | Reference | 0.04 |
| 350-380 kg | 1209 | 17.69 | 0.72 (0.54-0.95) | |
| > 380 kg | 646 | 15.14 | 0.63 (0.42-0.96) | |

Ettema and Santos (2004) showed that heifers with < 564 kg BW at first calving were less likely to experience dystocia, when compared to heifers with higher BW. In light of the literature, the findings of the present study suggest that too early pregnancy (<14 mo) with too low BW (<350 kg) is not desirable for heifer management as far as dystocia incidence is concerned. Future studies are required to comprehensively decide on optimal heifer BW, age, and ADG for optimal production in the first lactation and the whole productive life and for reduced incidence of metabolic disorders such as dystocia.

## CONCLUSION

Management decisions impact Holstein heifers' production potential in the first lactation and the incidence of dystocia. The heifer ADG prior to conception tended to affect milk and milk protein production and affected milk fat production during the first lactation. Heifers with > 380 kg BW at first insemination produced 470 kg more milk during the first lactation than did heifers with < 350 kg BW. Heifers becoming pregnant at > 15 month of age produced 4.2% greater milk during their first lactation than did heifers becoming pregnant at < 14 month of age. Insemination at the BW of > 380 kg decreased dystocia incidence rate at first parturition. Findings underline the importance of heifer age as well as BW and ADG in planning for the first insemination and conception. Low age at first calving (<23 mo of age) may jeopardize production performance during the first lactation and increase dystocia.

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