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Different aspects of lactation persistency in dairy cows

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ABSTRACT

Lactation persistency (cow's ability to maintain milk production after reaching its peak) is a very important economic characteristic in the dairy cattle production system. Different definition and functions for describing and measuring of this trait were proposed by researchers. The random regression model using Legendre polynomial was one of the common and effective methodologies for evaluation of persistency in the last decade. Several factors affecting persistency such as different characteristics of lactation curve, environment factors, reproduction traits and health status of the dairy cow. Based on different studies the heritability of this trait was low to medium and negative or positive amount of genetic correlation between persistency and total milk yield in dairy cattle is attributed to persistency measures and method of data analysis. Persistency is related with low and later peak yield and selecting cows for peak yield will improve persistency and lactation curve traits. Analysis of relationships between persistency and other functional traits show signs that genetic improvement for persistency is possible and favorable. Different aspects and relationships of persistency with various lactation and other functional traits in dairy cows are reviewed in this article.

Key words: Dairy cows, Genetic parameters, Lactation curve parameters, Persistency

Milk production has a great economic impact on the dairy cattle enterprise in terms of the level of income of dairy farms. Selection of dairy cattle has mainly focused on the efficiency of milk production and also other functional traits (Harder *et al*. 2006, Tekerli *et al*. 2000). Milk production trait follows a curvilinear pattern over the course of lactation which is called as lactation curve. A lactation curve of dairy cattle starts with initial milk yield, increasing production from the beginning to the peak of lactation, and then decreasing until the cow is dried off. Lactation curve equations are helpful tools that depict the lactation curve and using these equations parameters like peak time, peak yield and persistency can be predicted (Appuhamy 2006). Persistency of milk yield production is one of the most economically important traits of lactation curve, which is important for selection (Gengler 1995). Moreover, one of the main functions for measuring the persistency of lactation is incomplete gamma function.

Measures of persistency

Based on Cole and Null (2009) definition of persistency trait varies and is a key point. Moreover, they mentioned that there is no consistent definition of persistency and no clear consensus on the best way of measuring this trait, because there are a lot of differences in the nature of persistency measures. Several definitions of persistency have been proposed, and persistency measures were categorized in literature into 4 groups (Grossman *et al*. 1999), viz. measures based upon the parameters of different lactation curve functions; measures derived from variation of test day milk yield; measures expressed as different ratio of yield; measures using the functions of estimated breeding values (EBV) for days in milk obtained by different orders of Legendre polynomials with random regression test day models (RRTDM) (Jamrozik *et al*. 1998, Pereira *et al*. 2012). Definition of persistency is usually the rate of decline in milk production after the peak or the ability of a cow to maintain milk production at high level (Jamrozik and Schaeffer 1997). Based on different definitions of this trait, several functions with various parameters are presented in the literature for measuring milk yield persistency (Table 1). One of the most important simplified measures of persistency in log form $\{-(b+1)\ln c\}$ was proposed by Wood (1970) which can interpret difficulty in biological aspect (Grossman *et al*. 1999).

Persistency and lactation curve characteristics

Persistency of lactation is considered as a very important characteristic of the lactation curve. Pereira *et al*. (2012) mentioned that persistency is related to the shape of lactation curve not to the level of milk production or breeding value of milk yield. The shape of lactation curve differed between cows in the first and in later parities (Fig. 1). The first parity

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Table 1. Some persistency functions

Persistency function	Author
P = (3 + 4 + 5th months yield) – (7 + 8 + 9th months yield)/12 P = Total yield (sum of 7 months)/milk yield of last 3 months	Ludwin (1942)
$P = \sum (Y_i - S_i) \times (d_i - d_0)$	Cole and VanRaden (2006)
$P = EBV_{290} - EBV_{90}$	Cobuci *et al.* (2007)
$P = \sum_{i=61}^{300} EBV - 240 \times EBV_{60}$	Harder *et al.* (2006)
$P = \sum_{i=61}^{305} EBV - 245 \times EBV_{60}$	DeRoos *et al.* (2001)
$P = (milk_{270} / milk_{90}) \times 100$ $P = (milk_{225} / milk_{45}) \times 100$ $P = (\sum_{1}^{150} milk / maximum\ milk\ yield) \times 100$	Weller *et al.* (2006)
$P = 305\ day\ milk\ yield / the\ first\ 50\ \ day\ milk\ yield$	Yilmaz and Koc (2013)
$P = maximum\ milk\ yield / average\ milk\ yield$	Atashi *et al.* (2006)
$P = EBV_{280} / EBV_{65} \quad P = \sum_{66}^{280} EBV / \sum_{5}^{65} EBV$	Togashi and Lin (2004)
$P = (EBV_{280} / EBV_{60}) + y_{280})) / y_{60}))) \times 100$	Mostert *et al.* (2008)
$P = \sum_{i=61}^{280} milk - milk_{60}$	Jamrozik *et al.* (1997)
$P = 1/55 \sum_{255}^{350} milk - 1/21 \sum_{50}^{70} milk$	Kistemaker (2003)
$P = \sum_{101}^{200} milk / \sum_{1}^{100} milk \quad P = \sum_{201}^{305} milk / \sum_{1}^{100} milk$ $P = \sum_{1}^{100} milk / (MAX \sum_{1}^{100} milk \times 200)$	Johansson and Hansson (1940)
$P = \sum_{60}^{279} EBV - EBV_{280} \quad P = EBV_{280} - EBV_{60}$	Jakobsen *et al.* (2002)
$P = -(b+1) \ln c$	Wood (1970)
$P = 100\ (1 + 2\gamma_i)$	Kamidi (2005)

P, Persistency; EBV, estimated breeding value; (Yi-Si), ith test day yield deviation from the standard yield; (di-d0), ith test day days in milk deviation from the reference date in VanRaden equation. b and c are the inclining slope parameter up to yield peak and the declining slope parameter in Wood function, respectively; and y is a declaration constant in Kamidi function.

cows have lower initial and peak milk yield but a higher persistency. Moreover, milk production in latter parities is higher at peak in comparison to the first parity. In other words cows with very high production at peak would have a steeper slope than low producing cows (Mostert *et al.* 2008). In the study of Appuhamy (2006), the shape of lactation curve of primiparous cows with high, average and low persistency was completely different as in high persistent cow, more and less milk yield produce at the end and at the beginning of lactation respectively. Also the shape of the lactation curves for yield traits differed among parities within breeds. Other result indicated that persistency between first and later parities are much larger than difference between breeds (Cole and Null 2009). Cows in

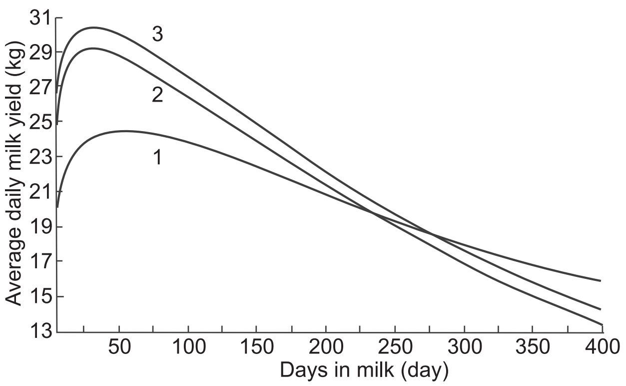

Fig. 1. Lactation curve of milk yield in the first, second and third parity.

the first lactation had flatter lactation curves for milk, fat, and protein yields; lower peak and higher persistency than cows in later lactations.

In other words in the first parity, the lactation curve is flatter which equals to greatest persistency but in higher parities, the persistency decrease gradually. So persistency will decrease with increasing parity number (Weller *et al.* 2006) (Fig. 1). In other words, parity seems to have the greatest influence on persistency. Moreover, Rekaya *et al.* (2000) suggested a moderate genetic correlation between milk yield persistency in the first three lactations (0.23 for the first and second lactation, 0.32 for second and third lactation and finally 0.23 for first and third lactation). They proposed that genetic evaluation of persistency in latter parities based on the first lactation is ambiguous but not decay it in subsequent lactations. Different studies revealed positive genetic correlations between persistency in different parities. For example in study of Weller *et al.* (2006), genetic correlation of persistency between first and second parity was 0.854 but between second and third parity was 0.965. Genetic and phenotypic correlations among lactation curve traits (level of production, production decrease after peak yield, production increase toward peak yield, peak time, peak milk yield, total 305 day milk yield, milk yield in specific days like 60 or 280 days and persistency) using different lactation curve functions are presented in many studies (Portillo and Pollott 2011, Tekerli *et al.* 2000). Different researches have shown that general level of production tends to increase with parity and the rate of decline after peak yield, tend to increase with parity too which indicates decreasing of persistency (Rekik *et al.* 2003) (Fig. 1). Phenotypic correlation between initial milk yield and persistency were –0.27 and –0.376 in the study of Farhangfar and Rowlinson (2007) and Cilek *et al.* (2009) respectively. This negative correlation indicates that cows with high initial milk yield during lactation would have lower persistency. Farhangfar and Rowlinson (2007) also reported negative genetic correlation between initial milk yield and persistency (–0.09). The phenotypic correlation between decreasing rate of yield after peak and persistency is completely different in studies. Farhangfar and Rowlinson (2007) and Cilek *et al.* (2009) reported a negative phenotypic correlation between these two traits (–0.68 and –0.723 respectively). The negative phenotypic correlation is in disagreement with those reported by Tekerli *et al.* (2000) and Bouallegue *et al.* (2013) which find the positive phenotypic correlation between decreasing rate of yield and persistency (0.057 and 0.18 respectively). The positive phenotypic correlation implies that cows with a lower rate of decline milk yield after peak have higher persistency (Bouallegue *et al.* 2013). Knowing the time and level of the peak milk yield is important as it correlates well with the persistency and the total milk yield during lactation. A study showed that the correlation between peak time and persistency is high in different seasons, which indicates that as the interval between initial milk yields and peak yield increases, the persistency improves (Elahi Torshizi 2016a). This is in agreement with the finding of Appuhamy (2006) who estimated high phenotypic correlation between persistency and peak time in first and latter lactations (0.7 and 0.82 respectively), which mean that persistency is correlated with late peak time (Muir *et al.* 2004). A positive phenotypic correlation between peak time and persistency using different measures (0.58, 0.27, 0.77, 0.80 and 0.64) has also been found in most studies (Farhangfar and Rowlinson 2007, Bouallegue *et al.* 2013, Boujenane and Hilal 2012, Tekerli *et al.* 2000, Portillo and Pollott 2011), which implies that early day of peak time had an unfavorable effect on persistency of milk yield. Also the moderate to large positive correlation between peak time and persistency indicate that it can be used as a selection criterion to improve persistency. One of the main reasons for higher persistency in the first lactation is later peak yield too. Many studies have shown that persistency has negative phenotypic correlation with peak yield (–0.22, –0.11, –0.19, –0.19 and –0.22) which implies that lower peak yield in dairy cows is associated with higher persistency (Tekerli *et al.* 2000, Dedkova and Nemkova 2003, Farhangfar and Rowlinson 2007, Boujenane and Hilal 2012, Bouallegue *et al.* 2013). So a more persistent cow would therefore have a curve with lower peak yield relative to less persistent cows. In an opposite research, Portillo and Pollott (2011) reported phenotypic correlation of 0.27 between persistency and peak yield using a biological model. It has been shown that persistency, correlated with lactation length genetically (r_g= 0.50 in the first lactation of Gyr cattle), which indicates that selection for persistency can improve lactation length.

Genetic parameters of persistency

Genetic parameters for persistency have been reported by different methods including single or multiple trait animal model, fixed regression and especially RRTDM based on partial estimation breeding value in many papers (Jamrozik *et al.* 1998, Jakobsen *et al.* 2002, Weller *et al.* 2006, Cobuci *et al.* 2007). The heritability of persistency and genetic correlation with partial and total milk yield vary depending upon parity, breed, methods of data analysis and how the persistency measure is defined. The heritability of persistency varies greatly in numerous studies. The heritability of milk yield persistency in different literatures is presented in Table 2, indicating that there is a large difference between the heritability of persistency reported in various studies. In general, the heritability of persistency is between low to medium (moderate heritability), which indicates the possibility of genetic improvement through selection (Swalve 2000).

Table 2. Heritability of milk yield persistency

Author	Heritability	Method
Kaygisiz *et al*. (1995)	0.5±0.204	ANOVA
Shanks *et al*. (1981)	0.02	Henderson model 3
Batra *et al*. (1986)	0.21	ANOVA
Jakobsen *et al*. (2002)	0.09–0.24	REML
Kheirabadi and Alijani (2014)	0.06 – 0.22	BYS
Elahi and Hosseinpour Mashhadi (2016b)	0.062–0.084	ANOVA
Weller *et al*. (2006)	0.164–0.269	REML
Khorshidi *et al*. (2012)	0.09–0.22	REML
Otwinowska-Mindur and Ptak (2015)	0.01– 0.08	REML
Gengler *et al*. (1995)	0.03–0.12	REML
Wasike *et al*. (2014)	0.171±0.02	REML
Pereira *et al*. (2012)	0.10–0.25	REML
Farhangfar and Rowlinson (2007)	0.08	EM-REML
Boujenane and Hilal (2012)	0.05	DF-REML
Rekaya *et al*. (2000)	0.14	BYS
Elahi Torshizi (2016a)	0.022–0.026	REML
Swalve (1995)	0.10–0.15	REML
Haile-Mariam *et al*. (2003)	0.1±0.01	REML
Muir *et al*. (2004)	0.18	BYS
Yamazaki *et al*. (2013)	0.013±0.01, 0.21±0.02	REML

ANOVA, Analysis of variance; REML, Restricted maximum likelihood; EM-REML, Expectation maximization REML; DF-REML, Derivative free REML; BYS, Bayesian.

As mentioned before, the heritability estimates for persistency vary according to the definition of persistency, population studies, parity, lactation stage and method of data analysis (Pereira *et al*. 2012) indicating that these items and also environmental factors have much large effects on this trait. For example lactation of low persistency produces more and less milk in early and during late lactation but this situation in high persistency lactation is vice versa (less milk at the beginning and more milk at the end of lactation) (Appuhamy 2006). Moreover, an important key characteristic of the persistency is its correlation with total 305-d milk yield. According to Jakobsen *et al*. (2002) a good persistency measure should have high heritability, large economic value, large genetic variance and it must be uncorrelated with 305-d yield because there is antagonist relationship between persistency and 305-d milk yield and selection for 305-d milk yield does not improve persistency of milk yield (Pereira *et al*. 2012) but it can increase peak yield and delay peak time (Rekaya *et al*. 2000). In other words a good measure of persistency should be independent of lactation milk yield (Otwinowska-Mindur and Ptak 2015). However, small positive genetic correlation between milk yield and persistency implies that selection for milk yield improves persistency (Muir *et al*. 2004). The lower the genetic correlation between persistency measures and EBV305-day milk yield, the better the evaluation of persistency. This means that animals with higher EBV for persistency are not necessarily the same as those with lower EBV (Cobuci *et al*. 2007). Different estimation of genetic correlation between persistency and total 305–d milk yield were reported by researchers. Cobuci *et al*. (2007) reported value of –0.45 for this correlation. Moreover, Otwinowska-Mindur and Ptak (2015) and Kheirabadi and Alijani (2014) found similar genetic correlation between 305–d milk yield and persistency (–0.55 and –0.33 respectively). Negative genetic correlation indicates that cows with high genetic level of persistency tend to have lower genetic level for total milk yield (Otwinowska-Mindur and Ptak 2015). Jakobsen *et al.* (2002) and Cobuci *et al*. (2004) studied different persistency measures using RRTDM and showed that genetic correlation between persistency and 305-d milk yield ranged from 0 to 0.47 and 0.31 to 0.55 respectively. In the study of Brazilian Gyr cattle based on a random regression model, the genetic correlations between different persistency measures and 305-d milk yield ranged from –0.52 to 0.03 (Pereira *et al*. 2012). Based on this study, the persistency measure with lower genetic correlation with 305-d milk yield (close to zero) is preferred. Correlation between estimated breeding values for different persistency criterion and 305-d milk yield in Iranian dairy cows were found to be between 0.34 and 0.97 (Elahi Torshizi *et al*. 2013). Otwinowska-Mindur and Ptak (2015) studied genetic properties of three measures of persistency (milk yield in second 100 DIM/milk yield in the first 100 DIM, milk yield in third 100 DIM/milk yield in the first 100 DIM, milk 280 DIM/ milk 60 DIM) using multiple-trait method. They found that all 3 measures had low heritability and minimum genetic correlation with total 305-d milk yield which was useful for including in genetic evaluation of dairy cattle. Also the second and third Eigenvector K matrix (additive genetic coefficient matrix obtain from random regression analysis method) estimated from test-day record of Holstein dairy cattle significantly increased genetic response to persistency (Togashi and Lin 2006). Studies of Muir *et al*. (2004) and Swalve (1995) indicated that genetic correlation between 305–d total milk yield and persistency varied in magnitude and sign depending on persistency measures used. Persistency measures based on variation and ratios have negative and positive correlation with total 305–d milk yield respectively (Mostert *et al*. 2008).

Environmental factors affecting lactation persistency

It has been reported that the lactation persistency is influenced by environmental factors such as common herd effects, level of milk yield, year of calving and production, milking frequency and season of calving and production (Yilmaz and Koc 2013, Boujenane and Hilal 2012, Bouallegue *et al*. 2013, Portillo and Pollott 2011). Differences in persistency amongst herds are due to variation in management, feeding and other environmental factors, as well as annual climatic changes. Cows that rose in high yield herds have higher persistency when compared with low herd production cows. In an opposite result, finding of Yilmaz and Koc (2013) indicated that in high yielding cows, persistency during lactation is difficult. Boujenane and Hilal (2012) found that cows calving from October to April have higher persistency compared to those calving from May to September but Dedkova and Nemcova (2003) observed that persistency was the highest for cows calving in August and September. Lactation starting in summer and autumn have more persistency than lactation starting in spring or winter (Portillo and Pollott 2011). The persistency was higher and lower in cows calved in summer and winter respectively (Yilmaz and Koc 2013, Bouallegue *et al*. 2013). Also Tekerli *et al*. (2000) obtained the highest persistency in cows that calved during summer and autumn. Milking frequency can have a significant impact on milk yield and persistency too. Cows milked once daily, have less persistency and less of production than cows milked twice daily. In three time milking cows, morning milk yield was higher compared to noon and night milk but night milk curve showed better persistency (Elahi Torshizi and Hosseinpour Mashhadi 2013). More persistency of night milk yield is due to higher flow of oxygen in the milking gland during days because of daily activity.

Persistency and reproduction traits

Favorite genetic relationship between persistency and various reproduction traits such as age at first insemination and calving, calving interval and difficulty, non-return rate and days open investigated in many studies (Strapakova *et al*. 2016, Muir *et al*. 2004, Haile-Mariam *et al*. 2003, Atashi *et al*. 2012, Yamazaki *et al*. 2014). Muir *et al*. (2004) reported negative genetic correlation between persistency and age at first insemination (–0.17±0.07) in heifers. It means that persistency was better in animals which inseminated at younger age than average. In an opposite study, Yamazaki *et al*. (2014) reported 0.17 for genetic correlation between days from calving to first insemination and persistency in Japanese Holstein cows. The shape of lactation curve and its parameters like persistency can influence by age at calving as well (Dedkova and Nemcova 2013). Persistency measures decreased with increasing age at first calving in Iranian Holsteins. So the best performance of lactation yield and persistency is related to the cows which calved in 24, 25 and 26 months (Elahi Torshizi 2016a). Muir *et al*. (2004) and Haile-Mariam *et al*. (2003) found a genetic correlation between persistency and calving interval of 0.17±0.09 and –0.02±0.09 respectively. Muir *et al*. (2004) reported 0.34 and 0.4 for this correlation. This indicated that the greatest persistency in the first lactation tends to longer calving interval from first to second parities (Strapakova *et al*. 2016). This supports the result of Atashi *et al*. (2013) who reported 24.42 for regression coefficient of calving interval on persistency of lactation in Iranian Holsteins. Based on this finding they mentioned that cows with greater milk yield persistency have longer calving interval as well. Strong genetic correlation between dystocia and persistency in dairy cattle (0.43±0.08) demonstrates that cows with dystocia in the first calving tend to have more milk yield persistency during the lactation (Muir *et al*. 2004). This is in agreement with the result of Atashi *et al*. (2012) who found that milk yield persistency was higher in cows that experienced calving difficulty in all parities except for second and fourth. These cows have lower peak yield and it might be the reason of higher persistency in the subsequent lactation. Another reproduction trait, which is associated with milk yield persistency is days open. Yamazaki *et al*. (2014) reported 0.28, 0.35 and 0.39 for genetic correlation between persistency and days open for the first three lactations of Japan Holstein cows, respectively, which means that longer period of days open corresponding to better milk yield persistency. These results support the finding of Zavadilova *et al*. (2005) who mentioned that different days open, can change the shape of lactation curve (steeper lactation curve), and it was associated with shorter days open in Czech Holstein cows. Positive genetic correlation (0.32) between non return rate at 56 d after first insemination and persistency in primiparous cows showed that animals inseminated in younger age tend to have better milk yield persistency (Muir *et al*. 2004) while cows with shorter interval from calving to the first heat tend to have higher milk yield persistency (r_g = –0.13) (Lopez-Villalobos *et al*. 2005). In this study the higher percentage of cows showed cycling at 42 d after calving.

Persistency and health disorders

Many common health characteristics and diseases such as lameness, metritis, ketosis, mastitis and displaced abomasum in dairy cattle can affect persistency (Appuhamy 2006). So the better health and lower incidence of diseases are associated with higher lactation persistency (Cole and Null 2009). Two of the main health characteristics, which are related to the persistency of milk yield are somatic cell count (SCC) and mastitis. SCC is the total number of cells per milliliter in milk. According to Capuco *et al*. (2003) mastitis increases the death of mammary cells so persistency and mastitis can affect each other negatively specially after the peak. In the first and subsequent lactations, the incidence of mastitis and displaced abomasum are more in cows with higher persistency and these diseases in early lactation of primiparous cows can increase milk yield persistency significantly (Appuhamy 2006). Different metabolic diseases after parturition increased the rate of persistency in German dairy Holstein cows which showed negative genetic correlation between metabolic disease and persistency (Harder *et al*. 2006). Negative or low genetic correlation was obtained between persistency and SCC in many studies. This negative genetic correlation indicates that decreasing of SCC can improve persistency of milk yield in different parities in dairy cattle. Haile-Mariam *et al*. (2003) and Strapakova *et al*. (2016) reported –0.29 and –0.123 for genetic correlation between persistency and SCC, respectively, while another study showed that the genetic correlations between these traits were –0.23 and –0.22 in the first and second lactations (Yamazaki *et al*. 2013). Meanwhile, Weller *et al*. (2006) found that the genetic relationship between lactation persistency and SCC in the first and second parity as –0.045 and –0.136, respectively, and also the study of Cole and Null (2009) indicated that genetic correlation of these traits ranged from –0.17 to –0.42 in 5 cattle breeds. Genetic correlation between persistency of the first lactation and SCC of the second lactation is almost –0.17, which indicate that the better lactation persistency in the first lactation is related to the lower SCC in the second lactation (Yamazaki *et al*. 2013). Cows with lower and later peak yield (cows with more persistency of milk yield) showed less negative energy balance so the rate of metabolic stress or diseases in early lactation in these animals is low (Ferris *et al*. 1985). Based on Simianer *et al*. (1991) finding, the sensitivity of high producing cows to different diseases is higher than low producing cows. Then selection of cows based on more persistency can be used as a mean to lower disease susceptibility in dairy cows (Appuhamy 2006). This support the findings of Mostert *et al*. (2008) who reported that selection for persistency is a useful method for prevention of disease that cannot be measured directly in dairy cattle. Cows with dystocia tend to have latter peak yield and this might improve lactation persistency (Muir *et al*. 2004). Harder *et al*. (2006) reported favorite and positive genetic correlation between persistency of milk yield and fertility and claw and leg problem in Holstein cows. They concluded that high persistent cows have lower fertility and foot and leg problems. Body condition score (BCS) which can be related to health status of dairy cows may influence milk yield characteristics as well. Berry *et al*. (2007) studied the relationship between parameters of Wilmink function (this parameter indicate the rate of decrease milk yield after the peak yield or persistency) and BCS. They explained that there is linear relationship between these traits as with decreasing body condition score after the calving, the persistency of milk yield decreased too. Positive and significant phenotypic correlation between BCS and persistency in late stage of lactation (0.24) reported by Yamazaki *et al*. (2011) suggested that healthy cows with optimum body reserve in late lactation are expected to be more persistent compare to the other cows.

Conclusions

Lactation persistency is an important feature to determine lactation yield which has different definition and several ways to calculate. There is a relationship between this trait and other functional traits in dairy cows. Moreover, persistency is affected by several genetic and environmental factors. Peak time and peak milk yield are two important characteristics of lactation curve, which have positive and negative phenotypic correlation with persistency of milk yield in dairy cows respectively while based on many studies it should be an inverse relationship between total 305-d milk yield and persistency. Because this trait has low to medium heritability, the effects of environmental factors (such as herd effect, feeding management, seasons of production and calving) affecting persistency were considered by many studies. It has been documented that reproduction and health characteristics are also associated with persistency. Considering these relationships indicates that persistency is a trait of economic importance and it should be included in the selection objective and genetic improvement of dairy cattle programs.

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REFERENCES

Appuhamy JADRN. 2006. ‘Phenotypic relationships between lactation persistency and common health disorders in dairy cows’. MSc Thesis, Virginia University.

Atashi H, Moradi Shahrebabak M and Abdolmohammadi A. 2006. Study of some suggested measures of milk yield persistency and their relationships. *International Journal of Agriculture and Biology* **3**: 387–90.

Atashi A, Zamiri M J and Sayyadnejad M B. 2012. Effect of twinning and stillbirth on the shape of lactation curve in Holstein dairy cows of Iran. *Archiv Tierzucht* **55**(3): 226–33.

Atashi A, Zamiri M J, Akhlaghi A, Dadpasand M, Sayyadnejad M B and Abdolmohammadi A. 2013. Association between the lactation curve shape and calving interval in Holstein dairy cows of Iran. *Iranian Journal of Veterinary Research* **14**(2): 88–93.

Batra T R. 1986. Comparison of two mathematical models in fitting lactation curves for pureline and crossline dairy cows. *Canadian Journal of Animal Science* **66**: 405–14.

Berry D P, Buckley F and Dillon P. 2007. Body condition score and live-weight effects on milk production in Irish Holstein-Friesian dairy cows. *Animal* **1**: 1351–59.

Bouallegue M, Haddad B, Aschi M S and BenHamouda M. 2013. Effect of environmental factors on lactation curves of milk production traits in Holstein – Friesian cows reared under North African condition. *Livestock Research and Rural Development* **25**: 5–10.

Boujenane I and Hilal B. 2012. Genetic and non-genetic effects for lactation curve traits in Holstein-Friesian cows. *Archiv Tierzucht* **55**(5): 450–57.

Capuco A V, Ellis S E, Hale S A, Long E, Erdman R A and ZhaandPaape M J. 2003. Lactation persistency: insights from mammary cell proliferation studies. *Journal of Animal Science* **81**: 18–31.

Cilek S, Keskin I, Ilham F and Sahin H. 2009. Lactation curve traits of Anatolian population of brown Swiss cows in Turkey. *Archiva Zootechnica* **12**(2): 71–78.

Cobuci J A, Euclydes R F, Costa C N, Lopes P S, Torres R A and Pereira C S. 2004. Analysis of persistency in the lactation of Holstein cows using test-day yield and random regression model. *Revista Brasileira deZootecnia* **33**: 546–54.

Cobuci J A, Euclydes R F, Costa C N, Torres R A and Carmen S P. 2007. Genetic evaluation for persistency of lactation in Holstein cows using a random regression model. *Genetic and Molecular Biology* **30**: 349–55.

Cole J B and VanRaden P M. 2006. Genetic evaluation and best prediction of lactation persistency. *Journal of Dairy Science* **89**: 2722–28.

Cole J B and Null D J. 2009. Genetic evaluation of lactation persistency for five breeds of dairy cattle. *Journal of Dairy Science* **92**: 2248–58.

Dedkova L and Nemcova E. 2003. Factors affecting the shape of lactation curves of Holstein cows in Czech Republic. *Czech Republic Journal of Animal Science* **48**(10): 395–402.

De Roos A P W, Harbers A G F and Dejong G. 2001. Random regression test-day model in the Netherlands. *Interbull Bulletin* **27**: 155–58.

Elahi Torshizi M. 2016. Effects of season and age at first calving on genetic and phenotypic characteristics of lactation curve parameters in Holstein cows. *Journal of Animal Science and Technology* **58**(8): 1–14.

Elahi Torshizi M and Hosseinpour Mashhadi M. 2013. Evaluation of test day daily milk yield and persistency of different milking times in primiparous Holstein dairy cows in Iran. *Indian Journal of Animal Sciences* **83**(11): 1187–92.

Elahi Torshizi M, Aslamenejad A A, Nassiri M R, Farhangfar H, Solkner J, Kovac M M, Meszaros G and Malovrh S. 2013. Analysis of test day milk yield by random regression models and evaluation of persistency in Iranian dairy cows. *Iranian Journal of Applied Animal Science* **3**(1): 67–76.

Elahi Torshizi M and Hosseinpour Mashhadi M. 2016. Evaluation of different measures of milk yield persistency in Iranian Holstein dairy cows. *Journal of Agriculture Studies* **4**(3): 58–73.

Farhangfar H and Rowlinson P. 2007. Genetic analysis of Wood's lactation curve for Iranian Holstein heifers. *Journal of Biological Science* **7**: 127–35.

Ferris T A, Mao I L and Anderson C R. 1985. Selection for lactation curve and milk yield in cattle. *Journal of Dairy Science* **68**: 1438–48.

Gengler N. 1995. Use of mixed models to appreciate the persistency of yields during the lactation of milk cows. Doctoral Dissertation, Faculte Universitaire des science Agronomiques de Gembloux.

Gengler N, Keown J F and Van Vleck L D. 1995. Various persistency measures and relationships with total, partial and peak milk yields. *Brazilian Journal of Genetics* **18**(2): 237–43.

Grossman M, Hartz S M and Koops W l G. 1999. Persistency of lactation yield: A novel approach. *Journal of Dairy Science* **82**: 2192–97.

Haile-Mariam M, Bowman P J and Goddard M E. 2003. Genetic and environmental relationship among calving interval, survival, persistency of milk yield and somatic cell count in dairy cattle. *Journal of Dairy Science* **80**: 189–200.

Harder B, Bennewitz J, Hinrichs D and Kalm E. 2006. Genetic parameters for health traits and their relationship to different persistency traits in German Holstein dairy cattle. *Journal of Dairy Science* **89**: 3202—12.

Jakobsen J H, Madsen P, Jensen J, Christensen L G and Sorensen D A. 2002. Genetic parameters for milk production and persistency for Danish Holstein estimated in random regression models using REML. *Journal of Dairy Science* **85**: 1607–16.

Jamrozik J, Jansen G, Schaeffer L R and Liu Z. 1998. Analysis of persistency of lactation calculated from a random regression test day model. *Interbull Bulletin* **17**: 64–69.

Jamrozik J and Schaeffer L R. 1997. Estimates of genetic parameters for a test day model with random regressions for yield traits of first lactation Holsteins. *Journal of Dairy Science* **80**: 762–70.

Jensen J. 2001. Genetic evaluation of dairy cattle using test day models. *Journal of Dairy Science* **84**: 2803–12.

Johansson I and Hansson A. 1940. Causes of variation in milk and butter far yield in dairy cows. *Kungliga Lantbruk-sakademiens Tidskrift* **79**: 1–127.

Kamidi R E. 2005. A parametric measure of lactation persistency in dairy cattle. *Livestock Production Science* **96**: 141–48.

Kaygisiz A, Bakir G and Yener S M. 1995. Genetic and phenotypic parameter estimation of persistency of milk yield in Holstein Friesian cows. *Turkish Journal of Veterinary and Animal Science* **19**(4): 259–63.

Kheirabadi K and Alijani S. 2014. Genetic parameters for milk production and persistency in the Iranian Holstein population by the multitrait random regression model. *Archiv Tierzucht* **57**: 1–12.

Kistemaker G J. 2003. Comparison of persistency definitions in random regression test day models. *Interbull Bulletin* **30**: 96–98.

Khorshidie R, Shadparvar A A, GhaviHossein-Zadeh N and JoezyShakalgurabi S. 2012. Genetic trends for 305-day milk yield and persistency in Iranian Holsteins. *Livestock Science* **144**: 211–17.

Lopez-Villalobos N, McNaughton L R and Spelman R J. 2005. The relationship between lactation persistency and reproductive performance in New Zealand dairy cattle. Proceedings of the 56th Annual Meeting of the EAAP. Uppsala, Sweden.

Ludwin I. 1942. The effect of number of daily milkings upon persistency of milk production. *Journal of Dairy Science* **1**: 300–308.

Mostert B E, Van der Westhuizen R R and Theron H E. 2008. Procedures for estimation of genetic persistency indices for milk production for the South African dairy industry. *South African Journal of Animal Science* **38**(3): 224–30.

Muir B L, Fatehi J and Schaeffer L R. 2004. Genetic relationships between persistency and reproductive performance in first-lactation Canadian Holsteins. *Journal of Dairy Science* **87**: 3029–37.

Otwinowska-Mindur A and Ptak E. 2015. Genetic analysis of lactation persistency in the polish Holstein – Friesian cows. *Animal Science Paper and Reports* **33**(2): 109–117.

Pereira R J, Verneque R S, Lopes P S, Santana M L, Lagrotta M R, Torres R A, VercesiFilho A E and Machado M A. 2012. Milk yield persistency in Brazilian Gyr cattle based on a random regression model. *Genetic Molecular Research* **1**: 1599–1609.

Portillo B A and Pollott G E. 2011. Environment factors affecting lactation curve parameters in United Kingdom's commercial dairy herds. *Archivos de Medicinaveterinaria* **43**: 145–53.

Rekik B, BenGara A, Ben Hamouda M and Hammami H. 2003. Fitting lactation curves of dairy cattle in different types of herds in Tunisia. *Livestock Production Science* **83**: 309–15.

Rekaya R, Carabano M J and Toro M A. 2000. Bayesian analysis of lactation curves of Holstein-Friesian cattle using a nonlinear model. *Journal of Dairy Science* **83**: 2691–701.

Shanks R D, Berger P J, Freeman A E and Dickinson F N. 1981. Genetic aspects of lactation curves. *Journal of Dairy Science*

64: 1852–60.

Simianer H, Solbu H and Schaeffer R L. 1991. Estimated genetic correlations between disease and yield traits in dairy cattle. *Journal of Dairy Science* **74**: 4358–65.

Sorensen A, Muir D D and Knight C H. 2008. Extended lactation in dairy cows: effects of milking frequency, calving season and nutrition on lactation persistency and milk quality. *Journal of Dairy Research* **75**: 90–97.

Strapakova E, Candrak J and Strapak P. 2016. Genetic relationship of lactation persistency with milk yield, somatic cell score, reproductive traits, and longevity in Slovak Holstein cattle. *Archive Animal Breeding* **59**: 329–35.

Swalve H H. 1995. Genetic relationship between dairy lactation persistency and yield. *Journal of Animal Breeding and Genetics* **112**: 303–11.

Swalve H H. 2000. Theoretical basis and computational methods for different test-day genetic evaluation methods. *Journal of Dairy Science* **83**: 1115–24.

Tekerli M, Akinci Z, Dogan I and Akcan A. 2000. Factors affecting the shape of lactation curves of Holstein cows from the Balikesir province of Turkey. *Journal of Dairy Science* **83**: 1381–86.

Togashi K and Lin C Y. 2004. Efficiency of different selection criteria for persistency and lactation milk yield. *Journal of Dairy Science* **87**: 1528–35.

Togashi K and Lin C Y. 2006. Selection for milk production and persistency using eigenvectors of the random regression coefficient matrix. *Journal of Dairy Science* **89**: 4866–-73.

Wasike C B, Kahi A K and Peters K J. 2014. Genetic relationship between lactation curve traits in the first three parities of dairy cattle. *South African Journal of Animal Science* **44**: 245–53.

Weller J I, Ezra E and Leitner G. 2006. Genetic analysis of persistency in the Israeli Holstein population by the multi-trait animal model. *Journal of Dairy Science* **89**: 2738–46.

Wood P D P. 1967. Algebraic model of the lactation curve in cattle. *Nature* **216**: 164–65.

Wood P D P. 1970. A note on the repeatability of parameters of the lactation curve in cattle. *Animal Production* **12**: 535–38.

Yamazaki T, Takeda H, Nishiura A, Sasai Y, Sugawara N and Togashi K. 2011. Phenotypic relationship between lactation persistency and change in body condition score in first-lactation Holstein cows. *Asian Australasian Journal of Animal Science* **24**: 610–15.

Yamazaki T, Hagiya K, Takeda H, Sasaki O, Yamaguchi S, Sogabe M, Saito Y, Nakagawa S, Togashi K, Suzuki K and Nagamine Y. 2013. Genetic correlations between milk production traits and somatic cell scores on test day within and across first and second lactations in Holstein cows. *Livestock Science* **152**: 120–26.

Yamazaki T, Hagiya K, Takeda H, Yamaguchi S, Osawa T D and Nagamine Y. 2014. Genetic correlations among female fertility, 305-day milk yield and persistency during the first three lactations of Japanese Holstein cows. *Livestock Science* **168**: 26–31.

Yilmaz H and Koc A. 2013. A research on milk yield, persistency, milk constituents and somatic cell count of red Holstein cows raised under Mediterranean climate conditions. *Bulgarian Journal of Agriculture Science* **19**(6): 1401–07.

Zavadilova L, Jamrozik J and Schaeffer L R. 2005. Genetic parameters for test-day model with random regressions for production traits of Czech Holstein cattle. *Czech Republic Journal of Animal Science* **50**: 142–54.