Effect on Calf Sex of Milk Yield in Holstein Friesian Cattle Breed

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SUMMARY

This study compared the effects of the sex of Holstein Friesian (HF) calves registered in the herdbook system on milk yield. The study material comprised 802042 milk and calving records between 2000 and 2014. When analyzing the data, the GLM ANOVA method was used to investigate the effects of the sex of the calf and other environmental factors on milk yield. Of the calves born, 54.3% were female and 45.7% were male calves. The results show that the average lactation milk yield (LMY) of (HF) cows is 8604±3.6 kg, 305-day milk yield (305 MY) is 7028±2.4 kg and lactation length (LL) is 372±0.1 days. When cows give birth to female and male calves, LMY, 305 MY and LL are 8720±15.3 kg, 7148±10.0 kg and 370±0.5 days, respectively; 8482±15.3 kg, 6901±10.0 kg and 373±0.5 days were determined. Based on these results, it was found that cows that gave birth to female calves had a higher milk yield, and the effect of sex on milk yield was significant. The results obtained demonstrate distinct differences between cows giving birth to female versus male calves. Specifically, it was found that (HF) cows that give birth to female calves have a higher milk yield during lactation, and these differences were statistically significant. When evaluated by lactation number, the milk yield superiority of cows giving birth to female calves over those giving birth to male calves ranged from 3.89% to 1.13% for total lactation milk yield and from 4.98% to 1.80% for 305-day milk yield. Additionally, it was observed that the lactation length of cows giving birth to male calves was 1.06% to 0.55% longer than that of cows giving birth to female calves. Overall, across all lactations, HF cows that gave birth to female calves had a higher milk yield, indicating that the sex of the calf significantly influenced the milk yield of the mother.

KEY WORDS

Calf-Sex Influence, Sex-biased milk yield.

INTRODUCTION

Milk production, which begins at birth in farmed mammals, is influenced by genetics and some environmental factors. In the studies carried out, calving age (lactation sequence), calving season, calving year, productive life, dry period, etc. were taken into account. It has been reported that, in addition to factors such as the sex of the calf, the milk yield of the cow is also influenced. The sex of the calf can influence the milk yield of the dam throughout lactation due to its hormonal effects on the development of the mammary glands and the effects on gestation age. The lengthening of the gestation period and indirectly also the dry period depending on sex leads to a shortening of the lactation period in herds that calve seasonally (1). The profitability of dairy farms is negatively affected by animals with low milk yields and decreases due to increased costs. The income of dairy cows is influenced by several environmental factors as well as the genetic makeup of the animals. In this context, it has been established that the sex of the calves influences the milk yield of some animal species. For example, studies on the Holstein breed (1-5), the French Holstein and Montbeliard breeds (6) have reported that the sex of calves influences milk yield in the Gir and Guzera breeds (7) and that cows that give birth to female calves produce more milk.

It has been found that hormones produced by the bovine fetus can cross the placenta and that the sex of the calf can influence maternal hormone levels (8). The intensities of sex hormones differ among female and male fetuses and can potentially affect the synthesis of breast milk when they enter the maternal circulation (9). On the other hand, prolactin and placental lactogens are recognized to play a role in lactogenesis and mammogenesis, yet the mechanisms of action of these hormones are still controversial, and the role of the sex of the calf in this regard remains unclear (10, 11).

Male calves are more frequently associated with dystocia due to their higher birth weights (12). Cows experiencing dystocia typically exhibit reduced milk fat, protein, and lactose content, along with an increased somatic cell count, indicating lower milk quality.

Cattle fetuses produce hormones. These hormones can cross the placenta and enter the cow's bloodstream, and the sex of

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the calf can influence maternal hormone levels in this way (8, 13-17). Therefore, changes in blood levels of hormones that play a role in lactogenesis can affect the mother's milk yield depending on the sex of the calf (1).
Furthermore, as dairy cows are first mated before they have fully developed their bodies, often at only 60% of their adult weight, the sex of the calf at first birth may influence milk production throughout the cow's life (18).
Chew et al (19) expressed that calves with higher birth weights were connected with higher milk production, which could be connected to higher concentrations of estrogen and placental lactogens during pregnancy. Indirectly, this may be one of the reasons why male calves have been connected with higher milk production in some cases, as male calves are generally heavier at birth (20).
The probability of male birth is higher in cows that lose less body condition after calving (21, 22). Roche et al. (21) showed that a higher loss of body condition was connected with a higher female birth rate. Cows with high milk yield generally lose more body condition points, so these types of cows give birth to a higher rate of female calves (22). This could be the reason why the female birth rate has a positive effect on milk production; but, the relationship among these factors can also be explained by the fact that cows with higher milk production have more female calves (23, 24).
The milk yield of the cow rises with the weight of the calf at birth (25), and the average weight of male calves at birth is higher (26). These differences due to birth weight for the sex of the calf can give rise to the thinking that milk production is connected to sex when virtually it solely expresses birth weight (1). Chew et al (19) reported that milk production in higher birth-weight calves was not related to sex.
As stated in the Trivers-Willard hypothesis, it was predicted that in some mammals, including humans, mothers in better condition should give birth to more male offspring than females (27). According to the same hypothesis, it was assumed that mothers who give birth to female children produce more milk (28).
Sexed sperm refers to sperm cells that have been separated and classified according to their sex (male or female). This technology is widely used in animal breeding, especially in livestock breeding, including cattle breeding.
The purpose of semen separated into X and Y chromosomes is to increase the likelihood of producing offspring of the wish sex. Breeders use sexed semen to have more control over the genetic composition of their herd. For example, if a breeder wants to increase the number of female calves for future milk production or breeding purposes, he can use sexed semen to influence the sex ratio of the offspring in favour of females. Sex-biased milk production, where cows are reared with sexed semen, can increase milk yield by 48 kg per cow per year and achieve economic results of €4.0 to €9.9 per cow per year, depending on the scenario (29).
Some studies suggest calf gender influences milk yield, with female calves generally leading to higher milk production in intensive systems, while other studies indicate male calves result in longer gestations and potentially higher milk yields in certain breeds.
Previous research has shown that calf sex can affect milk yield, but it is often difficult to determine the cause of this effect. In this study, the possible effects of calf sex on milk yield were investigated using an extensive data set.

MATERIALS AND METHODS

Material of the study

The study's material consisted of milk and reproduction data from 802042 Holstein Friesian (HF) cattle kept on farms in Turkey. The calving data were considered by taking into account the artificial insemination data of the cow and the data recorded by authorized personnel and under system control were used. Only monozygotic twin births producing offspring of the same sex were considered, while dizygotic twins with offspring of different sexes were excluded.

Analysis of data

For this study, records of herds registered in the herdbook system in Turkey between 2015 and 2020 were used. In the study, data on milk yield and sex traits of Holstein Friesian (HF) calves were analyzed. The GLM ANOVA method was used to analyze the effects of calf sex and lactation order on milk yield-related traits.
The data were analyzed with 2 different models. In the first model, each lactation was evaluated separately. In the other model, the lactation number was included in the model and all lactations were analyzed together.

Model-1, $y_{ijklm} = \mu + a_i + b_j + c_k + dl + e_{ijklm}$ (Eq. 1).

Model-2, $y_{ijlm} = \mu + a_i + b_j + dl + e_{ijlm}$ (Eq. 2).

Y_{ijklm}: the observation value of the studied trait, (Yijk N(μ, σ2)), μ: the general mean value of the studied trait, a_i: i. Calving year effect amount (2015 ………. 2020), b_j: j. Calving month effect (January………December, c_k: k. Calving order effect (1, 2., 3., 4, 5+), d_l: l. Calf sex represents the effect (male, female), e_{ijlm}, e_{ijklm}: normal, independent, random error.

RESULTS AND DISCUSSION

The results of this study show that the sex of the calf significantly influences the milk yield in Holstein Friesian (HF) cows. Cows that gave birth to female calves had higher lactation milk yield (LMY) and 305-day milk yield (305-d MY) compared to those that gave birth to male calves (Table 1).
Specifically, cows with female calves produced 238 kg more LMY (2.81%) and 247 kg more 305-d MY (3.58%) than cows with male calves, and these differences were statistically significant ($p<0.001$). These findings align with the notion that calf sex can impact milk production, a phenomenon observed in various mammalian species (30). Additionally, the lactation period (LP) was slightly shorter (by 3 days) for cows that gave birth to female calves.
When comparing these results to the existing literature, several similarities and differences emerge. Studies in Canada (31) and Iran (3) also found higher milk yields in cows that gave birth to female offspring, supporting this study's findings. Similarly, Hinde et al. (2) reported that Holstein cows in the USA produced 445 kg more milk in the first two lactations when female calves were born. These results are consistent with the trend observed in this study, where female calves led to increased milk production.
However, not all studies are in complete agreement. For example, Hess et al. (1) observed increased milk yield in the second lac-

tation in New Zealand Holstein-Friesians, while Barbat et al. (6) reported an increase only in the first lactation in French Holstein-Friesians. These discrepancies suggest that the effect of calf sex on milk yield may vary depending on breed, management practices, or environmental factors. In contrast to the findings of this study, Græsbøll et al. (4) and Barbat et al. (6) reported that cows that gave birth to male calves had slightly higher milk yields during the first lactation.

Additionally, Quesnel et al. (32) found that calf sex caused a 7.9% variation in milk yield in dairy cows, a larger difference than the 2.81% found in this study. This variation could be due to differences in breeds, genetic factors, or regional practices. Some studies, such as Quaresma et al. (23, 24) in Portugal, found no significant effect of calf sex on milk or protein production but noted that cows with female calves produced milk with higher fat content, which adds another layer of complexity to the effect of calf sex on milk composition.

In conclusion, while the results of this study align with much of the existing literature, particularly regarding higher milk yields in cows that give birth to female calves, some studies report differing effects based on lactation number, breed, and other factors. The variation in findings across different studies may be attributed to differences in genetic, environmental, and management conditions. Further research is needed to fully understand the mechanisms behind sex-biased milk production and how they may be influenced by external factors.

Additionally, the findings of this study are supported by Djedovi et al. (32), who reported that Holstein cows that give birth to female calves have higher milk and fat yields, particularly during the first lactation. This aligns with the current results, which demonstrate a significant advantage in both lactation milk yield (LMY) and 305-day milk yield (305-d MY) for cows that gave birth to female calves. Čačić (33) further confirmed that this trend extends beyond the first lactation, reporting significantly higher milk yields in both the first and second lactations ($p<0.0001$) for cows with female offspring. This consistency across multiple lactations suggests a sustained impact of calf sex on milk production, reinforcing the idea that female calves stimulate higher milk yields over time.

In comparison to the findings of Čačić (33), this study also

Table 1 - Variation of milk yield characteristics in Holstein Friesian cattle during different lactation periods according to calf Sex.

Lactations	Factors		N	LMY	305-d MY	LP
				$\bar{X} \pm S_x$	$\bar{X} \pm S_x$	$\bar{X} \pm S_x$
1. Lactation	General		267628	8743±6.2	7038±3.8	376±0.2
	Year			*p*<.0001	*p*<.0001	*p*<.0001
	Month		P value	*p*<.0001	*p*<.0001	*p*<.0001
	Sex			*p*<.0001	*p*<.0001	*p*<.0001
		Female	145295	8929±8.5	7228±5.2	374±0.3
		N	122333	8595±9.2	6885±5.7	378±0.3
2. Lactation	General		222826	8769±6.9	7171±4.7	373±0.2
	Year			*p*<.0001	*p*<.0001	*p*<.0001
	Month		P value	*p*<.0001	*p*<.0001	*p*<.0001
	Sex			*p*<.0001	*p*<.0001	*p*<.0001l
		Female	112417	8884±9.8	7288±6.7	372±0.3
		Male	110409	8728±9.9	7097±6.7	375±0.3
3. Lactation	General		145147	8644±8.6	7117±5.9	369±0.2
	Year			*p*<.0001	*p*<.0001	*p*<.0001
	Month			*p*<.0001	*p*<.0001	*p*<.0001
	Sex			*p*<.0001	*p*<.0001	*p*<.0001
		Female	72975	8744±12.3	7218±8.4	368±0.4
		Male	72172	8579±12.3	7023±8.4	371±0.4
4. Lactation	General		84187	8393±10.9	6941±7.4	367±0.3
	Year			*p*<.0001	*p*<.0001	*p*<.0001
	Month		P value	*p*<.0001	*p*<.0001	*p*<.0001
	Sex			*p*<.0001	*p*<.0001	*p*<.0001
		Female	41511	8471±15.8	7018±10.7	366±0.5
		Male	42676	8376±15.6	6884±10.6	369±0.5
5. Lactation	General		82254	8094±14.3	6731±9.6	364±0.4
	Year			*p*<.0001	*p*<.0001	*p*<.0001
	Month		P value	*p*<.0001	*p*<.0001	*p*<.0001
	Sex			*p*<.0001	*p*<.0001	*p*<.0001
		Female	40611	8145±15.8	6791±13.9	363±0.6
		Male	41643	8044±15.6	6671±13.9	365±0.6
All Lactations	General		802042	8604±3.6	7028±2.4	372±0.1
	Year			*F*(4,802021)=2396, *p*<.0001	*F*(4,802021)=3140, *p*<.0001	*F*(4,802021)=798, *p*<.0001
	Month		P value	*F*(11,802021)=65, *p*<.0001	*F*(11,802021)=315, *p*<.0001	*F*(11,802021)=180, *p*<.0001
	Lactation number			*F*(4,802021)=1376, p<.0001	*F*(4,802021)=1365, *p*<.0001	*F*(4,802021)=373, *p*<.0001
	Sex			*F*(1,802021)=826, *p*<.0001	*F*(1,802021)=2375, *p*<.0001	*F*(1,802021)=242, *p*<.0001
		Female	412809	8720±15.3	7148±10.0	370±0.5
		Male	389233	8482±15.3	6901±10.0	373±0.5
Eta squared (η^2)				0.0213	0.0301	0.0086

LMY: lactation milk yield, **305-d MY**: 305-days milk yield, **LP**: lactation period found a significant difference in milk yield across multiple lactations, with cows that gave birth to female calves showing a 3.89% to 1.13% advantage in LMY and a 4.98% to 1.80% advantage in 305-d MY. The presence of this advantage across multiple studies highlights the importance of calf sex as a factor influencing milk production, particularly during the critical first and second lactations.

The use of sexed semen is not yet as widespread as desired in many countries. However, the findings of this study highlight the significant benefits and necessity of sexed semen application.

In summary, the additional data from Djedovi et al. (32) and Čačić (33) strengthen the argument that female calves are associated with higher milk production, not only during the initial lactation but also in subsequent lactations. This reinforces the idea that sex-biased milk production is a persistent and significant phenomenon in dairy cattle, warranting further exploration to understand its biological mechanisms and practical implications for dairy management.

These η^2 values can be interpreted as follows:

- **For lactation milk yield (η^2 = 0.0213)**: This indicates that 2.13% of the total variance in lactation milk yield is explained by the factors studied. This suggests that the effect of the factors on lactation milk yield is small.
- **For 305-day milk yield (η^2 = 0.0301)**: The factors account for 3.01% of the variance in 305-day milk yield, showing a small but slightly larger effect compared to lactation milk yield.
- **For lactation period (η^2 = 0.0086)**: This value indicates that only 0.86% of the variance in the lactation period is explained by the factors, implying a very small effect on the lactation period.

In summary, while all factors had a statistically significant effect, the η^2 values suggest that the effect sizes are small. The lactation period is the least affected parameter, whereas the 305-day milk yield shows a slightly larger effect, but still a small one.

CONCLUSIONS

The results obtained show clear differences between cows giving birth to female and male calves. It was found that cows of the HF breed that give birth to female calves have a higher milk yield in lactation, and these differences were statistically significant. When evaluated by lactation number, the superiority of cows that gave birth to female calves over cows that gave birth to male calves was between 3.89% and 1.13% for lactation milk yield and between 4.98% and 1.80% for 305-day milk yield. It was also found that the lactation length of cows that gave birth to male calves was 1.06% to 0.55% longer than that of cows that gave birth to female calves. Across all lactations, it was found that cows of the HF breed that gave birth to female calves had a higher milk yield and that the sex of the calf caused a significant variation in the milk yield of the mother. Based on the results of this study, some recommendations for dairy farmers can be made;

1) *Selection and management:* the higher milk yield of HF breed cows giving birth to female calves should be taken into account in selection and management strategies. This can increase the genetic potential in the herd and optimize milk yield.
2) *Reproductive Strategies:* The fact that cows that give birth to female calves have a higher milk yield offers breeders the opportunity to review their reproductive strategies. Female calf births can be specifically planned and the aim is to use these strategies to increase milk yield.
3) *Sperm Selection and Presentation:* The selection of the sex of semen used in cattle breeding can be optimized by taking into account the effects of the sex of the calf on milk yield. This can have a direct impact on breeding plans and presentation.
4) *More Research:* Based on the results of this study, further research is needed on the effects of calf sex on milk yield. This could contribute to the development of more effective management strategies by filling knowledge gaps in the cattle industry.

In summary, this study represents an important step towards understanding the effects of calf sex on milk yield in Holstein Friesian cattle. The results can help farmers to develop strategies for milk production and management and improve the overall efficiency of dairy farming.

Acknowledgement

The use of the data of this study was permitted by the 'Central Union of Cattle Breeders of Turkey (CBAT)' with the decision of the Board of Directors dated 21.08.2019, decision number 2019/10. We would like to thank CBAT very much.

Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept, Statistical Analyses: Ali KAYGISIZ; Data Collection or Processing: Onur ŞAHİN; Litterature Search, Writing: İsa YILMAZ.

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