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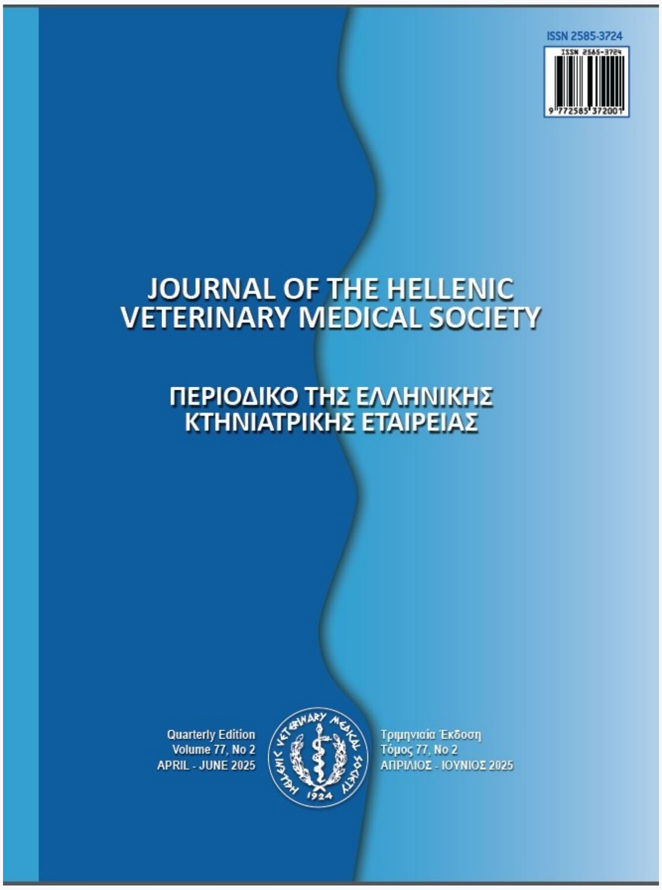

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A Kaygisiz, O Şahin, İ Yilmaz

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Research article
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Determination of adjustment factors of milk yield according to mature age in Brown Swiss breed cattle

Ali Kaygisiz,[1]* Onur Şahin,[2] Isa Yilmaz[2]

[1]Department of Animal Science, Faculty of Agriculture, Kahramanmaraş Sütcü Imam University, Kahramanmaraş, Türkiye

[2]Department of Animal Production and Technologies, Faculty of Applied Sciences, Muş Alparslan University, Muş, Türkiye

ABSTRACT: The study investigates environmental adjustment factors, specifically age and seasonal correction factors, to refine milk yield estimates in Brown Swiss cattle. The methodology includes the analysis of milk yield data (1987-2023 years) from 19,042 records spanning 10,127 cows across Türkiye, employing three methods—simple average, polynomial regression, and gross comparison. These factors aim to standardize milk yield to a mature equivalent basis, ensuring fair comparisons by accounting for systematic environmental influences such as calving season and age. This adjustment enhances the precision of genetic trend evaluations and aids in selecting superior breeding stock, ultimately improving dairy farming productivity and genetic advancements. The adjustment factors for milk yield for 305-day were calculated taking into account 22 different age groups and 4 seasonal groups. The ages of cows calving in spring, summer, fall and winter months to reach 305-day milk yield at mature age were 64-66 months, 52-54 months, 58-60 months and 37-39 months, respectively. The current results therefore show that cows that calve in winter reach mature age earlier than cows that calve at other times of the year.

Keyword: Brown Swiss cattle; adjustment factors; 305-day milk yield; adult-age milk yield.

Correspondence author:
Prof. Dr. Ali Kaygisiz Department of Animal Science, Faculty of Agriculture, Kahramanmaraş Sütcü Imam University, 46000 Kahramanmaraş, Türkiye. phone: +09 0 535 572 7044, e-mail: alikaygisiz@ksu.edu.tr

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INTRODUCTION

Milk yield is a complex trait influenced by both genetic and environmental factors. The development of dairy farming largely depends on improving milk yield through selection, which involves identifying individuals with superior genetic potential to form the next generation (Vanlı et al., 2024). However, the accuracy of selection depends heavily on reliable and unbiased yield records. Environmental factors such as age at calving, calving season, and management practices often obscure genetic potential, leading to distorted yield data that may not reflect the true performance of dairy animals (Açıkgöz et al., 2004; Anonymous, 2023).

To address these challenges, milk yield data must be systematically adjusted for known environmental influences. This standardization ensures more accurate comparisons among animals, enabling informed decisions in breeding programs. Without such corrections, the selection process risks favoring individuals based on external factors rather than intrinsic genetic merit, potentially compromising genetic progress (Wu et al., 2023).

The variability in raw milk yield data, particularly due to age and season-specific effects, underscores the need for accurate adjustment factors. These factors enable the standardization of milk yield data to a Mature equivalent basis, providing fair and comparable evaluations across individuals of different ages and calving conditions. Such adjustments are critical for identifying superior genetic traits and enhancing milk production efficiency. The reliability of these adjustment factors, however, depends on the size and quality of the dataset. Larger datasets minimize sampling errors, improving the precision of correction estimates (Vanlı et al., 2024).

Calving age, calving season and daily milking frequency are the main non-genetic factors affecting milk yield. Different parities significantly influence milk production, with first and second parity cows exhibiting distinct production levels compared to older parities, necessitating separate adjustment factors to prevent underestimation of mature equivalent production, particularly for first lactation records (Bagnato et al., 1994). The calving age of cows affects milk yield, with older cows generally producing more milk (Cho et al., 2004). Seasonal variations and calving month also play a role, with certain months providing higher production levels (Everett et al., 1982). Environmental factors such as herd year and lactation stages are crucial for developing the right adaptation factors (Cho et al., 2004). Therefore, before calculating the breeding values of cows, 305-day milk yield should be corrected for calving age, calving season and daily milking frequency (Petrović et al., 2017; Bakri and Djemali, 2021; Petrov et al. 2021; Kramarenko and Kramarenko, 2022; Susanto et al. 2023; Dhara and Gor, 2024).

Standardizing milk yield enables equitable comparisons across cows and herds by accounting for factors such as age, parity, and environmental conditions, thereby providing a clearer picture of genetic potential and facilitating selection programs aimed at improving milk production traits (Afroz et al., 2012; ElBoshra et al., 2016; Clancey et al., 2019). Adjusting yields to a mature equivalent allows for meaningful comparisons between cows of varying ages and parities, ensuring accurate performance evaluations across herds (Dhara and Gor, 2024). Such corrected yield data is essential for making informed breeding decisions, as it reflects the true genetic potential of animals and supports better resource allocation through optimized feeding and management practices (Sharma et al., 2024). Additionally, identifying high-performing cows through adjusted yields can enhance profitability by mitigating the effects of age-related yield discrepancies that might otherwise obscure superior production capabilities (Innes et al., 2024).

Various methods have been proposed for calculating adjustment factors, each with distinct strengths and weaknesses. The simple averages method, though straightforward, may yield biased results if the sample sizes within subclasses are uneven (Anonymous, 2023). The gross comparison method risks favoring high-performing individuals while penalizing lower-performing ones due to culling biases (Martinez et al., 1990). Conversely, the polynomial regression method offers greater precision by modeling the relationship between age and milk yield, mitigating the impact of irregular sample distributions. Among these methods, the polynomial regression approach is particularly effective in providing consistent and reliable results, as it minimizes potential biases without introducing directional effects (positive or negative) on outcomes.

This study utilizes a robust dataset comprising 19,042 records of 305-day milk yield from 10,127 Brown Swiss cows across 44 provinces in Türkiye, making it the most extensive dataset used for this purpose to date. By employing multiple correction methods, the study aims to (i) examine the effects of non-genetic factors on milk yield, (ii) adjust milk yield for variations caused by these factors, and (iii) evaluate the impact of these adjustments on genetic trend estimates.

Ultimately, this research contributes to the development of more accurate and equitable genetic evaluation systems for dairy cattle, supporting efforts to optimize productivity and genetic progress in the Brown Swiss breed. The findings offer valuable insights for researchers and farmers, providing practical guidelines for refining milk yield evaluations and improving the efficiency of dairy production systems.

MATERIAL AND METHODS

Material

The research data were obtained from the registration system of the Central Union of Cattle Breeders of Türkiye (CBAT). CBAT program plays a pivotal role in cattle breeding by integrating advanced genetic selection methods with environmental and management considerations. It focuses on optimizing the genetic potential of dairy cattle while ensuring sustainability and welfare in production systems. By utilizing genomic tools and data-driven approaches, CBAT helps breeders identify superior animals for traits such as milk yield, fertility, disease resistance, and adaptability to various climates. This holistic approach not only enhances productivity but also aligns with the growing emphasis on environmentally responsible and ethical livestock practices. The material of the study consists of 19 042 records of 305-day milk yield of 10 127 cows kept in 250 farms in 44 provinces of Türkiye.

Method

Three different methods were used to calculate the adult season-age correction coefficients: (i) simple average method, (ii) polynomial regression method and (iii) gross comparison method. Information on the details of these methods can be found in Vanlı et al. (2024).

(i) Simple Average Method

In the simple average method, all available yield data sets are included in certain class ranges (age groups). "Season-age adjustment factors" were determined by dividing the average 305-day milk yield of the most productive seasonal age group (Y_m) by the average of each season-age subgroup (Y_i).

$a_i = Y_m / Y_i$

In this formula; Y_m = 305-day milk yield average for the highest productive season-age group, Y_i = i. It represents the 305-day milk yield average for the season-age group.

(ii) Polynomial Regression Method

The calculation of the season-age correction coefficients with the polynomial regression method is the same as with the simple average method. However, with this method, the average 305-day milk yield calculated for each group corresponds to the expected average yield calculated with the polynomial regression method.

The polynomial method was used to calculate the correction coefficients depending on the mature equivalent. In this method, the relationship between the variables calving age (X) and milk yield (Y) is expressed with the formula $Y = a + bX + cX^2$. The terms in this equation are Y = 305-day milk yield and X = calving age between 20-160 months. The term "a" represents the point where the line crosses the Y-axis (Y-intercept), b and c represent linear and quadratic regression of milk yield on calving age, respectively. These coefficients were calculated using the PROC REG command in the SAS package program (1985).

The expected 305-day milk yield and the correction coefficients for the monthly age groups were calculated.

The polynomial regression equation was used to calculate the expected average 305-day milk yield for each seasonal age subgroup. The "age adjustment factors" were determined by dividing the average of the most productive seasonal age group separately by the expected yield average of each seasonal age group. While the "Simple Average Method" uses the actual yield averages obtained from the herd, the Polynomial Regression Method uses the calculated data obtained from the equation "$Y = a + bX + cX^2$".

$a_i = Y_m / Y_i$

Here: Y_m = average of the 305-day milk yield of the most productive age group of the season. Y = i. This is the 305-day average milk yield of the seasonal age group.

(iii) Gross Comparison Method

As with the simple averages method, age adjustment factors ("ai") were calculated by dividing the average of the seasonal age group in which the highest yield was measured by the expected average of each seasonal subgroup separately.

$a_i = Y_m / Y_i$

In these formulas, Y_m = 305-day milk yield average of the highest productive season-age group, Y_i = i. It represents the 305-day milk yield average of the season-age group. The ai values are stabilized using the 5-month weighted moving average using the formula given below. Thus, an ai' value was obtained for the age group of each season.

$$a_i' = \frac{\sum_{j=i-2}^{i+2} k_i n_i a_i}{\sum_{j=i-2}^{i+2} k_i n_i}$$

The weights of the ai' values here are kj = 1-2-3-2-1 (kj = 1 for i-2, kj = 2 for i-1, kj = 3 for i, kj = 2 for i+1, kj = 1 for i+2), ni = i. This refers to the number of yields in the seasonal age group, ai' = the values resulting from the given kj weights.

The "ai" values were calculated by dividing the "ai' values in each seasonal age group by the "ai' value corresponding to the highest age of yield in that seasonal age group. These coefficients were calculated using the PROC REG command in the SAS package program (1985).

In this study, for the simple average method, the correction factors are calculated by dividing the average milk yield of each age-season subgroup by the average yield of the most productive subgroup. The polynomial regression method models the relationship between age and milk yield through a quadratic equation ($Y = a + bX + cX^2$), providing a more refined adjustment based on expected yields. Lastly, the gross comparison method compares the yield of each age-season subgroup with the highest yield subgroup and adjusts accordingly. While the simple average method is straightforward, it may suffer from bias if subclass distributions are uneven. The polynomial regression method offers greater precision and reduces bias by modeling the age-performance relationship more dynamically. However, it requires more complex calculations and assumptions. The gross comparison method is practical but can lead to biases favoring higher-performing cows, especially in cases where lower-performing cows are culled early. By comparing these methods, this study will highlight their relative strengths and weaknesses, offering a more thorough understanding of the most suitable method for specific breeding contexts.

RESULTS

The 305-day milk yields according to calving seasons are given in Figure 1. The 305-day milk yield, the expected 305-day milk yield calculated using the regression method and the correction coefficients calculated using three different methods are shown in Tables 1-4.

According to the simple averages method, mature age adjustment factors were calculated by dividing the milk yield (6871 kg) obtained at the age of 64-66 months in cows calving in the spring by the milk yields of other monthly age groups (Table 2). To estimate the milk yield at 305-day of mature equivalent (ME-305-day), the milk yield of the youngest cow

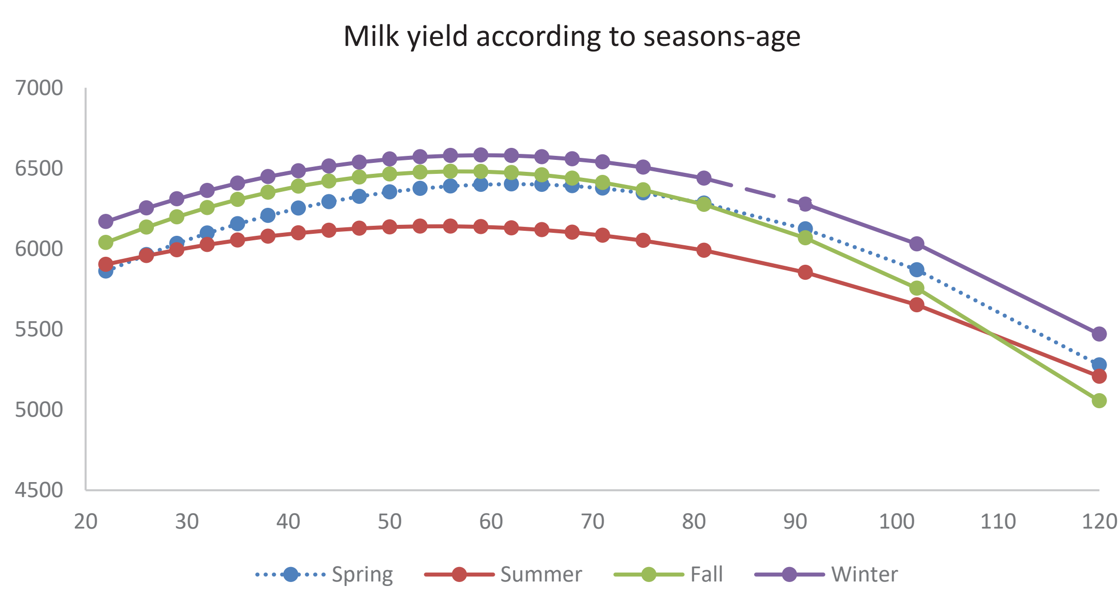

Figure 1. 305-day milk yield as a function of the calving seasons.

Table 1. Age adjustment factors for milk yield in Brown Swiss cows starting lactation in spring

Age (months)	N	Actual Milk Yield (kg)	Expected Milk Yield (kg)	Correction Factor		
				Method-1	Method-2	Method-3
≤ 24	141	6800±140,0	5917	1,103	1,086	1,125
25-27	834	5886±75,7	5967	1,197	1,077	1,136
28-30	638	5671±78,7	6038	1,239	1,064	1,143
31-33	229	5759±113,5	6103	1,213	1,053	1,125
34-36	64	7151±197,4	6162	1,014	1,043	1,067
37-39	387	6449±94,0	6215	1,055	1,034	1,014
40-42	384	6513±94,6	6263	1,067	1,026	1,012
43-45	293	6429±103,9	6304	1,097	1,020	1,020
46-48	183	6214±124,6	6339	1,125	1,014	1,023
49-51	248	6435±108,9	6369	1,048	1,009	1,016
52-54	207	6460±118,3	6392	1,057	1,005	1,013
55-57	172	6304±127,4	6410	1,109	1,003	1,020
58-60	134	6284±142,0	6421	1,091	1,001	1,021
61-63	168	6245±128,5	6427	1,093	1,000	1,015
64-66	130	**6871±143,2**	**6426**	**1,000**	**1,000**	**1,000**
67-69	99	6228±161,0	6420	1,095	1,001	1,010
70-72	90	6316±168,8	6408	1,071	1,003	1,021
73-78	188	6151±123,1	6382	1,112	1,007	1,034
79-84	93	6173±165,6	6324	1,080	1,016	1,039
85-96	116	6091±150,3	6175	1,085	1,041	1,059
97-108	81	5510±176,3	5908	1,210	1,088	1,094
≥109	76	5519±181,8	5709	1,241	1,126	1,128
Total	4955			$Y = 5103.6 + 41.77X^{***} - 0.34X^{2***}$		

*** P<0.0001

(≤ 24th month) must be multiplied by 1.103 and the milk yield of the oldest cow (≥ 109th month) must also be multiplied by 1.241.

Using the polynomial regression method, the highest expected milk yield of cows that calved in spring was calculated in the age group from 61 to 66 months (6427 kg). Accordingly, the milk yield of the youngest cow (≤ 24th month) must be multiplied by 1.086 and the milk yield of the oldest cow (≥ 109th month) by 1.126 to estimate the ME-305-day milk yield.

The relationship between calving age and milk yield was found to be highly statistically significant (P<0.0001) in all seasonal groups. This shows that the method and equations used in the calculation have a reliable and measurable effect. Thus, the "P 0.0001" for "b" strengthens the argument that calving age is an important variable to consider when developing breeding strategies and management practices aimed at optimizing milk yield in dairy cows.

The gross comparison method was used to calculate the highest expected milk yield of cows calving in spring in the 64 to 66-month age group. To estimate the daily milk yield ME-305-day, the milk yield of the youngest cow (≤ 24th month) must therefore be multiplied by 1.125 and the milk yield of the oldest cow (≥ 109th month) by 1.128.

Using the simple average method, the adjustment factors for mature age were calculated by dividing the milk yield (7215 kg) at 52-54 months of age for summer calving cows by the milk yield of the other monthly age groups (Table 2). To estimate the daily milk yield of mature age 305-day, the milk yield of the youngest cow (≤24th month) must therefore be multiplied by 1.323 and the milk yield of the oldest cow (≥109th month) by 1.346.

The polynomial regression method was used to calculate the highest expected milk yield of cows calving in summer in the 52-57 month age group (6137 kg). To estimate the daily milk yield of ME-

Table 2. Age adjustment factors for the milk yield of Brown Swiss cows at the beginning of lactation in summer

Age (months)	N	Actual Milk Yield (kg)	Expected Milk Yield (kg)	Correction Factor		
				Method-1	Method-2	Method-3
≤ 24	135	5454±158,7	5901	1,323	1,040	1,189
25-27	893	5679±99,8	5955	1,270	1,030	0,980
28-30	589	5802±104,6	5991	1,244	1,024	1,167
31-33	202	5961±134,2	6023	1,210	1,019	1,146
34-36	63	7150±210,5	6052	1,009	1,014	1,111
37-39	314	6221±119,6	6076	1,160	1,010	1,090
40-42	324	6065±119,6	6096	1,190	1,007	1,090
43-45	272	6261±125,2	6112	1,152	1,004	1,087
46-48	167	6368±145,3	6124	1,133	1,002	1,067
49-51	226	6187±132,1	6133	1,166	1,001	1,035
52-54	239	**7215**±130,4	**6137**	**1,000**	**1,000**	**1,000**
55-57	151	7167±149,9	**6137**	1,007	**1,000**	**1,000**
58-60	154	6279±148,3	6134	1,149	1,001	1,031
61-63	130	6007±158,4	6126	1,201	1,002	1,082
64-66	127	6109±159,7	6115	1,181	1,004	1,107
67-69	92	6045±179,7	6099	1,194	1,006	1,120
70-72	93	6200±179,5	6080	1,164	1,009	1,134
73-78	145	5673±152,4	6048	1,272	1,015	1,156
79-84	97	5840±175,3	5986	1,235	1,025	1,165
85-96	142	5826±153,1	5849	1,238	1,049	1,184
97-108	87	5528±183,3	5647	1,305	1,087	1,207
≥ 109	77	5362±192,9	5491	1,346	1,118	1,233
Total	4719			$Y = 5477.6 + 24.14X^{***} – 0.22X^{2***}$		

*** P<0.0001

305-day, the milk yield of the youngest cow (≤ 24th month) must therefore be multiplied by 1.040 and the milk yield of the oldest cow (≥ 109th month) by 1.118.

The gross comparison method was used to calculate the highest expected milk yield of cows calving in summer in the age group from 52 to 57 months. To estimate the daily milk yield ME-305-day, the milk yield of the youngest cows (≤ 24th month) must therefore be multiplied by 1.189 and the milk yield of the oldest cows (≥ 109th month) by 1.233.

Using the simple average method, the adjustment factors for mature age were calculated by dividing the milk yield (7054 kg) at 58-60 months of age for cows calving in the fall by the milk yield of the other monthly age groups (Table 2). Thus, to estimate the daily milk yield of ME-305-day, the milk yield of the youngest cows (≤ 24th month) must be multiplied by 1.143 and the milk yield of the oldest cows (≥ 109th month) by 1.418.

According to the polynomial regression method, the highest expected milk yield of cows that calved in the fall was calculated in the age group 55-60 months (6481 kg). Accordingly, to estimate the daily milk yield ME-305-day, the milk yield of the youngest cows (≤ 24th month) must be multiplied by 1.065 and the milk yield of the oldest cows (≥ 109th month) by 1.184.

The gross comparison method was used to calculate the highest expected milk yield of cows calving in the fall in the 55-60-month age group. Therefore, to estimate the daily milk yield ME-305-day, the milk yield of the youngest cows (≤ 24th month) must be multiplied by 1.055 and the milk yield of the oldest cows (≥ 109th month) by 1.142.

Using the simple average method, the adjustment factors for mature age were calculated by dividing the milk yield (7101 kg) at 37-39 months of age for cows calving in winter by the milk yield of the other

Table 3. Age adjustment factors for milk yield in Brown Swiss cows that started lactation in the fall

Age (months)	N	Actual Milk Yield (kg)	Expected Milk Yield (kg)	Correction Factor		
				Method-1	Method-2	Method-3
≤ 24	123	6169±164,5	6087	1,143	1,065	1,055
25-27	735	6178±102,6	6134	1,142	1,057	1,053
28-30	545	6167±106,3	6198	1,144	1,046	1,048
31-33	216	6142±134,6	6255	1,148	1,036	1,042
34-36	53	6952±233,8	6306	1,015	1,028	1,029
37-39	281	6495±127,1	6350	1,086	1,021	1,018
40-42	327	6483±121,3	6388	1,088	1,015	1,013
43-45	251	6407±131,0	6420	1,101	1,010	1,010
46-48	189	6836±144,0	6445	1,032	1,006	1,006
49-51	210	6661±138,5	6463	1,059	1,003	1,003
52-54	184	6385±144,9	6475	1,105	1,001	1,001
55-57	160	6443±151,8	**6481**	1,095	**1,000**	**1,000**
58-60	156	**7054±153,3**	**6480**	**1,000**	**1,000**	**1,000**
61-63	168	6463±149,0	6473	1,091	1,001	1,001
64-66	115	6028±171,4	6459	1,170	1,003	1,002
67-69	95	6382±184,2	6439	1,105	1,007	1,006
70-72	86	6429±191,7	6412	1,097	1,011	1,012
73-78	144	6329±157,1	6366	1,115	1,018	1,022
79-84	90	6612±188,1	6276	1,067	1,033	1,040
85-96	100	5969±180,2	6067	1,182	1,068	1,071
97-108	64	5649±216,5	5722	1,249	1,133	1,109
≥ 109	73	4973±204,8	5473	1,418	1,184	1,142
Total	4365			$Y = 5308.4 + 41.09X^{***} – 0.36X^{2***}$		

*** P<0.0001

monthly age groups (Table 2). Thus, to estimate the daily milk yield of ME-305-day, the milk yield of the youngest cows (≤ 24th month) must be multiplied by 1.019 and the milk yield of the oldest cows (≥109th month) by 1.428.

Using the polynomial regression method for cows calving in winter, the highest expected milk yield was calculated by dividing the milk yield obtained at 55-63 months of age (6577 kg) by the milk yield of the other monthly age groups (Table 2). To estimate the daily milk yield ME-305-day, the milk yield of the youngest cow (≤ 24th month) must therefore be multiplied by 1.067 and the milk yield of the oldest cow (≥ 109th month) by 1.135.

The gross comparison method was used to calculate the highest expected milk yield of cows calving in winter in the age group 37-39 months. Therefore, to estimate the daily milk yield ME-305-day, the milk yield of the youngest cow (≤ 24th month) must be multiplied by 1.079 and the milk yield of the oldest cow (≥109th month) by 1.223.

DISCUSSION

In this study, adjustment factors were calculated for the milk yield of the Turkish Brown Swiss population as a function of age at maturity. In all 3 methods, the adjustment factors were calculated considering 4 calving seasons.

As expected, the trend of multiplicative adjustment factors gradually decreased from the youngest age to the mature age and then gradually increased. The results obtained in this study were consistent with the results obtained in Brown Swiss cattle (Çilek and Tekin, 2006a; İnci et al., 2007; Çilek and Goto, 2012); Simmental cattle (Kaygisiz et al., 1998; Çilek and Tekin, 2006b); Red Chittagong cattle (Habib et al., 2012) and Holstein Friesian cattle (Açıkgöz et al., 2004; Bakri and Djemali, 2021). Similar to these

Table 4. Age Adjustment factors for the milk yield in Brown Swiss cows started lactation in winter

Age (months)	N	Actual Milk Yield (kg)	Expected Milk Yield (kg)	Correction Factor		
				Method-1	Method-2	Method-3
≤ 24	143	6969±164,5	6166	1,019	1,067	1,079
25-27	807	6078±102.6	6250	1,168	1,052	1,096
28-30	708	5867±106.3	6307	1,210	1,043	1,106
31-33	252	5942±134.6	6358	1,195	1,034	1,094
34-36	308	6995±127.1	6404	1,015	1,027	1,048
37-39	61	**7101**±233.8	6445	**1,000**	1,021	**1,000**
40-42	393	6483±121.3	6480	1,095	1,015	1,002
43-45	292	6407±131.0	6510	1,108	1,010	1,007
46-48	202	6836±144.0	6534	1,039	1,007	1,007
49-51	245	6661±138.5	6553	1,066	1,004	1,008
52-54	220	6385±144.9	6566	1,112	1,002	1,015
55-57	190	6443±151.8	**6574**	1,102	**1,000**	1,021
58-60	135	6654±153.3	**6577**	1,067	**1,000**	1,027
61-63	154	6463±149.0	**6574**	1,099	**1,000**	1,036
64-66	129	6028±171.4	6566	1,178	1,002	1,051
67-69	121	6382±184.2	6553	1,113	1,004	1,052
70-72	82	6429±191.7	6534	1,105	1,007	1,044
73-78	164	6329±157.1	6495	1,122	1,013	1,042
79-84	113	6612±188.1	6425	1,074	1,024	1,054
85-96	116	5969±180.2	6279	1,190	1,047	1,097
97-108	68	5649±216.5	6009	1,257	1,094	1,152
≥ 109	60	4973±204.8	5797	1,428	1,135	1,223
Total	4963			$Y = 5532.8 + 35.47X^{***} - 0.30X^{2***}$		

*** $P<0.0001$

research results, Çilek and Tekin (2006a) reported that high milk yield (4750 kg) was observed in the age group of 76-80 months old Brown Swiss cows in the Ulaş farm of Türkiye, while Çilek and Goto (2012) reported that milk yield was reached at the seventh calving in Brown Swiss cattle ($P<0.05$).

Cows that calved in spring, summer, fall and winter reached their adult milk yield of 305-day at 64-66 months, 52-54 months, 58-60 and 37-39 months, respectively.

The current results therefore show that cows that calve in winter reach mature age earlier than cows that calve at other times of the year. The milk yield of cows that calve in winter is higher in the first months of lactation due to the good nutrient level. When evaluating the Türkiye in general, dairy cows are more disturbed by heat than by cold. In this study, Cows that calves in spring have a low milk yield after the peak of lactation because they are exposed to high ambient temperatures.

In Türkiye, temperatures vary significantly across seasons, influencing dairy cattle performance. Spring temperatures range between 10.5°C in January and 29°C in July in coastal areas like Antalya, while the interior regions experience more extreme seasonal variation with higher summer temperatures, often exceeding 30°C. Cows calving in spring are exposed to increasingly high temperatures shortly after lactation peak (Turkish State Meteorological Service, 2023). High ambient temperatures, particularly in summer, can lead to heat stress, which is known to negatively impact milk yield. Heat stress reduces feed intake, impairs metabolic processes, and disrupts the hormonal balance required for optimal milk production. Consequently, cows calving during the warmer months may experience a decline in milk yield after the lactation peak due to these environmental stressors. This is why spring-calving cows often show reduced productivity in the latter stages of lactation compared to those calving in cooler seasons, where the risk of heat stress is minimized.

The results of this study are similar to the findings of Çilek and Tekin (2005), who reported that the influence of calving season on milk yield is important and that milk yield is high in cows that calve in winter. On the other hand, maximum milk production in Friesian cattle in Egypt was recorded at 76.9, 78.8, 85.7, 96.8 and 80.1 months of age in winter, spring, summer and fall, respectively (Khattap and Ashmawy, 1990). In the Kazova farm, it was reported that high milk yield (5111 kg) was observed in Simmental cows calving at 104-108 months of age (Çilek and Tekin, 2006b). On the same farm, Kaygisiz et al. (1998) reported that cows calving in the fall reach mature age (4th lactation) earlier than those calving at other times of the year. It has been reported that the milk yield of Simmental cows in Çorum province, which was low in the first lactation, increased in the second lactation and decreased in the following lactations (Bolacali and Öztürk, 2018).

The reproduction rate in dairy cows is slightly lower than in other animal species, and on average one female offspring is produced per cow every 2.5 years (Şahin, 2023). For this reason, the number of heifers that can be added to the herd is limited. Accordingly, in the case of intensive selection among cows, it is more appropriate to apply the simple average method (Vanlı et al., 2024)

On the other hand, it can be seen that milk yield begins to fall in all seasonal groups after reaching a mature age, but increases again from a certain age (Figure 1). This increase can be explained by the fact that high-yielding cows are kept in the herd.

CONCLUSIONS

This study aligns with previous research findings, indicating that cows giving birth in winter have significantly higher milk yields. It is suggested that conducting studies with large datasets can lead to more precise correction factors by minimizing sampling errors. In contrast to the previously published studies, this study used a much larger data set for Türkiye to calculate the adjustment factors. It is therefore to be expected that the resulting adjustment factors will contain fewer sampling errors.

In this study, three methods for calculating adjustment factors were employed: the simple average method, the polynomial regression method, and the gross comparison method.

- The simple average method is straightforward, but it can yield biased results when sample sizes within subclasses are uneven, as it does not account for more complex relationships between age and milk yield (Anonymous, 2023).
- The polynomial regression method provides a more refined approach, modeling the relationship between age and yield through a quadratic equation. This method reduces bias by accounting for these relationships dynamically, offering greater precision in adjusting for age effects (Martinez et al., 1990). However, it requires more complex calculations.
- The gross comparison method is a practical and easy-to-implement approach but may favor high-performing cows due to its method of adjusting based on the highest yielding subgroup. This can lead to biases, particularly when low-performing cows are culled early (Wu et al., 2023).

Among these, the polynomial regression method is the most advantageous. It offers the highest precision by modeling the non-linear relationship between age and yield, making it the most reliable for generating accurate adjustment factors. While it is more computationally intensive, its ability to minimize bias and provide more consistent results makes it the preferred method for standardizing milk yield in this context.

The primary advantage of this study lies in its use of a larger sample size, which helps reduce sampling errors and provides more reliable correction factors. This leads to more accurate adjustment of milk yield data, improving the overall precision of genetic evaluations (Vanlı et al., 2024).

The practical implication of these improvements is that better adjustment factors allow for the selection of more suitable replacement heifers, leading to improved genetic progress. This results in enhanced milk yield and potentially greater profitability for producers, as higher-yielding cows contribute to more efficient production. The ability to more accurately assess milk yield across different ages and seasons can also help optimize farm management decisions, ultimately boosting both milk production and economic returns.

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ETHICS APPROVAL

There was no physical or visual contact with animals, in this study was used records belonging to Central Union of Cattle Breeders of Türkiye in the study.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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