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Evaluation of Milk Yield and Reproductive Performance of Pure Holstein and Its F1 Crossbreds with Montbeliarde in Egypt

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ABSTRACT

The present study was carried out to compare the milk yield and reproductive performance of pure Holstein (HO) cows with those of their first generation (F1) crossbreds with Montbeliarde cows (MO) in four commercial dairy herds under Egyptian conditions. Data used in the current study comprised 2268 records for the first four lactations of 531 HO and 536 MO × HO F1 crossbred cows during the period between 2012 and 2020. Data were analyzed using the least squares method by XLSTAT software. The MO × HO crossbred cows were significantly superior compared with pure HO cows for 305-day milk yield, scoring 9210 ± 96 kg versus 7987 ± 149 kg. Moreover, MO × HO F1 crossbred cows had a significantly higher daily milk yield (30.0 ± 0.45 kg) than pure HO cows (25.9 ± 0.52 kg). However, pure HO cows had significantly greater days in milk (399 ± 6 days) than MO × HO crossbred cows (341 ± 5.2 days). With regard to reproductive performance, MO × HO F1 crossbred cows had significantly less number of services per conception and days open than pure HO cows (2.6 ± 0.16 vs. 3.7 ± 0.18) and (132 ± 5.2 days vs. 190 ± 6 days), respectively. However, the statistical difference between MO × HO F1 crossbred cows and pure HO cows for age at first calving was not significant (22.9 ± 0.11 vs. 23.1 ± 0.15 months, respectively). It can be concluded that under Egyptian subtropical conditions, the first generation of MO × HO crossbred cows exhibit better performance, compared to pure HO cows in milk yield and reproductive traits. These findings could provide an effective strategic option for the genetic improvement of dairy cattle in hot subtropical regions.

Keywords: Crossbreeding, Egypt, Holstein, Milk Yield, Montbeliarde, Reproduction

INTRODUCTION

Over the last decades, worldwide milk production has been dominated by the Holstein (HO) breed due to the intensive continuous selection for milk production (Heins et al., 2012). However, the superiority in milk production had direct negative effects on other functional traits related to survival and reproduction as a result of consistent increases of inbreeding leading to higher rates of culling and reduction of profitability (Heins et al., 2012; Puppel et al., 2018).

To overcome these challenges, dairy cattle holders have tended to use the crossbreeding between pure Holstein and other dairy breeds. Crossbreeding dairy breeds may be a feasible way to achieve significant improvement in milk yield, fertility, and health characteristics more quickly than pure breeding (Dezetter et al., 2017). Crossbreeding seeks to take advantage of positive heterosis effects and complementarity between dairy breeds by introducing the desirable genes and decreasing the rate of inbreeding (Sørensen et al., 2008; Knob et al., 2020; Clasen et al., 2021).

Several previous studies have been conducted to compare the performance of pure Holstein with their first generation (F1) crosses, including HO × Simmental cows (Knob et al., 2020; Knob et al., 2021), HO ×Viking Red cattle (Hazel et al., 2017a), HO × Nordic Red cattle (Clasen et al., 2018), HO × Jersey cows (Prendiville et al., 2010), and HO × Brown Swiss (Blöttner et al., 2011; El-Tarabany et al., 2016). These studies had shown positive outcomes of crossbred cows compared with pure HO cows especially for fertility, health, and survival traits with the possibility to increase the rate of genetic gain for these economically valuable traits (Shonka-Martin et al., 2019; Clasen et al., 2021).

Recently, the Montbeliarde (MO) breed has received considerable interest as the best complement with Holstein in crossbreeding programs (Hazel et al., 2017a). Montbeliarde is a French breed that was subjected to heavy selection for fertility, health traits, body condition, and milk quality traits (Heins and Hansen, 2012; Hazel et al., 2017a). Numerous comparative studies have been conducted between pure HO and MO × HO crossbreds to assess their productive and reproductive performances. The productive traits in terms of milk, fat, and protein yields were very close between the two genetic groups with slightly higher estimates for pure HO cows (Hazel et al., 2013; Buckley et al., 2014; Hazel et al., 2014).

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However, MO × HO crossbred cows revealed superiority compared to pure HO cows for fertility traits in terms of first-service conception rates, days open, days to first breeding, and a number of services per conception (Hazel et al., 2014; Hazel et al., 2017a). Likewise, MO × HO crossbred cows had advantages over pure HO cows for survival traits, including survival of subsequent calving and mortality rates (Heins et al., 2012; Hazel et al., 2014; Hazel et al., 2017a). Consequently, MO × HO crossbred cows had greater longevity and lower total health cost per cow than pure HO cows which means greater profitability for crossbreds. Furthermore, the calves resulted from the mating of Montbeliarde sires with Holstein dams had significantly greater birth weight than calves from pure HO with no significant increase in calving difficulty and stillbirth rate (Heins et al., 2010). Also, milk from MO × HO crossbred cows exhibits a lower somatic cell score compared with milk from pure HO cows (Heins and Hansen, 2012).

In Egypt, the performance of HO and its crosses with different breeds has been intensively studied (Ibrahim et al., 2009; Rushdi, 2015; El-Tarabany et al., 2016). But, no available studies were found concerning the milk yield or reproductive traits on MO × HO crosses. Therefore, this work is considered the first study on the Montbeliarde cows in Egypt. The objective was to compare the milk yield and reproductive performance of pure Holstein cows with those of first generation crossbreds of Montbeliarde with Holstein cows in four commercial dairy herds in Egypt.

MATERIALS AND METHODS

Ethical approval

The study was carried out with existing records from four commercial dairy herds and did not involve animal handling.

Data collection

Data of productive and reproductive traits used in the current study were collected from 2268 records for the first four lactations of 531 pure HO and 536 first generation crossbred MO × HO cows. These records covered the period from 2012 to 2020. Pure Ho cows were daughters of 42 sires, whereas, MO × HO crossbred cows were daughters of 23 Montbeliarde sires. Cows in this study either pure HO or MO × HO crossbred were generated from artificial insemination (AI) proven bulls from the United States for both HO and MO breeds mated to locally born pure Holstein dams. The locally born HO cows originated from European HO dams. Data used were provided from four commercial dairy herds where pure HO and MO × HO crossbred cows were kept together all the time. These herds were located at four different governorates namely (herd one: Helaly farm, Dakahlia governorate, herd two: Osama Nigm farm, Gharbia governorate, herd three: Elyosr farm, Ismailia governorate, and herd four: Shash farm, Sharkia governorate). Table 1 indicates the distribution of the two genotypes among the four herds. All the data for the four herds were entered using Dairy Live 0.3 software (Version, 5.208A, USA) manually by the managers and owners.

Table 1. Distribution of Holstein cows and Montbeliarde × Holstein F1 crossbred cows among the four herds

Herd	HO	MO × HO	Total
Helaly farm, Dakahlia governorate	25	64	89
Osama Nigm farm, Gharbia governorate	64	73	137
Elyosr farm, Ismailia governorate	412	270	682
Shash farm, Sharkia governorate	30	129	159
Total	531	536	106

HO: Holstein cows, MO × HO: Montbeliarde × Holstein F1 crossbred cows

Herd management

All cows in the four herds were fed an *ad libitum* total mixed ration (TMR) diet consisting of 50 % forage and 50 % concentrate and was adjusted monthly to account for dry matter. The ingredients consist of corn silage, Alfalfa hay or Egyptian clover, soybean meals, ground corn, vitamins and minerals, yeast, and other additives. Cows were fed 4-5 times a day by a TMR mixer. Cows were machine milked three times per day and housed in open yards equipped with a cooling system in groups depending on milk production level and lactation number. Automated recording of milk yield was conducted on daily basis to calculate the aggregated total milk production for each cow. Cows were dried off two months before the expected calving dates. The crossbred heifers have inseminated artificially for the first time when reached 12-13 months and 350-370 Kg. The pregnant cows were determined via ultrasound at 28-33 days after insemination, follow-up confirmation via rectal palpation at approximately 60 and 100 days after inseminated.

Studied traits

The milk yield traits were total milk yield (TMY, kg) calculated by the cumulated amount of milk yield in kilograms of a cow throughout the lactation period, 305-day milk yield (305-dMY, kg) calculated using the International Committee for Animal Recording equation (ICAR, 2000) as follows:

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The 305-dMY = [(TMY+405) / (100+LP)]

where, TMY is the total milk yield and LP signifies lactation period, days in milk (DIM, days) is defined as a number of days in milk from calving to drying-off date, and daily milk yield (DMY, kg) is calculated by dividing total milk yield in kilograms by lactation period length in days. The reproductive traits included age at first calving (AFC, months) which is defined as the number of months from birth to first calving date of the cow, number of services per conception (NSPC) denotes the number of artificial insemination times required for each cow to be pregnant, and days open (DO, days) is estimated by the number of days from calving date to conception date. The descriptive statistics of the milk yield and reproductive studied traits dataset are presented in Table 2.

Table 2. Descriptive statistics of the milk yield and reproductive studied traits for Holstein cows and Montbeliarde × Holstein F1 crossbred cows in Egypt

Variable	N	Minimum	Maximum	Mean	SD
Milk yield traits					
Total milk yield (kg)	2268	2131	22491	9597	2226
305-day milk yield (kg)	2268	1833	21376	8544	2299
Days in milk (days)	2268	230	1071	358	99.3
Daily milk yield (kg)	2268	5.6	72.5	28.3	8.61
Reproductive traits					
Age at first calving (months)	1045	20	33	24	2.7
Number of services per conception	2268	1	18	3.2	2.7
Days open (days)	2268	23	866	151	99.1

N: Number of observations, SD: Standard deviation

Statistical analysis

Data were analyzed using the least square means technique as applied in XLSTAT 2020.3.1.27 program with the following two statistical models.

To analyze TMY, 305-dMY, DIM, DMY, NSPC, and DO, model 1 was used as follows:

$Y_{ijklmn} = \mu + G_i + H_j + P_k + S_l + Y_m + (G \times H)_{ij} + e_{ijklmn}$ (Model 1)

Where, Y_{ijklmn} is the observations on TMY, 305-MY, DIM, DMY, NSPC, and DO, µ refers to the overall mean, G_i stands for the fixed effect of the i^{th} genotype (i=1, 2), in which, 1: pure HO cows and 2: HO × MO F1 crossbred cows, H_j signifies the fixed effect of the j^{th} herd (j:1, 2, 3 and 4), where, 1: Helaly farm, Dakahlia governorate; 2: Osama Nigm farm, Gharbia governorate; 3: Elyosr farm, Ismailia governorate and 4: Shash farm, Sharkia governorate, P_k is the fixed effect of the k^{th} parity (k:1, 2, 3 and 4), S_l refers to the fixed effect of the l^{th} season of calving (l:1, 2, 3 and 4), where, 1: winter (December to February), 2: spring (March to May), 3: summer (June to August), and 4: autumn (September to November), Y_m signifies the fixed effect of the m^{th} year of calving, starting from 2012 and ending by 2020, $(G \times H)_{ij}$ is the effect of the interaction between i^{th} genotype and j^{th} herd, and e_{ijklmn} is residual error assumed to be N I D (0, σ^2e).

To analyze AFC, model 2 was employed.

$Y_{ijkmn} = \mu + G_i + H_j + S_k + Y_m + e_{ijkmn}$ (Model 2)

Where, Y_{ijkmn} is the observations of AFC, µ refers to the overall mean, G_i stands for the fixed effect of the i^{th} genotype (i:1, 2), where, 1: pure HO cows and 2: HO × MO F1 crossbred cows, H_j signifies the fixed effect of the j^{th} herd (j:1, 2, 3 and 4), where, 1: Helaly farm, Dakahlia governorate; 2: Osama Nigm farm, Gharbia governorate; 3: Elyosr farm, Ismailia governorate and 4: Shash farm, Sharkia governorate, S_k is the fixed effect of the k^{th} season of birth (l:1, 2, 3 and 4), where, 1: winter (December to February), 2: spring (March to May), 3: summer (June to August), and 4: autumn (September to November), Y_m is the fixed effect of the m^{th} year of birth, starting from 2011 and ending by 2017, and e_{ijkmn} is residual error assumed to be N I D (0, σ^2e).

RESULTS AND DISCUSSION

Milk yield

The least squares means (LSM) and standard errors (SE) for TMY, 305-dMY, DIM, and DMY are presented in Table 3. It could be observed that MO × HO crossbred cows have higher TMY (9827 ± 119 kg), compared with pure HO cows (9616 ± 138 kg) but the difference was not statistically significant ($p > 0.05$). On the other hand, MO × HO crossbred cows had significantly ($p < 0.05$) higher 305-dMY (9210 ± 96 kg) than pure HO (7987 ± 149 kg). Pure HO cows had significantly greater DIM (399 ± 6 days) than MO × HO crossbred ones (341 ± 5.2 days). Crossbred cows showed significantly superior milk yield performance, compared to pure HO cows due mainly to their higher DMY (30.0 ± 0.45 kg versus 25.9 ± 0.52 kg, respectively).

The herd had a significant effect on TMY, 305-dMY, and DMY ($p < 0.05$) with the highest values observed for herd one (Helaly farm, Dakahlia governorate, Egypt), scoring 10195 ± 179 kg, 9003 ± 191 kg, and 29.4 ± 0.67 kg for

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TMY, 305-dMY, and DMY, respectively. While the lowest values were recorded for herd three (Elyosr farm, Ismailia governorate, Egypt), having 8933 ± 161 kg, 7910 ± 148 kg, and 25.6 ± 0.61 kg for TMY, 305-dMY, and DMY, respectively. However, the length of DIM was not significantly different across herds.

The interaction of the genotype and herd was significant for all productive traits ($p < 0.05$, Table 4). The LSM of TMY, 305-dMY, DIM, and DMY for genotype by herd revealed that MO × HO crossbred cows exhibited significant superiority than pure HO cows under the same management system for TMY, 305-dMY, and DMY across herds one, two, and four with significantly longer DIM for pure HO cows. Among the different herds, MO × HO crossbred cows located in herd one had a magnitude advantage for TMY and DMY over other crossbreds herds. However, pure HO cows exhibited a significant superiority over MO × HO crossbred cows for TMY in herd three with relatively higher LSM of 305-dMY and DMY for MO × HO cows, compared to HO cows without any significant differences for 305-dMY and DMY between the two genotypes.

Table 3. Least squares means and standard errors of milk yield traits for Holstein cows and Montbeliarde × Holstein F1 crossbred cows in Egypt

Classification	N	Traits			
		TMY (kg)	305-dMY (kg)	DIM (days)	DMY(kg)
		LSM±SE	LSM±SE	LSM±SE	LSM±SE
The overall mean	2268	9722 ± 47	8598 ± 48	370 ± 2.1	27.9 ± 0.18
Genotype		NS	*	*	*
HO	1096	9616^{a} ± 138	7987^{a} ± 149	399^{b} ± 6	25.9^{a} ± 0.52
MO × HO	1172	9827^{a} ± 119	9210^{b}± 96	341^{a} ± 5.2	30.0^{b} ± 0.45
Herd		*	*	NS	*
1	236	10195^{c} ± 179	9003^{b} ± 191	370^{a} ± 7.8	29.4^{b} ± 0.67
2	311	10094^{c} ± 153	8923^{b} ± 178	372^{a} ± 6.6	28.8^{b} ± 0.57
3	1338	8933^{a} ± 161	7910^{a} ± 148	369^{a} ± 7	25.6^{a} ± 0.61
4	383	9664^{b} ± 182	8557^{b} ± 193	368^{a} ± 7.9	28^{b} ± 0.68
Parity		*	*	NS	*
1	1052	9384^{a} ± 109	7999^{a} ± 106	377^{a} ± 4.7	26.6^{a} ± 0.41
2	768	9603^{b} ± 121	8735^{b} ± 108	367^{a} ± 5.2	27.8^{b} ± 0.45
3	344	9714^{bc} ± 152	8748^{b} ± 150	366^{a} ± 6.6	28.1^{b} ± 0.57
4	104	10185^{c} ± 237	8910^{b} ± 263	370^{a} ± 10.3	29.3^{b} ± 0.89
Season of calving		*	*	*	*
Winter	736	9522^{a} ± 123	8622^{b} ± 110	363^{b} ± 5.4	28.3^{b} ± 0.46
Spring	243	9783^{ab} ± 181	8221^{a} ± 166	397^{d} ± 7.8	26.5^{a} ± 0.68
Summer	427	9731^{ab} ± 145	8503^{ab} ± 128	375^{c} ± 6.3	27.1^{a} ± 0.54
Autumn	862	9850^{b} ± 119	9047^{c} ± 101	345^{a} ± 5.2	29.9^{c} ± 0.45
Year of calving		*	*	*	*
2012	13	8866^{a} ± 622	7223^{a} ± 589	348^{b} ± 27	26.1^{bc} ± 2.33
2013	69	8575^{a} ± 288	7112^{a} ± 214	417^{e} ± 12.5	22.5^{a} ± 1.08
2014	145	8907^{a} ± 212	7457^{a} ± 202	406^{de} ± 9.2	23.6^{ab} ± 0.80
2015	200	9282^{a} ± 181	7953^{b} ± 188	385^{cde} ± 7.9	26^{bc} ± 0.68
2016	317	10146^{b} ± 140	8569^{c} ± 146	382^{cd} ± 6.1	28.4^{cd} ± 0.53
2017	348	10656^{b} ± 137	9522^{d} ± 142	371^{bc} ± 6	30.7^{de} ± 0.51
2018	553	10382^{b} ± 137	9106^{d} ± 141	361^{bc} ± 5.9	30.5^{de} ± 0.51
2019	572	10185^{b} ± 141	9283^{d} ± 145	346^{b} ± 6.1	30.6^{de} ± 0.53
2020	51	10495^{b} ± 333	9323^{d} ± 374	313^{a} ± 14.5	33.5^{e} ± 1.25
Genotype and herd interaction	2268	*	*	*	*

Means followed by different superscripts within each column are significantly different (*$p < 0.05$), LSM±SE: Least squares means ± standard errors, N: Number of observations, NS: Non-significant, TMY: Total milk yield, 305-dMY: 305-day milk yield, DIM: Days in milk, DMY: Daily milk yield, HO: Holstein cows, MO × HO: Montbeliarde × Holstein F1 crossbred cows, herd 1: Helaly farm, Dakahlia governorate, herd 2: Osama Nigm farm, Gharbia governorate, herd 3: Elyosr farm, Ismailia governorate, herd 4: Shash farm, Sharkia governorate

Table 4. Least squares means and standard errors of interaction between genotypes and cow herds

Traits	Herd 1		Herd 2		Herd 3		Herd 4	
	HO (n=25)	MO × HO (n=64)	HO (n=64)	MO × HO (n=73)	HO (n=412)	MO × HO (n=270)	HO (n=30)	MO × HO (n=129)
TMY (kg)	10001^{cd} ± 283	10389^{d}±189	9800^{c} ± 200	10388^{d}±192	9166^{b} ± 163	8700^{a} ± 182	9498^{bc} ± 293	9830^{c} ± 158
305-dMY (kg)	8102^{a} ± 300	9904^{c} ± 196	7908^{a} ± 239	9938^{c} ± 207	7790^{a} ± 161	8030^{a} ± 183	8146^{a} ± 325	8967^{b} ± 151
DIM (days)	415^{de} ± 12.3	326^{a} ± 8.2	416^{e} ± 8.7	327^{a} ± 8.4	382^{c} ± 7.1	356^{b} ± 7.9	382^{cd} ± 12.7	354^{b} ± 6.8
DMY(kg)	26^{a} ± 1.06	32.9^{c} ± 0.71	25.2^{a} ± 0.75	32.4^{c} ± 0.72	25.4^{a} ± 0.61	25.7^{a} ± 0.68	26.9^{ab} ±1.10	29.1^{b} ± 0.59
NSPC	3.9^{cd} ± 0.34	2.1^{a} ± 0.23	3.8^{cd} ± 0.25	2.0^{a} ± 0.24	4.1^{d} ± 0.26	3.8^{cd} ± 0.28	3.2^{bc} ± 0.39	2.4^{ab} ± 0.20
DO (days)	204^{d} ± 12.3	116^{a} ± 8.2	205^{d} ± 8.7	116^{a} ± 8.4	176^{c} ± 7.1	149^{b} ± 7.9	175^{c} ± 12.7	145^{b} ± 6.8

Means within a row with different superscript are significantly different (*$p < 0.05$), Results are expressed as mean value ± standard error, HO: Holstein cows, MO × HO: Montbeliarde × Holstein F1 crossbred cows, TMY: Total milk yield, 305-dMY: 305-day milk yield, DIM: Days in milk, DMY: Daily milk yield, NSPC: Number of services per conception, DO: Days open, n: Number of cows, herd 1: Helaly farm, Dakahlia governorate, herd 2: Osama Nigm farm, Gharbia governorate, herd 3: Elyosr farm, Ismailia governorate, herd 4: Shash farm, Sharkia governorate

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Parity had a significant effect ($p < 0.05$) on TMY, 305-dMY, and DMY. The three traits increased gradually with increasing parity order. The LSM of TMY, 305-dMY, and DMY were the highest (10185 ± 237 kg, 8910 ± 263 kg, and 29.3 ± 0.89 kg, respectively) at the fourth lactation. The length of DIM was not significantly different across parities.

Season of calving explained a significant variation for all productive traits ($p < 0.05$). The LSM highest estimates for TMY, 305-dMY, and DMY (9850 ± 119 kg, 9047 ± 101 kg, and 29.9 ± 0.45 kg, respectively) were observed in autumn. However, the lowest estimate for TMY (9522 ± 123 kg) was observed in winter, whereas the lowest estimates for 305-dMY (8221 ± 166 kg) and DMY (26.5 ± 0.68 kg) were observed in spring. The length of DIM was significantly different across seasons. The DIM was significantly longer in spring and shorter in autumn.

Year of calving significantly affected all the studied productive traits ($p < 0.05$). Cows calved in 2013 had significantly longer DIM (417 ± 12.5 days), compared with other years. On the contrary, the LSM for TMY (8575 ± 288 kg), 305-dMY (7112 ± 214 kg), and DMY (22.5 ± 1.08 kg) were significantly lower for cows calving in 2013. On the other hand, DIM (313 ± 14.5 days) was significantly shorter for dams that calved in 2020. However, cows that calved in 2017 had significantly greater TMY (10656 ± 137 kg), 305-dMY (9522 ± 142 kg), and DMY (30.7 ± 0.51 kg). It could be observed from Table 3 that the LSM of TMY for calving years (2012 to 2015) was significantly different from the other years.

In contrast to the findings of the present study, many studies have shown that pure Holstein cows tended to have higher total milk yield, and consequently higher daily milk yield than MO × HO crossbred cows during a uniformed lactation period of 305 days. Heins et al. (2006) reported that pure Holstein cows had significantly higher 305-days milk yield (9757 kg) than MO × HO cows (9161 kg) during the first lactation. Likewise, Heins and Hansen (2012) found that pure Holstein cows had significantly higher 305-day milk yield (11417 kg), compared to MO × HO crossbred cows (10744 kg) across the first five lactations. Hazel et al. (2014) observed higher 305-dMY for pure HO cows versus MO ×HO crossbreds without significant difference during their first five lactations. Furthermore, Hazel et al. (2013) reported that MO × HO crossbred cows had significantly lower total milk yield, compared to pure HO cows during the first 150 days of the first lactation. Likewise, 305-dMY was lower for MO × HO crossbred, compared to HO cows without significant difference.

The higher trend of TMY, 305-dMY, and DMY for MO × HO crossbred cows than pure HO cows in the current study could be attributed to the positive heterotic effect for these traits. According to Sørensen et al. (2008), the heterosis effect for yield traits was approximately 3% depending on the average production of the parental purebreds that were crossed as well as environmental conditions. Furthermore, the pure Montbeliarde breed is genetically adapted to hot climates and has a higher heat stress tolerance than pure HO cows (Allouche et al., 2018; Ouarfli and Chehma, 2018). Consequently, MO × HO crossbred cows were able to produce more efficiency under Egyptian subtropical environmental conditions than pure HO cows.

Reproductive performance

Table 5 shows the LSM of NSPC and DO. The effect of genotype on NSPC and DO was significant ($p < 0.05$). Crossbred cows (MO × HO) had significantly lower ($p < 0.05$) NSPC and DO than pure HO cows (2.6 ± 0.16 vs. 3.7 ± 0.18 for NSPC) and (132 ± 5.2 days vs. 190 ± 6 days for DO), respectively with significant advantages of approximately one dose fewer for NSPC and 58 days fewer for DO.

Herds differed significantly ($p < 0.05$) in NSPC which was significantly greater (3.9 ± 0.25) in herd three (Elyosr farm, Ismailia governorate, Egypt). However, DO estimates were not significantly different across herds. The interactions of genotype and herd were significant ($p < 0.05$) for NSPC and DO traits (Table 4). The MO × HO crossbred cows showed significantly lower NSPC and DO, compared to pure HO cows within the same herd with a magnitude advantage for crossbreds found in the first two herds than in the third and fourth herds. Parity had no significant effect on both NSPC and DO. Season of calving explained a significant variation for the two reproductive traits. The NSPC was significantly greater in winter and spring (3.4 ± 0.17 and 3.8 ± 0.27, respectively) compared to summer and autumn (2.7 for both). Dams calved in autumn had significantly shorter DO (136 ± 5.2 days), while cows calved in spring and summer had longer DO (188 ± 7.9 and 165 ± 6.3 days, respectively). Year of calving was a significant source of variation in both NSPC and DO. Cows calved in 2013 had significantly greater NSPC (3.7 ± 0.36) and longer DO (206 ± 12.5 days) compared with other years. Cows calved in 2012 scored the lowest NSPC (2.5 ± 0.74), and those calves in 2020 had significantly the shortest DO (105 ± 14.5 days).

Many studies arrived at the same results of the current study concerning the superiority of MO × HO crossbred cows compared to pure Holstein cows in reproductive traits. Hazel et al. (2017a) reported that the MO × HO cows had fewer bred times (2.07) than pure HO cows (2.30) during the first lactation in eight high-performance dairy herds in the United States. Furthermore, Malchiodi et al. (2014) found that the MO × HO cows were inseminated fewer times (2.02) than the first lactation pure HO cows (2.53). However, Walsh et al. (2008) observed no significant difference in the NSPC between MO × HO cows (1.97) and pure Holstein-Friesian cows (1.98) in Ireland. The results of DO were in

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accordance with those of Hazel et al. (2014) who reported that MO × HO cows had significantly shorter DO (128 days), compared with that of pure HO cows (167 days) during their first five lactations. Similarly, Hazel et al. (2017a) found that MO × HO cows had fewer DO (113 days) than pure HO cows (125 days) during the first lactation. The same trend was observed by Malchiodi et al. (2014) who found that DO was 83.7 days for MO × HO cows versus 109.1 days for HO cows in the first lactation. Heins et al. (2012) also found that DO was 19 days longer for pure HO cows compared with MO × HO crossbred. Furthermore, the current findings agreed with those of Heins and Hansen (2012) who observed that the advance of parity in MO × HO crossbred cows led to a significantly fewer DO ranging from 131 days in the first lactation to 110 days in the fifth lactation. On the other hand, the authors of this study found that pure HO cows tended to have greater DO with the advance of parity with a range from 148 days in the first lactation to 157 days in the fifth lactation.

Table 5. Least squares means and standard errors of number of services per conception and days open for Holstein cows and Montbeliarde × Holstein F1 crossbred cows in Egypt

Classification	N	Traits	
		NSPC	DO (days)
		LSM±SE	LSM±SE
The overall mean	2268	3.2 ± 0.06	161 ± 2.1
Genotype		*	*
HO	1096	3.7^{b} ± 0.18	190^{b} ± 6
MO × HO	1172	2.6^{a} ± 0.16	132^{a} ± 5.2
Herd		*	NS
1	236	3.0^{a} ± 0.22	160^{a} ± 7.8
2	311	2.9^{a} ± 0.19	161^{a} ± 6.6
3	1338	3.9^{b} ± 0.25	162^{a} ± 7
4	383	2.8^{a} ± 0.24	160^{a} ± 7.9
Parity		NS	NS
1	1052	3.4^{bc} ± 0.15	168^{a} ± 4.7
2	768	3.4^{c} ± 0.17	158^{a} ± 5.2
3	344	3^{ab} ± 0.21	157^{a} ± 6.6
4	104	2.8^{a} ± 0.32	160^{a} ± 10.3
Season of calving		*	*
Winter	736	3.4^{b} ± 0.17	154^{b} ± 5.4
Spring	243	3.8^{b} ± 0.27	188^{d} ± 7.9
Summer	427	2.7^{a} ± 0.20	165^{c} ± 6.3
Autumn	862	2.7^{a} ± 0.16	136^{a} ± 5.2
Year of calving		*	*
2012	13	2.5^{a} ± 0.74	138^{b} ± 27
2013	69	3.7^{c} ± 0.36	206^{e} ± 12.5
2014	145	3.6^{bc} ± 0.27	196^{de} ± 9.2
2015	200	3.1^{abc} ± 0.23	174^{cde} ± 7.9
2016	317	3.0^{abc} ± 0.19	173^{bcde} ± 6.1
2017	348	2.7^{ab} ± 0.19	162^{bcd} ± 6
2018	553	3.4^{abc} ± 0.22	153^{bc} ± 6
2019	572	3.4^{abc} ± 0.23	138^{b} ± 6.1
2020	51	2.9^{abc} ± 0.53	105^{a} ± 14.5
Genotype and herd interaction	2268	*	*

Means followed by different superscripts within each column are significantly different (*p < 0.05), LSM±SE: Least squares means ± standard errors, N: number of observations, NS: Non-significant, NSPC: Number of services per conception, DO: Days open, HO: Holstein cows, MO × HO: Montbeliarde × Holstein F1 crossbred cows, herd 1: Helaly farm, Dakahlia governorate, herd 2: Osama Nigm farm, Gharbia governorate, herd 3: Elyosr farm, Ismailia governorate, herd 4: Shash farm, Sharkia governorate

Table 6 shows the LSM of age at first calving (AFC). The values of AFC for the two genotypes were very closed (22.9 ± 0.11 and 23.1 ± 0.15 months for MO × HO and pure HO cows, respectively) and the difference was not significant (p = 0.156). A similar trend was recorded by Hazel et al. (2017b) who found that there was no significant difference for AFC between MO × HO crossbred cows and pure HO cows (23.8 vs. 23.9 months, respectively). All herds could significantly affect AFC (p < 0.05) with the highest value observed for Shash farm, Sharkia governorate (25.7 ± 0.20 months). While heifers of herd two (Osama Nigm farm, Gharbia governorate, Egypt) had the lowest AFC with 21 ± 0.19 months. The effect of the season of birth was significant (p < 0.05) on AFC. Heifers born in spring had significantly lower AFC (22.6 ± 0.16 months) and calved for the first time 0.7 months earlier than those born in summer (23.3 ± 0.16 months). Also, the year of birth affected significantly AFC (p < 0.05). Heifers born in 2015 significantly showed the highest AFC of 24.1 ± 0.18 months, compared with other years.

In the current study, despite MO × HO crossbred cows scored a high mean of milk yield, they revealed better and significant reproductive performance than that of pure HO ones. This result showed the positive heterosis direction for

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fertility along with milk yield traits for the first generation of MO × HO crossbred cows under Egyptian subtropical conditions.

Table 6. Least squares means and standard errors of age at first calving for Holstein cows and Montbeliarde × Holstein F1 crossbred cows in Egypt

Classification	N	Trait
		AFC (months)
		LSM±SE
The overall mean	1045	22.9 ± 0.08
Genotype		NS
HO	524	$23.1^{a} \pm 0.15$
MO × HO	521	$22.9^{a} \pm 0.11$
Herd		*
1	87	$21.1^{a} \pm 0.26$
2	136	$21^{a} \pm 0.19$
3	152	$24.2^{b} \pm 0.14$
4	670	$25.7^{c} \pm 0.20$
Season of birth		*
Winter	317	$23.1^{bc} \pm 0.13$
Spring	172	$22.6^{a} \pm 0.16$
Summer	177	$23.3^{c} \pm 0.16$
Autumn	379	$22.9^{ab} \pm 0.13$
Year of birth		*
2011	61	$22.7^{a} \pm 0.26$
2012	105	$22.7^{a} \pm 0.21$
2013	75	$22.6^{a} \pm 0.23$
2014	172	$23.1^{a} \pm 0.17$
2015	218	$24.1^{b} \pm 0.18$
2016	271	$23.1^{a} \pm 0.19$
2017	143	$22.8^{a} \pm 0.23$

Means followed by different superscripts within each column are significantly different (*p < 0.05), LSM±SE: Least squares means ± standard errors, N: Number of observations, NS: Non-significant, AFC: Age at first calving, HO: Holstein cows, MO × HO: Montbeliarde × Holstein F1crossbred cows, herd 1: Helaly farm, Dakahlia governorate, herd 2: Osama Nigm farm, Gharbia governorate, herd 3: Elyosr farm, Ismailia governorate, herd 4: Shash farm, Sharkia governorate

The reasons behind the superiority of MO × HO crossbred cows, compared to pure Holstein cows, for fertility traits were explained in several previous studies. Hazel et al. (2013) and Hazel et al. (2014) found that the body traits of MO × HO crossbred cows were characterized by significantly greater body weight and body condition score (BCS) without consuming extra dry matter intake than pure HO cows across the first five lactations. The larger body characteristics for MO × HO crossbred cows were attributed to continuous selection for BCS and feed efficiency for pure MO breed that was in contrast to breeding goal for HO breed to enhance angularity features. Greater BCS at the time of calving or less loss in BCS after calving increases the reproductive ability for cows in the next parity (Hazel et al., 2014). Likewise, greater BCS for MO × HO crossbred cows was associated with enhancement of immunity and a lower rate of health problems, and consequently, improved the reproductive performance for MO × HO crossbred cows than pure HO cows (Walsh et al., 2008; Hazel et al., 2013; Hazel et al., 2017a).

Furthermore, Sørensen et al. (2008) stated that the heterosis estimate for fertility traits was at least 10% for the first generation crosses when unrelated two breeds are mating involving HO cows. The power of the heterosis for fertility traits could be generated from the new combinations of additive genetic effects in the F1 crosses. Moreover, crossing between unrelated breeds contributed to significant changes in genes interaction within and among loci in terms of non-additive genetic effects of dominance and epistasis (Sørensen et al., 2008). In addition, crossbreeding between genetically different breeds leads to an increase in the proportion of animals with heterozygous loci over the animals with homozygous loci especially when the two breeds had a greater genetic distance; and consequently, obtain crossbred with better performance compared with the average of the purebred parental breeds (Sørensen et al., 2008). According to Malchiodi et al. (2014), the intensive selection for high milk production that HO cows were subjected to, may alter their metabolic physiology to use the energy for production over reproduction; however, MO × HO crossbred cows may have a different metabolic mechanism that allows to better respond to the physiological process of production, reproduction, and survival at the same time in early lactation.

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The magnitude of economic advantages for reproductive superiority of MO × HO crossbred cows is due to lower costs required for hormonal treatment for synchronization programs, lower rate of culling for fertility problems, lower replacement costs, and a faster return to peak production at second lactation (Hazel et al., 2017a).

CONCLUSION

Under Egyptian subtropical conditions, the first generation of MO × HO crossbred cows showed better performance compared to pure HO cows for milk yield and reproductive traits. Crossing pure Holstein with Montbeliarde may provide an effective strategic option for the genetic improvement of dairy cattle raised in hot subtropical climates. Further studies are required to define the best gene combination (s) for crossing and also, phenotypic, genetic, and molecular characterization of the crossbreds are needed.

DECLARATIONS

Authors' contribution

R. R. Sadek, S. Abou-Bakr and A. A. Nigm designed the study. M. A. A. Awad and M. M. Badr collected the data. M. A. M. Ibrahim and M. A. A. Awad performed the editing and statistical analysis of data. M. A. A. Awad interpreted the results and wrote the manuscript. R. R. Sadek, S. Abou-Bakr and A. A. Nigm edited and revised the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors have not declared any conflict of interest.

Ethical consideration

Ethical issues including plagiarism, consent to publish, data fabrication, and double publication have been checked by all the authors.

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