



## **Analysis of Variance in Milk Yield and Milk Components According to Season of Calving, Sex of Calf, and Parity in Holstein Cows in Iraq**

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### **Abstract**

The objective of this study was to determine the effects of three predominant non-genetic effects; season of calving, newborn sex and parity order on milk yield and its components recorded from Holstein cows raised at Al-Khalis Cattle Station located at Diyala Province during 2024–2025 production season. Sixty three lactating cows participated in this study and daily milk yield, 305 day milk yield, total milk yield and milk components including fat percentage, protein percentage, lactose percentage, total solids and specific gravity were recorded. Descriptive statistics were conducted and Multifactorial ANOVA was applied to find out the significance of the main effects and interactions among studied factors. Results indicated that season of calving had a significant impact on milk yield traits as cows calved during winter, summer and autumn seasons showed higher daily milk yield and total milk yield in comparison to cows calved during spring season. Furthermore, cows calved during winter and summer seasons showed significantly higher fat percentage than cows calved during spring season. Results from this study showed significant effect of newborn sex on milk yield as cows delivered female calves showed significantly higher milk yield compared to cows delivered male calves while no significant effect of calf sex was found on milk components. Results confirmed that parity order had significant effect on milk yield where cows in second and third parity had the highest average milk production in comparison to cows at their first parity. Effects of parity were significant only on fat percentage while no effects were observed on milk yield or any other milk components. The outcome of this study highlighted the importance of environmental effects and management practices on productive performances of Holstein cows in local conditions that should be taken into consideration while implementing improvement programs and production management plans.

**Keywords:** Milk production, milk components, Holstein cows, season of calving, parity, calf sex, analysis of variance

## Introduction

Livestock production has a major contribution to agricultural development and poverty alleviation as livestock is one of the cornerstones of the food system of the world, providing about 40% of global agricultural production [1]. Dairy cattle are specialized in converting feeds of low nutritive value to high-quality milk and meat. They have a great importance in agricultural economy due to their capability to produce not only milk and meat but also leather, fertilizer, and fuel [2]. Recently, local breeds in Iraq have low productivity which motivated people to look for imported breeds. Holstein breed is highly specialized dairy breed due to their ability to produce high amounts of milk and adapt quickly to the local environment; hence many farmers showed great interest in raising Holstein dairy cows. Dairy farm economics is highly affected by milk production and milk components especially fat and protein percentage [3]. Holstein [4] cattle are one of the most prominent and raised dairy breeds in the world, and they have a superior worldwide reputation as the highest milk producing cattle breed than any other known dairy cattle breed in the world. This breed productivity is attributed to decades of genetic selection programs implemented scientifically in a well-planned manner for more than 200 years in Netherlands and other countries of the world [5]. Production of milk in Holstein cows plays a key role in the agricultural economy of developed countries as well as developing countries that seek to improve their livestock sector such as Iraq where Holstein cows have gained attention from farmers and governmental bodies to include them in national programs for rebuilding and improving livestock after recent economical and social issues. Despite the great reputation of Holstein cattle worldwide, Iraq's distinctive environmental and climatic conditions

including extreme temperatures, variable humidity rate, and long periods of drought may present certain challenges on this breed productive ability. Extreme weather may directly affect Holstein cows adaptability physiologically and behaviorally to those conditions [6]. Production of milk and milk components are considered to be some of the economically important traits as they have the highest monetary value among other traits in livestock production. Milk production and its components are affected by several interrelated genetic and non genetic (environmental and management) factors [7]. Among those non genetic factors are season of calving, calf sex, and parity. Those factors were selected based on their known importance and direct effect on milk yield and some milk components.

Season of calving is deemed to be one of the environmental factors which affects milk production and composition since cows that calf in different seasons are subjected to different environmental conditions whether in temperature, humidity or available pasture and feeds [8]. Numerous studies demonstrated that season of calving has a significant effect on milk yield where cows that calved during autumn and winter seasons yielded higher milk than cows that calved during summer months. This may be due to better environment that the calf experiences during its most rapid growth period if it calves during autumn and winter seasons [9]. Multiple studies have revealed that calf sex could affect the productive performance of dairy cows due to its effects on maternal endocrine during gestation and lactation periods. Female calves require more energy from the mother during gestation than males which may affect milk production for cows that carried male fetuses during their preceding pregnancy [10]. Parity is one of the major factors affecting physiological status of dairy cows which ultimately dictate their production ability. As the mammary gland

matures with age and previous lactations it reaches its peak production capabilities during the cow's second and third lactation then production starts to decline slowly as the cow ages [11].

While numerous studies conducted all over the world tackled the effect of calving season and parity on milk yield and its components, there are no local studies that evaluate the combined effect of those two non genetic factors on Holstein cattle. Also, most of the prior studies only investigated one or two of those factors individually. Therefore, there is a need to evaluate all of those factors together and study their interactive effect on milk production and milk components in Holstein cows raised in Iraqi climatic conditions. The main objective of this study was to evaluate the effect of season of calving, calf sex and parity on milk production and milk components (fat, protein, carbohydrates, and total solids) in Holstein cows. Variables were analyzed under the combined effect of the three major factors using a multi-way ANOVA model.

## Material and methods

### Sample Collection

Data collection took place at Al-Khalis Large Dairy Cattle Station located in Al-Khalis District, Diyala Province during the 2024–2025 production cycle. Information about season of calving, calf sex and parity were obtained from 63 Holstein dairy cows. Average daily milk yield was measured based on recording milk samples from morning and evening milkings once daily according to milking schedule of the station. Milk fat, protein, carbohydrates, total solids and specific gravity were recorded from milk samples taken during morning milking session daily. Milk samples were analyzed using milk analyzer machine available at the station laboratory manufactured by (FUNKE GERBER) Germany. Examination of cows was done by veterinary consultant for the study of health

status, physiological state and reproduction performance cows received routine observations by the investigator. All cows were observed in housing areas for availability of concentrate and water during the study period.

### Statistical Analysis

Data were analyzed statistically using the Statistical Analysis System (SAS) software program, version 9.4. Analysis of variance (ANOVA) was performed, and Duncan's multiple range tests were applied to determine whether the means of studied traits differed significantly from each other. Effects of season of calving, divided into spring (1 March–31 May), summer (1 June–31 August), autumn (1 September–30 November) and winter (1 December–28 February), sex of the calf (male and female) and parity (first, second and third calving) taken jointly on mean values of daily milk yield, 305 day milk yield and total milk yield during lactation season expressed in kg were tested. In addition, effects of mentioned factors on the percentage of fat, protein, lactose and total solids in milk and on specific gravity of analyzed samples were tested using the following model:

$$Y_{ijkl} = \mu + S_i + G_j + T_k + (SG)_{ij} + (ST)_{ik} + (GT)_{jk} + (SGT)_{ijk} + e_{ijkl}$$

where:

- $\mu$  represents the overall mean,
- $S(i)$  the effect of calving season ( $i = 1, 2, 3, 4$ ),
- $G(j)$  the effect of calf sex ( $j = male, female$ ),
- $T(k)$  the effect of parity ( $k = 1, 2, 3$ ),
- $(SG)(ij)$  the interaction between calving season and calf sex,

- **(ST)(ik)** the interaction between calving season and parity,
- **(GT)(jk)** the interaction between calf sex and parity,
- **(SGT)(ijk)** the three-way interaction among all factors, and
- **e(ijkl)** the random error term, assumed to be normally distributed with a mean of zero and variance  $\delta^2e$ .

## Results and Discussion

### Effect of Calving Season on Milk Production and Its Components

There was a statistically significant ( $P \leq 0.05$ ) effect of calving season on daily milk yield, 305-day milk yield, and total milk yield

during lactation season (Table 1). Average daily milk yield and 305-day milk yield were significantly higher ( $P \leq 0.05$ ) for cows that calved in winter, summer and autumn compared with cows that calved in spring. Also, cows that calved in winter and summer recorded significantly higher total milk yield during lactation season compared to those calving in autumn and spring seasons. This might suggest that calving in seasons with cold or warm weather conditions could lead to better physiological performance by the cows and better utilization of feed nutrients leading to higher milk production than cows that calve during season where climate conditions could fluctuate (spring).

**Table 1. Effect of Calving Season on Milk Production**

Season	Number of observations	Means $\pm$ SE		
		Daily milk yield	305-day milk yield	Total milk yield (during lactation season)
Winter	13	14.58 $\pm$ 1.18 a	4447.9 $\pm$ 361.0 a	4732.5 $\pm$ 521.3 a
Summer	11	14.00 $\pm$ 1.32 a	4270.0 $\pm$ 402.6 a	4510.0 $\pm$ 426.1 a
Autumn	29	13.14 $\pm$ 0.87 a	4007.4 $\pm$ 266.3 a	3607.5 $\pm$ 280.4 ab
Spring	10	11.88 $\pm$ 0.72 b	3621.9 $\pm$ 219.0 b	3521.2 $\pm$ 338.4 b
Significance level		*	*	*

Different letters within the same column indicate significant differences among means at ( $P \leq 0.05$ ) and NS = non-significant.

The analysis of variance showed a significant difference ( $P \leq 0.05$ ) in the percentage of total milk fat, where cows producing in winter, summer, and autumn had higher fat percentages compared with those

producing in spring (Table 2). In contrast, calving season had no significant effect on protein, lactose, total solids, or specific gravity.

**Table 2. Effect of Calving Season on Milk Components**

Season	Number of observations	Means $\pm$ SE				
		Fat %	Protein %	Lactose %	Total solids %	Specific gravity
Winter	13	4.217 $\pm$ 0.272 a	2.786 $\pm$ 0.047 a	4.153 $\pm$ 0.070 a	7.708 $\pm$ 0.176 a	1.02483 $\pm$ 0.000 a

Summer	11	4.203 ± 0.195 a	2.783 ± 0.067 a	4.092 ± 0.094 a	7.697 ± 0.122 a	1.02450 ± 0.000 a
Autumn	29	4.142 ± 0.267 a	2.775 ± 0.037 a	4.083 ± 0.055 a	7.617 ± 0.051 a	1.02417 ± 0.000 a
Spring	10	3.688 ± 0.465 b	2.663 ± 0.060 a	3.925 ± 0.088 a	7.425 ± 0.153 a	1.02375 ± 0.000 a
Significance level		*	NS	NS	NS	NS
Different letters within the same column indicate significant differences among means at (P≤0.05) and NS = non-significant.						

### Effect of Calf Sex on Milk Production and Its Components

The results showed that calf sex had a significant effect on milk production, as cows that gave birth to female calves exhibited a

significant superiority ( $P \leq 0.05$ ) in daily milk yield, 305-day milk yield, and total milk production during the lactation season, compared with cows that gave birth to male calves (Table 3).

**Table 3. Effect of Calf Sex on Milk Production**

Sex	Number of observations	Means ± SE		
		Daily milk yield	305-day milk yield	Total milk yield (during lactation season)
Male	39	12.56 ± 0.65 b	3830.2 ± 197.4 b	3816.3 ± 259.8 b
Female	24	14.84 ± 1.01 a	4526.2 ± 306.9 a	4194.0 ± 310.8 a
Significance level		*	*	*
Different letters within the same column indicate significant differences among means at (P≤0.05) and NS = non-significant.				

The results presented in Table (4) indicate that calf sex had no significant effect on the percentage of fat, protein, lactose, or total

solids. Likewise, calf sex showed no significant effect on the specific gravity of the milk produced.

**Table 4. Effect of Calf Sex on Milk Components**

Sex	Number of observations	Means ± SE				
		Fat %	Protein %	Lactose %	Total solids %	Specific gravity
Male	39	4.172 ± 0.160 a	2.753 ± 0.037 a	4.081 ± 0.056 a	7.614 ± 0.093 a	1.02465 ± 0.000 a
Female	24	4.068 ± 0.241 a	2.796 ± 0.047 a	4.140 ± 0.069 a	7.720 ± 0.123 a	1.02432 ± 0.000 a
Significance level		NS	NS	NS	NS	NS
Different letters within the same column indicate significant differences among means at (P≤0.05) and NS =						

non-significant.

### Effect of Parity on Milk Production and Its Components

Parity in cows is considered one of the factors associated with variation in milk production. The analysis of variance (Table 5) showed a significant effect ( $P \leq 0.05$ ) of parity

on daily milk yield, 305-day milk yield, and total milk production during the lactation season. Cows in their second and third parity exhibited a significant superiority compared with those in their first parity.

**Table 5. Effect of Parity on Milk Production**

Parity	Number of observations	Means $\pm$ SE		
		Daily milk yield	305-day milk yield	Total milk yield (during lactation season)
1	27	11.61 $\pm$ 0.71 b	3541.4 $\pm$ 216.8 b	3411.7 $\pm$ 271.5 b
2	14	15.56 $\pm$ 0.99 a	4746.6 $\pm$ 302.4 a	4854.4 $\pm$ 404.5 a
3	22	15.25 $\pm$ 1.17 a	4651.2 $\pm$ 357.1 a	4278.8 $\pm$ 320.8 a
Significance level		*	*	*
Different letters within the same column indicate significant differences among means at ( $P \leq 0.05$ ) and NS = non-significant.				

The analysis of variance showed a significant superiority ( $P \leq 0.05$ ) in the percentage of total milk fat among cows in their first and second parity compared with

those in their third parity (Table 6). In contrast, parity had no significant effect on protein, lactose, total solids, or specific gravity.

**Table 6. Effect of Parity on Milk Components**

Parity	Number of observations	Means $\pm$ SE				
		Fat %	Protein %	Lactose %	Total solids %	Specific gravity
1	27	4.200 $\pm$ 0.210 a	2.825 $\pm$ 0.045 a	4.192 $\pm$ 0.065 a	7.808 $\pm$ 0.116 a	1.02492 $\pm$ 0.000 a
2	14	4.481 $\pm$ 0.193 a	2.781 $\pm$ 0.042 a	4.106 $\pm$ 0.068 a	7.650 $\pm$ 0.100 a	1.02419 $\pm$ 0.000 a
3	22	3.638 $\pm$ 0.208 b	2.631 $\pm$ 0.044 a	3.900 $\pm$ 0.070 a	7.306 $\pm$ 0.109 a	1.02400 $\pm$ 0.000 a
Significance level		*	NS	NS	NS	NS
Different letters within the same column indicate significant differences among means at ( $P \leq 0.05$ ) and NS = non-significant.						

## Discussion

### Effect of Calving Season on Milk Production and Its Components

Calving season impacted daily milk yield, 305 day milk yield, and total milk production during the lactation season since cows that produced milk during winter, summer and autumn had highly significant superiority ( $P \leq 0.05$ ) over cows that produced milk during spring consistent with findings of [12] [13]. Overall, results of the present study indicate that calving season has a significant effect on milk production traits, Cows that calved during winter showed highest daily milk yield, 305 day yield and total seasonal milk production while cows that calved during spring showed the least productive performance similar to [14]. This clear distinction among seasons demonstrate that seasonal environmental changes had highly influence on expressing the productive ability of dairy cows as reported by [15]. This might be due to cows that calved during cooler weather or moderate temperatures always record better productive performance over those that calved during periods with high degree of heat stress. During winter cows experienced superiority may be credited to increased thermal comfort resulting from reduced effect of heat stress which is considered one of the environmental factors with the highest influence on depressing physiological processes involved milk production in agreement with [16], When housed under moderate temperatures cows experience an increase in feed intake as well as

increase nutrient uptake for milk production since both respiratory rate and heart rate (increase with increasing ambient temperature in an effort to get rid of excess body heat) are low, Whereas the difference noted between summer and autumn compared to spring might be associated with management systems such as availability of green forages in addition to good housing environment encountered during summer and autumn compared with spring, in line with [17]. Also spring may experience abrupt increase in temperatures or climatic fluctuations which tend to have negative effect on consistent productive performance throughout the season thus effecting physiological status of the cow as well as her ability to produce milk following calving.

Season of calving significantly affected percentage of total milk fat since cows producing milk during winter, summer and autumn recorded the highest percentages of milk fat compared to cows calving during spring. However, no seasonal differences were detected for protein, lactose, solids non fat and specific gravity. This reflects the same change noticed when considering milk yield since milk fat is very sensitive to seasonal changes either due to environmental or nutritional changes. Milk fat percentage is know to be the most sensitive milk component to nutritional and environmental changes mostly because milk fat synthesis relies on volatile fatty acids that are produced from fermentation of fiber consumed by the cow in the rumen with emphasis on acetate and butyrate. During winter cows experienced greater dry matter intake along with suitable temperature; this

will benefit holstein cattle since they are breed of cattle adapted to cooler climates leading to higher production of these fatty acids which lead to higher percentages of fat. Increased fat percentage noticed during summer may also be explained by a dilution effect since lower total milk production means less water portion of milk is produced leaving cows to record higher fat percentages. During autumn season increased amount of good quality forages with high fiber contents were available to the cow resulting in higher volatile fatty acids production in the rumen. Lower percentages of fat noticed during spring may be linked to amount of green forages included in the ration during the season. Green forages are rapidly fermentable feeds that are low in fiber and highly digestible causing less amount of acetate to be produced by cows during spring. Also higher milk yields noticed during spring in cows could be another reason causing lowered milk fat percentage due to greater milk volume (dilution effect).

However, contrary to milk fat; season of calving had no significant effect on percentage of protein, lactose, solids non fat and specific gravity. This could be because these components are tightly regulated physiologically within the mammary gland and not directly affected by other environmental factors like milk fat. For example lactose being the major determinant of milk volume is said to be one of the stablest component of milk whose synthesis depends on amount of glucose available in the blood stream of cow and not on other external effects. Also protein composition of milk is greatly affected by

energy and protein balance in a diet which does not change significantly between seasons when compared with factors affecting milk fat synthesis. Similarly solids non fat and specific gravity depends on protein and carbohydrate composition of milk and will remain stable if these components do not experience any seasonal differences, this results consistent with [18]. These results show that out of the components considered; only milk fat showed seasonal sensitivity under the studied production conditions. Therefore nutrition and composition of ration should be considered and manipulated during spring to help prevent any drops in percentage of fat while milk production can produce milk with stable components unaffected by season.

#### **Effect of Calf Sex**

Study findings demonstrated that calf sex had a significant impact on milk production traits as cows that calved female were significantly greater ( $P \leq 0.05$ ) in daily milk yield, 305 day yield and total milk produced during the lactation season compared with cows that calved male calves consistent with [19]. This suggests there is indeed a physiological effect on fetal sex during gestation and the postpartum period which can impact the productive abilities of the dam during the calving and following lactation season, Such an advantage is likely attributed to what is known as fetal programming in which fetal hormones send signals that may affect functional development of the mammary gland. As females secrete greater amounts of estrogenic growth related hormones compared to males during gestation, better mammary

development may occur which could cause higher production during the peripartum period. Additionally, cows gestating female calves typically require less nutrition during pregnancy when compared to males and therefore can keep the dam in better body condition going into parturition which also carries over to milk production during the lactation season ,Based on the results obtained [20].

Fetal sex may also impact milk production as calving with a bull calf tends to be more physically demanding on the dam. Since many breeds are considered large framed, cows often experience greater strain parturition after carrying a larger male calf. This additional stress can cause lower feed intake in the early postpartum period which leads to less milk production during the early stages of lactation, In accordance with the findings [21],which we know is the most influential on total season yield. Furthermore, cows that calf females have shown to be better at “producing greater quantities of milk due to internal hormonal effects that extend past parturition.” Calf sex may explain some of the variation in milk production as cows that calf females are generally able to produce greater amounts of milk than cows that calf males. Although this reproductive factor may not directly affect milk production it highlights the interactions between reproduction, endocrinology, and production of the dairy cow. Therefore, results from this study emphasize that calf sex should be considered as a non genetic factor affecting productive performance when performing herd evaluation

studies and statistical analysis models due to its influence on milk production during a lactation period. Additionally, cows that delivered female calves may have greater economic relevance to the producer if they are able to “produce” more milk compared to cows that delivered male calves in a breeding system that aims to increase herd efficiency and genetic merit.

No significant differences were observed between milk component percentages, including fat, protein, lactose and total solids or milk specific gravity based on calf sex , According to what has been found [22]. This can be reflective of milk components and their stable physiological nature. Milk components are not influenced by reproductive factors like fetal sex. Instead, they are regulated by highly specific internal processes that depend on mammary gland function and milk synthesis hormones (i.e. prolactin, oxytocin, metabolic hormones). Prolactin and oxytocin are the same hormones involved with milk letdown and do not vary according to fetal sex. Components such as protein and lactose rely on dietary energy and protein along with enzymatic activity that is responsible for the synthesis of these molecules in mammary epithelial cells.

Fat content is the only exception as it can fluctuate with nutritional and environmental changes. However, fetal sex has little to no influence on this trait. Milk fat is highly dependent on ruminal fermentation and the rate of fiber fermentation, the cows ration and her fatty acid balance. Again, none of these change with calf sex. Likewise, SNF and

specific gravity are determined by the concentration of protein, lactose and minerals present in milk. Because these do not differ by calf sex, no difference is expected to be seen in specific gravity. Therefore, reproductive effects associated with calf sex are usually limited to quantitative traits affecting milk production (i.e. DMY, 305 day yield) and do not typically have an effect on qualitative traits like milk composition due to strong physiological regulation.

This suggests calf sex does not play a major role in milk quality or chemical composition of milk and that these components will vary more on a cow's nutrition, management, stage of production, and her environment. As a result, a lack of difference in milk component percentages between cows that delivered males and females supports the claim that fetal sex only impacts factors involved in milk production and secretion levels, and has no effect on milk quality or physicochemical properties of milk. Highlighting the need to manage feeding and general herd management before accounting for reproductive factors.

### **Effect of Parity on Milk Production and Its Components**

However, the effect of parity was significant ( $P \leq 0.05$ ) for daily milk yield, 305 day yield, and total milk production during lactation because cows in their second and third parity were significantly superior to those in their first parity this results consistent with [23], suggesting that parity is another non genetic factor that affects production level in dairy cows. The likely reason for improved production in cows of second and third parity

compared with those in first parity is that cows complete both physiological and physical growth by the time they reach their second and third parities, which are generally considered their age of productive maturity. In accordance with the findings [24]. The mammary gland grows and matures along with the rest of the body during the first parity, resulting in competition between the cow's need for structural and muscle growth and milk production. Meanwhile, older cows that have completed most of their growth are able to allocate more of their dietary and metabolic resources toward milk production. In addition, mammary tissue continues to develop and become more productive with each pregnancy and lactation cycle, in agreement with [25].

Highest lactation performance is often seen between the 2nd and 4th parities before it levels off or slowly begins to decline due to old age, as reported by [26]. Since cows in their second and third parity also typically have better body condition and are able to eat more (have greater dry matter intake capacity) compared with cows in their first parity, this also helps to increase their total production level. Therefore, after all growth has been completed in cows following first parity milk production gradually increases, peaking during the second and third parity (productive maturity) when cows are the most efficient at converting feed into milk. After cows pass this point milk production will often level off or slowly decline due to reproductive stress, accumulated physiological demand, or old age-related decline in mammary efficiency.

Based on these findings, parity should be considered when analyzing factors that influence milk production as well as when implementing herd management and genetic selection programs. Primiparous cows may experience lower production due to physiological factors associated with growth and mammary gland development while cows in their second and third parity excel in productivity until age begins to negatively affect milk production. Results also indicated that cows in their first and second parity had significantly ( $P \leq 0.05$ ) higher percentage of total milk fat compared with cows in their third parity [27]. No significant difference was observed for the percentages of protein, lactose, total solids, or specific gravity between parities. This suggests that parity may only affect certain components of milk, particularly fat percentage, while other components are not affected by parity because they remain relatively constant, According to what has been found [28].

The higher percentage of fat seen in cows of first and second parity can likely be explained by their stage of physiological development and higher milk production efficiency. Cows in their first and second parity are generally growing and producing more efficiently volatile fatty acids, particularly acetate and butyrate, which are required for milk fat synthesis. In addition, because primiparous cows and those in their second parity generally produce less milk compared with older cows, fat percentage is increased through the dilution effect. On the other hand, lower percentage of fat in cows of

third parity can be explained by the fact that by the time cows reach their third parity they often experience their highest level of production in terms of quantity. As cows produce more milk, milk fat is diluted, resulting in lower percentage of fat. Age related physiological deterioration of mammary tissue may also decrease efficiency of fiber digestion or utilization, which will subsequently decrease production of volatile fatty acids required for milk fat synthesis.

The reason why parity had no effect on percentages of protein, lactose, total solids, or specific gravity is most likely because these are stable components that do not physiologically change with age or parity. Protein and lactose percentages are regulated by metabolic activity within the mammary gland that is dictated by energy balance and availability of glucose and protein synthesis, both of which are not affected by parity. Since solids non fat and specific gravity are determined by milk components that do not change with parity (protein and lactose being the major constituents), no effect was observed.

These results are expected because parity is known to have larger effects on milk yield than milk composition or quality, and fat percentage is the milk component most affected by fluctuations in production level and milk volume.

## **Conclusion**

This study provides clear evidence that non-genetic factors such as season of calving, calf sex, and parity exert significant influences on milk yield and selected milk components in

Holstein cows raised under Iraqi conditions. The findings demonstrated that cows calving in winter and summer achieved superior milk yield and fat percentage compared with those calving in spring, highlighting the role of environmental and climatic factors in shaping productive performance. Moreover, the sex of the calf was shown to affect milk yield, with dams delivering female calves producing significantly more milk than those delivering male calves, although no differences were observed in milk composition. Parity also emerged as a critical determinant, with cows in their second and third lactations outperforming primiparous cows in milk yield, while fat percentage was more pronounced in earlier parities.

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