**Effects of First-Lactation Milk Production and Culling Reasons on Lifetime
Performance Traits of Holstein Cows Culled from an Intensive System in Egypt**

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Title of the manuscript: Effects of First-Lactation Milk Production and Culling Reasons on
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Abstract

Objective: This study investigates the effects of first-lactation milk production and culling reasons on the lifetime performance traits of Holstein cows culled from an intensive system in Egypt.

Methods: Complete lactation records of 12209 for 4522 second-sixth parity cows culled during 2008-2019 were enrolled in this study.

Results: Means of days in milk(DIM), lifetime total milk yield(LTMY), lifetime daily milk yield(LDMY), productive life(PL), longevity, number of services/conception(NSPC), days open(DO) and calving interval(CI) were 371 days, 30223 kg, 13.5 kg, 38 months, 68 months, 3.6, 169 days and 437 days, respectively. The first-lactation milk production (FMY) affected all the lifetime performance traits significantly ($p < 0.0001$). Cows that produced higher FMY had higher both LTMY and LDMY. Cows of $FMY > 12000$ kg had the longest both PL and longevity. With the increase of FMY, the values of NSPC, DO and CI increased. Culling reasons significantly affected all lifetime performance traits ($P < 0.0001$). Cows culled due to reproductive problems had the greatest longevity whereas those culled due to endemic diseases recorded the lowest. The highest LDMY was recorded by cows culled due to metabolic disorders while the highest LTMY was recorded by cows culled due to lameness. Cows culled as a result of reproductive problems, metabolic disorders or mastitis recorded higher values of NSPC, DO and CI than those culled due to other reasons.

Conclusion: The higher the first-lactation milk production, the higher the productive performance and the lower the reproductive performance. The performance traits of culled cows

differed depending on the reason caused culling. Reasons for culling should be studied through their inter-relationships since one disorder may cause or support the occurrence of others.

Keywords: Culling; First-lactation milk; Holstein; Lifetime performance

INTRODUCTION

Culling is one of the main factors which directly influences the profits of milk production. Culling decision is usually taken against cows that showed a defect in one or more performance traits that are strongly linked with milk productivity. Lifetime performance sums up the features of the cows during their staying in the herd. Lifetime performance traits are traits related to health, fertility, and milking ability. Longevity and productive life are the most important lifetime traits [1]. They are used to measure the cow's staying ability in the herd. Longevity is the period between cow birth and culling whereas productive life includes the period from first calving to culling. Long longevity increases the opportunities to sell more heifers and to enhance the rate of voluntary culling which positively reflects on the herd profits [2]. Cows remained five lactations in the herd, decreased the replacement costs by 74% compared with cows culled after the first lactation [3]. Productive life (PL) is interrelated with productive and reproductive performance [4]. Long PL raises the herd profits as it increases the lifetime milk and the number of calves [5]. To achieve high profits, long PL should be combined with a high daily milk yield [6]. Reproductive traits are also one of the major performance traits which greatly affect cow profitability. Increased the number of services per conception(NSPC), the number of days open (DO), and calving intervals(CI) are associated with high insemination costs, low lifetime milk production (LTMY) and so high culling rate and low selection intensity [7]. Performance traits also include the number of lactations, lifetime productivity and average lifetime productivity during a definite period [8,9]. Studying factors affecting lifetime

performance traits may provide opportunities to improve these traits by considering the results when designing breeding programs. The lifetime performance of cows relies on their productive and reproductive traits in early lactations [10]. They could be predicted depending on the first-lactation milk production because the first-lactation milk yield revealed the production potential in the subsequent lactations. It is an important indicator for selection and culling [11]. There is a potential association between definite culling reasons and the lifetime performance of dairy cows [12]. Cow longevity is significantly interrelated with culling reasons, lactation numbers, lactation length, and LTMY. Continued researches on the association between certain performance traits and culling reasons in cows are necessary [13]. The effects of the first-lactation milk production on lifetime performance traits in dairy cows were studied as a whole whereas, no researches were done on culled cows. Also, the effects of culling reasons on lifetime performance traits were not studied. Therefore, the objective of this work was to study the lifetime performance traits of culled cows in Egypt during the last decade as affected by first-lactation milk production and different culling reasons.

MATERIALS AND METHODS

Data source

Data of the current study were belonging to an intensive dairy farm in Egypt (80 km northwest of Cairo, west of Cairo-Alexandria Desert Road, at a latitude angle of 30.14 ° and a longitude angle of 30.33 ° on 75 m above the sea level). Data were extracted from that were recorded by the herd management software of Dairy Comp 305 (Valley Ag Software, Tulare, CA). Complete lactation records of 12209 for 4522 second-sixth parity cows and culled in 2008-2019 were enrolled in the study. Data were classified according to culling reason, first-lactation milk production, year and season of calving (Table 1).

Animals and management

Cows were kept in free-stall barns under an open yard system shaded with corrugated metal sheets. The yards' floors were earthen and sand-covered. Water bunks were under each shaded area. Cows were fed total mixed ration (TMR) all over the year. The TMR was composed of concentrate feed mixture, corn silage, alfalfa hay, vitamins and minerals supplementation. Rations were presented three times a day according to cow body weight and milk production level. Freshwater was offered all day. Heifers were artificially inseminated the first time at about 370 kg body weight. Machine-milking was practiced three times a day at eight-hour intervals (06:00, 14:00 and 22:00 hr.). Cows were dried off two months before the expected calving dates. The farm was provided with cooling system. All cows were managed under the same conditions.

Studied traits

-Number of lactations (NL): ~~The the~~ number of complete lactations that the cow produced during her ~~spent~~ stay in the herd-(NL)-.

~~days~~ Days in milk (DIM, day): the number of days the cow milked during lactation.-(DIM, kgday),

~~lifetime~~ Lifetime total milk yield (LTMY, kg): the milk that the cow produced ~~through during~~ the her stay in the herd ~~productive life of cow~~-(LTMY, kg)-. It was estimated by summing the amounts of milk of all lactations of the cow.

-Lifetime daily milk yield (LDMY, kg): milk yield per day of cow age. It was estimated by dividing LTMY by longevity in days. (LDMY, kg);

~~productive~~ Productive life (PL, month-): the number of months between the dates of the cow's first calving and ~~the her~~ last milk recording ~~(PL, month)-.~~

~~longevity, the~~ Longevity: the number of months between the dates of the cow's birth and the culling.

~~the~~ Number of services per conception (NSPC): the services required for conception for each cow (NSPC).

~~days~~ Days open (DO, day): the days from calving until conception. ~~(DO, day) and~~
~~calving~~ Calving interval (CI, day): the days between two subsequent calvings ~~(CI, day).~~

Data analysis

All statistical analyses were performed using the XLSTAT version 2020.3.1. The effects of first-lactation milk production and culling reasons were investigated using the following model:

$$Y_{ijklm} = \mu + F_j + C_i + Y_k + S_l + e_{ijklm},$$

where: Y_{ijklm} = an observation of the trait, μ = the overall mean, F_j = the fixed effect of the j^{th} first-lactation milk production, ($j = 1, 2, 3$), 1 = <9000 kg, 2 = 9000-12000 kg and 3 = >12000 kg, C_i = the fixed effect of the i^{th} culling reason, ($i = 1, 2, \dots, 8$), 1 = low milk yield, 2 = mastitis, 3 = reproductive problems, 4 = metabolic disorders, 5 = lameness, 6 = endemic diseases, 7 = respiratory diseases and 8 = unknown, Y_k = the fixed effect of the k^{th} period of calving, ($k = 1, 2, 3$), 1 = 2008-2011, 2 = 2012-2015 and 3 = 2016-2019, S_l = the fixed effect of the l^{th} season of calving ($l = 1, 2, 3, 4$), 1 = Winter (Dec.-Feb.), 2 = Spring (March-May), 3 = Summer (June-August) and 4 = Autumn (Sept.-Nov.), and e_{ijklm} = random residual effect.

RESULTS

The overall means of the lifetime productive and reproductive performance traits are displayed in Table 2 and Table 3, respectively.

Effects of first-lactation milk production on lifetime performance traits

Productive traits

Reproductive traits

Effects of culling reasons on lifetime performance traits

Productive traits

The effects of ~~Culling-culling~~ reasons significantly affected ~~all~~ the productive traits included in this study were displayed in Table 2. All effects were significant ($P < 0.0001$). Table 2. presents the productive traits as affected by reasons of culling. Expect for the trait of NL, ~~cows~~ Cows culled due to low milk yield recorded had average values 5% lower than the overall mean for all the studied traits. Also, they recorded the shortest DIM (356 days) and the lowest LTMV (28730 kg) compared with the cows culled due to other reasons.

It can be calculated from Table 2. that culled cows spent more than 43% of their lives as unproductive. Unproductive life was the longest in the cows culled due to reproductive problems, about 51% of their lives were unproductive followed by those culled due to low milk yield and endemic diseases (45% for each).

Reproductive traits

Table 3. showed that ~~All~~ all the reproductive traits were significantly affected by culling reasons ($P < 0.0001$). ~~presents that cows~~ Cows culled due to low milk yield showed the shortest averages of both DO (164 days) and CI (425 days) in the study.

DISCUSSION

Variations in lifetime performance traits of Holstein in different studies may be returned to the differences in individual genetics, production system, environmental conditions, nutrition, diseases and management procedures.

Effects of first-lactation milk production on lifetime performance traits

Productive traits

In this study, it was found that the more FMY the cows produce, the fewer NL they give. Cows scored FMY >12000 kg recorded 2.6 lactations. The same trend was recorded in Poland [22], authors stated that Holstein produced FMY >11000 kg milk gave lower NL (2.3). Conversely, in Germany, it was found that the correlation coefficient between FMY and NL was significantly positive [9].

Effects of culling reasons on lifetime performance traits

Productive traits ~~traits~~

Cows culled voluntarily due to low milk yield recorded average values of productive traits 5% lower than the overall mean for all the studied traits. It is the most important reason for voluntary culling [32] which directly affects the cow's profitability.

The greatest longevity (75 months) in this study was recorded by cCows culled due to reproductive problems ~~reproductive disorders scored the greatest longevity (75 months)~~ compared with cows culled due to other reasons. However, the PL of these cows was not the longest. ~~It was (-37 months, while the values of PL in this study were 35-40 months).~~ It means that these cows spent long times as unproductive (51% of their lives) so they. ~~Therefore, they recorded~~ provided the lowest LDMY (12.2 kg). Although these cows scored the longest DIM (388 d), they produced LDMY (29925 kg) lower than the overall mean (30223 kg) of the herd. All of these ~~current results~~ findings reflect the risk of keeping cows having reproductive

problems. It was believed that the elongation of the lactations lengths may compensate for the decline in reproductive performance ~~b-But~~ when we look at the issue in the long run, we ~~will~~ find that it will inevitably lead to economic loss. ~~So-Therefore,~~ improvement of reproductive performance by good management and nutrition is a main issue. Also, it should be ~~paid-given~~ more attention in breeding programs as the same as milk production.

Cows culled due to metabolic disorders recorded the greatest LDMY (14.1 kg). It means ~~the cows of High milk cows may have high milk production, but will not have a good lactation curve. So, milk production requires an excessive metabolism to supply the cow's body with the energy needed for milk synthesis. Improper or insufficient nutrition may lead to an imbalance in the metabolism, which~~ cause negative affects-results in problems directly on milk production and indirectly on reproduction, that force to cull cows.

The lowest values of longevity and PL were recorded by Cows-cows culled due to endemic diseases ~~recorded the lowest values of longevity, therefore they recorded the lowest LTMV in this study (28809 kg). This is because the highest proportion of these cows were culled in the first lactation [27]-and PL, they were lesser than the overall mean by 5.8% and 7.8%. So they recorded the lowest LTMV (28809 kg) which was lower than the overall mean by 4.6%. Also, cows culled due to respiratory diseases recorded longevity and LP lower than the overall mean by 2.9% and 2.6%, respectively. Both endemic and respiratory diseases led to culling cows in their early lactations causing great economic loss. Early culling causing great economic loss as it~~ inhibits the cows from reaching maximum production which commonly happens at the third to fourth lactations [3028].

Reproductive traits performance

In this study, the lower reproductive traits performance were not limited to cows that were excluded for due to reproductive problems. The same was noticed in [4]. In present study, cows culled due to metabolic disorders, such as high level of NSPC, DO and CI as with no significant differences with those the same as cows culled due to reproductive problems. This could indicate a failure to provide cows with feeds appropriate for their production level or physiological status, resulting in metabolic disruption which might have negatively affected fatty acid synthesis and lipid mobilization. It has been shown that the reduction of intracellular lipid mobilization were associated with delay in uterine involution which is associated with delay in the return to cyclicity causing high NSPC [31], elongating DO and so CI. Besides, changes in the follicular fluid composition may occur in cows that have blood metabolism disorders, impairing follicular steroidogenesis and oocyte development, as well as cyclical resumption and fertility [32,33].

The low productive performance of high lactating SPCD and Cows is already well known by dairy farmers and it is one of the main problems in dairy farming. However, the exact mechanism of the relationship between mastitis and low milk production is still unclear. The relationship between mastitis and low milk production are multifactorial making it difficult to fully comprehend their relationship so different mechanisms for their relationship were suggested [34]. One mechanism is that mastitis causes an increase in body temperature, high temperatures may reduce the secretion of

progesterone by luteal cells and inhibit the synthesis of steroids in granulosa cells resulting in disturbance in the development of oocytes and embryos [35]. Another mechanism is that mammary gland infection causes immune responses, resulting in the abnormal secretion of cytokines and hormones affected the hypothalamic–pituitary–gonadal axis, ovary, and corpus luteum, causing disorders in the secretion of hormones like GnRH, FSH, LH, oestrogen, and progesterone, which promoted oocyte apoptosis and resulted in abnormal follicular development, delayed oestrus, increased embryonic apoptosis [36].

Interferences between mastitis and metabolic diseases such as dystocia, clinical ketosis and retained placenta make accumulative harmful effects on reproductive performance [37] resulting in culling, the reason of culling will be recorded as a reproductive problem which gives misleading information taking us away from the root of the problem. These findings indicate the importance of studying reasons for culling through their inter-relationships since one disorder may cause or support the occurrence of others.

CONCLUSION

The first-lactation milk production affected (It can be concluded that the lifetime performance traits of culled Holstein cows, could be predicted upon the first lactation milk production. It was associated positively with productive performance and negatively with reproductive performance. The lifetime performance traits differed according to the reason caused culling. The similarities of low reproductive performance in cows culled due to metabolic disorders or mastitis and cows culled as a result of reproductive problems indicated that reasons for culling should be studied through their inter-relationships since one disorder may cause or support the occurrence of others.

~~and the cows farrowing should be studied through their relationships, since cows can encourage the occurrence of the cows farrowing~~

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Table 1. Descriptive statistics of categorized culling reasons, first-lactation milk production, year and season of calving for 4522 Holstein dairy cows culled from an intensive system in Egypt during 2008-2019

Variable	Categories	Counts	%
Culling reason			
	Low milk yield	391	8.7
	Mastitis	1084	23.9
	Reproductive problems*	852	18.8
	Metabolic disorders	618	13.6
	Lameness	515	11.4
	Endemic diseases**	493	10.9
	Respiratory diseases	196	4.3
	Unknown	373	8.4
First-lactation milk production			
	<9000 kg	1496	33.2
	9000-12000 kg	1747	38.6
	>12000 kg	1279	28.2

Year of calving

2008-2011	1026	22.6
2012-2015	2770	61.3
2016-2019	726	16.1

Season of calving

Winter	1193	26.5
Spring	1079	23.8
Summer	1037	22.9
Autumn	1213	26.8

*Reproductive problems included dystocia, metritis, pregnancy toxemia, uterus prolapse and uterus adhesion.

** Endemic diseases; represented by lumpy skin disease, bovine ephemeral fever and foot & mouth disease.

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Accepted Article

Table 2. Effects of culling reasons and first-lactation milk production on number of lactations, days in milk, lifetime total milk yield, lifetime daily milk yield, productive life and longevity in Holstein dairy cows culled from an intensive system in Egypt during 2008-2019

Category	NL		DIM (day)		LTMV (kg)		LDMV (kg)		PL (month)		Longevity (month)		P-value
	LSM	SE	LSM	SE	LS	SE	LSM	SE	LSM	SE	LSM	SE	
The overall mean	2.7	0.2	371	2.0	30223	374	13.5	0.4	38	0.4	68	0.4	<0.0001
Culling reason													
Low milk yield	2.9 b	0.05	356 a	3.5	28730 a	629	12.9 b	0.1	37 b	0.5	67 bc	0.7	
Mastitis	3.0 c	0.03	367 b	2.1	30913 b	381	13.8 cde	0.1	39 c	0.7	68 c	0.6	
Reproductive problems	2.7 a	0.03	388 d	2.4	29925 ab	437	12.2 a	0.1	37 b	0.6	75 e	0.6	
Metabolic disorders	2.8 ab	0.04	379 c	2.7	31127 b	499	14.1 e	0.1	38 b	0.5	67 bc	0.6	
Lameness	3.0 c	0.04	373 bc	3.0	32589 c	545	14.0 de	0.1	40 c	0.6	71 d	0.5	
Endemic diseases	2.7 a	0.04	366 b	3.1	28809 a	566	13.5 c	0.1	35 a	0.7	64 a	0.7	
Respiratory diseases	2.8ab	0.07	368 b	5.0	30000 ab	909	13.7 cd	0.2	37 b	0.5	66 abc	1.1	
Unknown	2.7 ab	0.05	373 bc	3.5	29695 ab	635	13.7 cd	0.1	37 b	1.0	66 ab	0.5	

First- lactation milk production

<9000 kg	2.9 c	0.03	329 a	2.0	26998 a	369	12.2 a	0.05	36 a	0.4	66 a	0.4
9000-<12000 kg	2.8 b	0.02	358 b	1.8	29815 b	337	13.5 b	0.04	37 a	0.4	67 a	0.4
>12000 kg	2.6 a	0.03	427 c	2.3	33858 c	417	14.8 c	0.05	40 b	0.4	71 b	0.5

LSM = least squares means, SE= standard error, NL=number of lactations, DIM=days in milk, LTMY= lifetime total milk yield, LDMY= yield per day of cow life, PL=productive life (the number of months between the dates of first calving and the last milk recording and Longevity = the number of months between the dates of birth and the culling. Different letter in the same column shows the significantly ($P<0.05$) different effect on the average values.

Table 3. Effects of culling reasons and first-lactation milk production on number of services/conception, days open and calving interval in Holstein dairy cows culled from an intensive system in Egypt during 2008-2019

Category	NSPC		DO (days)		CI (day)		P-value
	LSM	SE	LSM	SE	LSM	SE	
The overall mean	3.6	0.05	169	2.1	437	3.4	
Culling reason							<0.0001
Low milk yield	3.6 ab	0.09	164 a	3.6	425 a	3.7	
Mastitis	3.7 b	0.05	171 b	2.2	439 bc	2.3	
Reproductive problems	3.9 c	0.06	178 c	2.5	445 c	2.6	
Metabolic disorders	3.8 bc	0.07	172 bc	2.8	441 bc	3.0	
Lameness	3.6 ab	0.08	166 a	3.1	436 bc	3.2	
Endemic diseases	3.6 ab	0.08	165 a	3.2	433 ab	3.4	
Respiratory diseases	3.6 ab	0.13	166 a	5.2	436 bc	5.4	
Unknown	3.5 a	0.09	165 a	3.6	439 bc	3.8	
First- lactation milk production							<0.0001
<9000 kg	2.5 a	0.05	124 a	2.1	390 a	2.1	
9000-<12000 kg	3.3 b	0.05	155 b	1.9	421 b	1.9	
>12000 kg	5.1 c	0.06	229 c	2.4	500 c	2.4	

LSM = least squares means, SE= standard error, NSPC= number of services per conception, DO= days open, CI=calving interval. Different letter in the same column shows the significantly ($P<0.05$) different effect on the average values.