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Relationship between Growth Pattern, Age at First Calving and Next Reproduction in Holstein Heifers

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ABSTRACT

Growth rate during rearing, which varies depending on provided nutrition, has been related with age at 1st calving (AFC). This study investigated the effect of upgrowth parameters during the rearing period on the reproduction of nulliparous Holstein heifers. The study comprised 77 successively born heifers from the same herd. Growth rate and fertility traits were measured during rearing and fertility parameters were recorded in lactations 1. Growth parameters (body weight, height, heart girth and body length) were measured at the approximate birth time, 270 and 450 d of age. Reproduction data collected included age at 1st breeding, number of services per conception (S/C), pregnancy rate to 1st artificial insemination, AFC. Animals were subsequently divided into 4 AFC groups for analysis: <23 mo, 23~25 mo, 26~30 mo and >30 mo. The AFC reflected both upgrowth rate and heifer reproduction, with later calving heifers smaller. Increased skeletal growth (at 270 and 450 d) was related with a reduced AFC (p<0.05). Early calving animals (<23 mo) had the best reproduction as nulliparous heifers, with most conceiving at first service (87.5%). Fertility in the first lactation was the worst in the oldest AFC group (>30 mo). In the 1st lactation period, a number of services per conception (3.1±0.3) increased with increasing AFC (>30 mo). Sub-optimal upgrowth related with an increased AFC could be mitigated by improved monitoring of replacement heifers during the rearing period.

(Key words : heifers, age at first calving)

INTRODUCTION

The goal of a dairy replacement programme is to produce Holstein heifers that will calve at 24 months of age in a cost-effective solution (Donovan and Braun, 1987; Lammers *et al.*, 1999). Reproduction in heifers is often superior to that of lactating cows, but a variety of potential replacement heifers may never attain 1st calving because they do not to conceive or are significantly deferred in conceiving (Esslemont and Kossaibati, 1997). The capability of replacement heifers to attain puberty at a physiologically expected age, cycle normally, conceive at the appointed time, maintain the pregnancy to term, calve normally, and continuously commence their first lactation is a principal part of dairy industry (Velazquez *et al.*, 2008). A prior economic analysis showed that reducing age at first calving (AFC) from 25 to 24 mo decreased replacement costs by 4.3% (Tozer and Heinrichs, 2001). In contrast increasing AFC to 29 mo increased replacement costs by 14%.

Age at first calving is dependent upon the age when breeding is started and on its results. AFC is a major factor in deciding the length of the non-productive period as well as affecting next reproduction and productivity (Ettema and Santos, 2004; Evans *et al.*, 2006). Thus, breeding strategy is a determining factor. Rearing heifers to unite the herd at an age and body weight (BW) that will make them possible to achieve their full lifetime potential, concerning both yield and longevity, is also fundamental. Since puberty is not attained until the heifer gains a definitive weight, breeding age depends on the upgrowth rate. Upgrowth should be appropriate so that heifers attain sexual maturity and have 55% to 60% mature BW at the appointed time of breeding (Margerison and Downey, 2005). A relation between BW gain and the timing of puberty has been examined in many species. Accordingly, increased upgrowth is related with the earlier attainment of puberty in heifers (Yelich *et al.*, 1995; Lammers *et al.*, 1999; Brito *et al.*, 2007).

Variability in upgrowth patterns within groups of animals

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can attract to a wide range in the age at which heifers are bred for the first time (Ettema and Santos, 2004). The reproductive accomplishment of heifers at this stage will then affect the age at conception and hence, the AFC. AFC is a role of the age at the beginning of first breeding, associated with the reproductive efficiency of the animal. Poor reproduction can effect to a wide range in AFC and there may be large variation between the goal and actual AFC achieved.

The effect of AFC on subsequent reproductive performance remains unclear. The dairy industry would benefit considerably if even at a young age, certain animals at risk of failing to conceive can already be identified. The objective of this study was to analyze the relationship between AFC and subsequent fertility of dairy cattle.

MATERIALS AND METHODS

1. Growth Parameters

All heifers studied (n=77) were evaluated at approximately 270 d for age and 450 d for growth measurement. BW was measured at a mean age of birth, specifically at 9 and 15 mo, and ADG (average daily gain) was calculated from birth. BW was estimated using the portable weighing scales. Weighing apparatus was calibrated before each sampling. Height at withers (HT) and body length (BL) were measured using height stick, and heart girth (girth) was measured using a tape measure. The 9 mo measurement was took away the equivalent 15 mo measurement and divided by a number of days between the 2 time points to get the average daily change (ADC) in each upgrowth parameter (BW, HT, girth, BL) from 9 to 15 mo.

2. Fertility Parameters

For all nulliparous heifers (n=77) that attained the commencement of the first breeding period, service details were collected from records. Heifers were originally served at the first found estrus and once more at any subsequent estrus from the commencement of the service period. The AFB (for age at first breeding), S/C (services per conception), first service conception rate (CR) and AFC were recorded to identify the outcome traits and define fertility parameters (Table 1). A fortunate insemination, resulting in conception, was checked up a pregnancy diagnosis or by a next calving date and gestation length of 280±10 d. The consequence (conceived or failed to conceive) of each insemination was noted. Subsequent calving, animals were artificially inseminated at found estrus after the voluntary wait period of 45 d, and pregnancy was checked by transrectal palpation or ultrasound examination. Following each calving, reproduction was noted as days to 1st service (DFS), days to conception (DTC), S/C and first service CR.

3. Statistical Analysis

Heifers were grouped on their actual AFC; <700 d (<23 mo, n=8), 701～760 d (23～25 mo, n=10), 761～912 d (26～30 mo, n=37) and >912 d (>30 mo, n=22). Data were subjected to the Generalized Linear Model procedure (PROC-GLM) of the Statistical Analysis System (SAS Institute, Cary, NC, USA). Ratio (%) among the animals in the experimental groups was computed. Differences among group means were determined using Duncan's multiple range tests. Statistical significance was established at $p<0.05$.

RESULTS

BW measures during the rearing of heifers in this study are

Table 1. Definition of fertility parameters

Fertility trait	Definition
Age at 1st breeding (AFB)	Number of days from birth to the 1st artificial insemination
Number of services per conception (S/C)	Number of inseminations before a calving event
Pregnancy rate to 1st AI	Number of animals pregnant to 1st artificial insemination divided by the total number of 1st inseminations given to animals that conceived
Age at conception	Number of days from birth to the day of conception
Age at 1st calving (AFC)	Number of days from birth to 1st calving
Days to first service (DFS)	Number of day from calving to the day of 1st insemination
Days to conception (DTC)	Number of day from calving to the day of conception

presented in Table 2. Greater upgrowth during the rearing period was related with the decreased AFB and at calving. There were no significant differences among AFC group at 15 mo of age, even if the youngest one were significantly heavier than the rest by about 18 to 24 kg. Heifers in the youngest AFC group (<23 mo) were similarly heavier at 9 mo and exhibited higher ADG of 0.78 kg/d. Larger heifers in terms of HT and BL (9 and 15 mo) were on youngest at first breeding (p<0.05, Table 2). By the time they reached 15 mo, animals in the <23 mo AFC group had a larger girth (170.88±1.56, p< 0.05) than animals in the other three AFC groups (girth means of 164 to 166).

The reproductive achievement of the 77 heifers that conceived and calved without painful experiencing reproductive damage is summarized in Table 3. Heifers in the youngest AFC group were on an average of 4 mo younger at first breeding parallel with heifers calving at >30 mo. Heifers in the youngest AFC group (<23 mo) had the best reproduction, with most heifers conceiving to the first service (87.5%, Table 3). This good reproduction was achieved despite them being the youngest at the first service when breeding started at 14 mo of age. The higher AFC in the other groups can be partly attributed to the suspended AFB and poor conception rate. The mean AFC about all 77 nulliparous heifers was 853.5±8 (range 680 to 1,064). The affect of S/C was great in this study (1.1±0.1 vs. 3.1±0.3 S/C in the <23 mo and >30 mo AFC groups respectively). The AFB influenced AFC (431.3±5.3 vs. 541.3±21.9 d in the <23 mo and >30 mo AFC groups respectively), by a suspension of about 4 mo.

Data on reproduction measures in the first lactation period are summarized in Table 4. In lactation 1, DFS (means of 98 to 127 d), first service CR (means of 31.8 to 50%) or DTC (means of 205 to 263 d) have no significant effect on the AFC group. However, there was a tendency for cows calving at >30 mo to need more S/C (3.1±0.3) compared with means of 1.8 in the younger AFC groups. There was also a trend for a longer term from calving to conception (260.6±23.1 d) for heifers calving at >26 mo compared to those calving at <26 mo (means

Table 2. Body growth during the heifer rearing period in connection to age at first calving

	Age at 1st calving				p-value
	<23 mo	23～25 mo	26～30 mo	>30 mo	
No. heifers	8	10	37	22	
Body weight 15 mo (kg)	400.38±13.43	385.50±9.01	382.59±5.48	376.50±5.88	
Wither height 15 mo (cm)	134.75± 0.49[a]	131.90±0.67[b]	131.68±0.61[b]	129.55±0.72[b]	p<0.05
Body length 15 mo (cm)	149.50± 0.63[a]	144.20±0.90[b]	143.46±0.63[b]	140.05±0.88[c]	p<0.05
Heart girth 15 mo (cm)	170.88± 1.56[a]	166.00±1.85[b]	166.00±0.43[b]	164.68±1.00[b]	p<0.05
Body weight 9 mo (kg)	253.25±11.19[a]	234.70±5.22[ab]	233.78±3.97[ab]	229.59±6.17[b]	p<0.05
Wither height 9 mo (cm)	116.88± 0.58[a]	113.90±0.85[b]	113.62±0.60[b]	113.18±0.92[b]	p<0.05
Body length 9 mo (cm)	126.00± 0.78[a]	120.50±1.75[b]	119.11±1.03[b]	119.00±0.95[b]	p<0.05
Heart girth 9 mo (cm)	141.50± 2.82	138.40±1.06	137.92±0.88	137.14±1.30	
Body weight birth (kg)	41.00± 1.78	40.80±1.04	40.3±0.99	40.36±0.86	
ADG birth-9 mo (kg/d)	0.78± 0.04[a]	0.73±0.02[ab]	0.72±0.01[ab]	0.70±0.02[b]	p<0.05
ADG 9～15 mo (kg/d)	0.85± 0.05	0.84±0.06	0.81±0.03	0.80±0.04	
Wither height 9～15 mo (cm/d)	0.10± 0.00	0.10±0.01	0.09±0.00	0.08±0.01	
Body length 9～15 mo (cm/d)	0.14± 0.00	0.13±0.01	0.13±0.01	0.12±0.01	
Heart girth 9～15 mo (cm/d)	0.17± 0.01	0.16±0.01	0.15±0.00	0.15±0.01	
ADG birth-15 mo (kg/d)	0.79± 0.03	0.76±0.02	0.75±0.01	0.75±0.01	

* Values are mean±SEM ; with rows a>b.

Table 3. Nulliparous heifer reproduction in relation to their age at first calving

	Age at 1st calving				*p*-value
	<23 mo	23~25 mo	26~30 mo	>30 mo	
No. heifers	8	10	37	22	
Age at first breeding (d)	431.3±5.3[b]	474.4±10.4[ab]	520.6±14.7[a]	541.3±21.9[a]	$p<0.05$
Services per conception	1.1±0.1[b]	1.4±0.2[b]	1.6±0.1[b]	3.1±0.3[a]	$p<0.05$
First service conception rate	7/8 (87.5%)[a]	7/10 (70%)[a]	20/37 (54.0%)[ab]	3/22 (13.6%)[b]	$p<0.01$
Age at conception (d)	441.9±9.4[c]	496.2±4.2[c]	592.5±19.8[b]	723.9±13.2[a]	$p<0.05$
Age at first calving (d)	696.6±4.3[d]	764.1±2.6[c]	833.3±6.7[b]	985.1±10.5[a]	$p<0.05$

* Values are mean±SEM; with rows a>b>c>d.

Table 4. Reproductive achievement of cows during their first lactation term in relation to age at first calving

	Age at first calving				*p*-value
	<23 mo	23~25 mo	26~30 mo	>30 mo	
No. heifers	8	10	37	22	
Days to first service	98.1±11.1	101.3±9.1	119.6±4.7	127.1±16.9	
Services per conception	1.8±0.3[b]	2.3±0.5[ab]	2.4±0.3[ab]	3.1±0.3[a]	$p<0.05$
First service conception rate	4/8 (50.0%)	4/10 (40.0%)	14/37 (37.8%)	7/22 (31.8%)	
Days to conception	235.5±41.8	205.3±31.2	263.5±30.8	256.4±32.3	

* Values are mean±SEM; with rows a>b.

of 205 to 235 d).

DISCUSSION

There is a perception within the dairy enterprises that heifer reproduction is not a problem and that troubles only arise once cows are on lactation. However, it was learned in this study that 48% of heifers needed <2 inseminations to conceive, 28% were significantly suspended in conceiving, and calved for the first time after 30 mo of age. These indicate that sub-optimal fertility and infertility are also problems in non-lactation of animals. The results of this study indicate that the animals which were calved for the first time at <26 mo surpassed the later calving ones in terms of fertility.

Despite a goal AFC of 24 mo in all farms, half over of the heifers were calved at >26 mo, and the mean AFC was 28.2 mo. This confirmed prior reports of delays in AFC in other countries. For instance, AFC averaged 25.8 mo in Ireland (Evans *et al.*, 2006), 26.4 mo in Ireland (Mayne *et al.*, 2002), 26.9 mo in United States (Hare *et al.*, 2006), 27.7 mo in Costa Rica (Vargas *et al.*, 1998), 28.1 mo in Italy (Pirlo *et al.*, 2000), 28.4 mo in Sweden (Schneider *et al.*, 2007) and 29.3 mo in China (Wu *et al.*, 2012). The considerable difference in calving age may be caused by variation in age at breeding as a result of farm management, poor growth rate, or heifer fertility. These may show physiological immaturity at the time when heifers are first bred. Heifers with poor initial conception rates or with late embryonic/early fetal damage will clearly calve later than those which have already conceived. Approximately 1.3 to 4.8% of heifers have aborted their first pregnancies (Brickell *et al.*, 2009; Bach, 2011). This resulted in either an instant culling, late AFC if they required rebreeding, or young AFC if their pregnancy was enough advanced to initiate a lactation.

Nulliparous heifers with poor initial reproductive capability will clearly calve later than those which have already conceived. The study determined that younger heifers at the first breeding had the best reproduction. This is in agreement with previous studies showing that reproduction dropped as heifers

aged, with first service CR of 56% for heifers first bred at 13 ~16 mo and dropping to 42% at 26~27 mo (Kuhn *et al.*, 2006). Increasing growth from birth to conception from 0.68 to 0.82 kg/d has been shown to reduce age at conception by 32 d and at calving by 31 d (Bar-Peled *et al.*, 1997). In like manner, the study found out that younger calving heifers (<23 mo) had the highest ADG of up 9 mo of 0.78 kg/d.

Upgrowth rate is a major influence on heifer reproduction. Determination regarding the time of first breeding are often based on their body size. According, a suspended AFB may in session be due to poor heifer upgrowth, regardless the timing of puberty. Heifers in calving at >30 mo were considered too small to breed at 15 mo, resulting from poor upgrowth during the rearing term, and were not bred until at an average of 20 mo of age. Upgrowth rates vary considerably in accordance with the provided nutrition, with increased energy and protein intake increasing the rate of body upgrowth.

Body weight obtain has previously been related with the timing of estrus cyclicity. To cite, heifers with escalated growth rate were 1.9 mo younger at the first standing estrus than those fed to grow at slower rates (Gardner *et al.*, 1977). Similarly, heifers on escalated growth regimes (1 vs. 0.7 kg/d) were younger at puberty (10 vs. 11 mo) (Lammers *et al.*, 1999). There are earlier reported differences in average growth rates between 1 and 6 mo of about 0.5 to 1.0 kg/d between dairy farms (Brickell *et al.*, 2009). Upgrowth rates are however, as multiplex between different heifers on the same dairy farm. For instance 0.45 to 1.15 kg/d (Brickell *et al.*, 2009), and similar results (0.10 to 1.58 kg/d) were found in another study (Soberon and van Amburgh, 2012). Such differences commonly reflect surrounding conditions and calf health risk such as diarrhea, respiratory disease and septicemia (Donovan *et al.*, 1998, Soberon and van Amburgh, 2012). In particular, the duration of pneumonia before 6 mo influenced weight gains (Donovan *et al.*, 1998). More progress should be made on farms to maintain sufficient growth rates for all heifers within a group during the rearing period so that the animals are ready at reach the commencement of the breeding period with adequate body size. At first service, heifers should have attainded about 55 to 60% of their mature BW and this should have increased at 85 to 90% by the first calving (Margerison and Downey, 2005). At this stage, they are sharing assimilated nutrients for their own growth as well as for reproduction. Mature BW of Holstein cows can diversify considerably in accordance with selection choice. To calve between 550 and 625 kg at 24 mo of age, it is necessary to start first breeding at 13 to 14 mo at about 360 kg. An ADG of at least 0.75 kg/d throughout the rearing period will be necessary to meet these targets.

Results of this study have confirmed that AFC affects reproduction in the first lactation. Animals calving at <25 mo tended to have the best reproduction during lactation 1, in accordance with previous reports that heifers calving at 25 to 26 mo had a trend for a lower next CI (Evans *et al.*, 2006). In addition, animals calving between 700 and 750 days had higher CRs in the first lactation term (Ettema and Santos, 2004). Animals continue to grow until the end of their third lactation, although upgrowth rate slows at almost 450 d of age (Coffey *et al.*, 2006). Accordingly, younger calving cows must continue to grow to a greater range after calving and the nutrient demand for upgrowth will be at the expense of reproduction. In contrast to, it is thought that heifers calving with higher body condition following mobilize more body tissue, which also has damaging consequences on reproduction (Wathes *et al.*, 2008). Accordingly, this study showed that heifers calving in the oldest AFC tended to have the worst fertility and had become too fat.

Heifer performance in terms of fertility is fundamental for farm profitability. Improved monitoring of upgrowth at regular terms could help make sure proper body size for the first breeding at 13 to 14 mo, and hence calve close to 24 mo. Accomplishing these targets consistently requires providing the calf with enough energy and protein, beginning at birth, to pioneer its early growth potential. This study work can encourage farmers to commence weighing their calves periodically with the aim of ameliorating heifer growth during the rearing period. Improving reproductive efficacy of heifers also gains profitability through lower rearing costs.

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