Effects of Seasonal Changes and Forage Availability on Milk Yield of Cows among Smallholder Households in Ala-Buka, Kyrgyzstan

Munavar ZHUMANOVA
Main Specialist
Department of Agrarian Development
Ala-Buka, Zhalal-Abad region, Kyrgyzstan
munavar.ozh@gmail.com

Zakaria Amidu ISSAHAKU
Graduate Student
Graduate School for International Development and Cooperation
Hiroshima University
1-5-1 Kagamiyama, Higashi Hiroshima, 739-8529 Japan
Zakh2000us@gmail.com

Keshav Lall MAHARJAN
Professor
Graduate School for International Development and Cooperation
Hiroshima University
1-5-1 Kagamiyama, Higashi Hiroshima, 739-8529 Japan
mkeshav@hiroshima-u.ac.jp

Abstract

This study employs Wood's Gamma model to estimate the parameters of lactation curve at smallholder level and the effect of changing seasons on these parameters. Data on lactation of 89 indigenous and crossbreed cows in Baltagulov Village Government (BVG), Ala-Buka, Kyrgyzstan were used to estimate the Wood's Gamma model and to generate the lactation curves. Lactation curve parameters including a scaling factor associated with initial milk yields (β_0), the inclining (β_1) and declining (β_2) slopes before and after peak yields respectively were analyzed by calving season. Results show that initial milk yield is higher among winter and autumn cows than spring and summer calvers. The inclining and the declining slopes are, however, lower in winter and autumn compared to spring and summer. Peak milk yield and lactation persistence can serve as criteria for herders in selecting cows. In this study, peak milk yield is associated with total milk yield and can used as a useful guide in selecting breeders as opposed to lactation persistence. Peak milk yield is higher in winter and autumn vis-à-vis spring and summer. The effect of calving season is largely dependent on the availability of pasture forage. Forage shortage in spring and early summer, and lack of fodder from the end of winter to mid spring are perceived as the major problems by almost 50% of households in BVG. It is imperative to note that seasons of calving affect milk yield through their impact on forage availability. Forage shortage during spring and summer tend to decrease productivity of cows. The sweltering heat in summer and autumn do not also auger well for optimum milk production. The study recommends the manipulation of calving to match periods of forage availability. It also recommends protection of cows from adverse weather conditions to optimise milk production in BVG, Kyrgyzstan.

1. Introduction

Smallholder dairy farming in Kyrgyzstan contributes to improved household food security and incomes. Indigenous and local crossbreeds, Ala-Too, are raised because of their ability to survive harsh climatic condition of Kyrgyzstan and to produce higher amount of milk than other meat-dairy direct crossbreeds. Currently, quantity of milk produced at district and national levels in

Kyrgyzstan is still increasing due to the growth in the number of cattle raised. However, milk yield is declining, particularly among smallholder agro-pastoral production systems that are common in most mountainous areas. The declining trend of milk yield is attributable to low level of management skill, insufficient supplementary feeds, diseases and seasonal forage shortages (Zhumanova, 2011).

Improving efficiency in milk production requires good knowledge of lactation curve, which shows the relationship between milk yield and time after calving. It helps in nutritional and reproductive management of lactating animals (Anwar et al., 2009). The lactation curve can be employed to estimate lactation yield, expected time of peak milk production, peak milk yield, and persistency of yield and this is useful for managers of dairy farms in culling low milk producers in planning for feed and farm resources (Wood, 1967). Variations in the shape of the lactation curve for dairy cows are believed to stem from both genetic and environmental factors (Wood, 1980; 1970a; 1970b; 1969). Olori et al. (1999) fitted data obtained from a single uniformly managed herd to five different models, none of which adequately described individual lactations. They inferred that the suitability of empirical models of the lactation curve does not depend on the mathematical form of the function alone but rather, more on the biological nature of the lactation. Seasonal patterns in pasture availability for instance, are a major environmental factor contributing to typical lactations that cannot be adequately described by standard models (Kamidi, 2005). Consequently, animals respond to changes in the environment and management regimes to determine the animal's production level (Beede et al., 1985).

Information on the shape of lactation curves in indigenous and crossbreed cows of Kyrgyzstan is very limited. There are few studies about mathematic modelling of lactation curves for smallholders in agro-pastoral systems. Most of the studies conducted on mathematic modelling of lactation curve are on large dairy and breeding farms with well organised farming systems (Rook et al., 1993; Dijkstra et al., 1997; Pollot, 2004; 2000). Unlike those studies, this study aim to apply Wood's Gamma model to analyse the shape of the lactation curve among lactating cows in smallholders' farm with different agro-pastoral management systems of indigenous and local crossbreeds in Kyrgyzstan. The rest of this paper is structured as follows: the next section puts forward the analytical model for undertaking this research; section three presents and discusses the results of this study. Section four underlines the environmental conditions affecting the milk production in Kyrgyzstan; and section five concludes the paper by summarizing major findings of this research.

2. Material and methods

2.1 Study area

This study was conducted in Ala-Buka district, Zhalal-Abad region in the south western part of Kyrgyzstan. There are eight Local Administrative areas in Ala-Buka district and Baltagulov Village Government (BVG) was selected for this study. During Soviet period, BVG was one of the largest sovkhozes, which was specialized on breeding meat-dairy direct local crossbreed cattle, Ala-Too[1]. Currently, most of the smallholders (67 % of 120 sampled households) keep this breed and its annual milk production ranges between 1000 and 3500 kg in this area. Other households, who live in remote mountainous area, prefer to keep indigenous breed[2]. The total milk amount of indigenous breed ranges from 500 kg to 1000 kg annually. Usually, lactating cows in study area are fed under the open grazing, seasonal grazing and stall feeding systems. Majority of households use seasonal grazing systems. During spring, summer and autumn, animals graze in near-village pastures and in winter, they are kept under stall feeding systems. There are few households who move to pastures under the transhumance system. Households who live near village or district centres, use stall feeding system.

2.2 Analytical Model

The lactation curve technique is often used to estimate lactation yield, expected time of peak milk production, peak milk yield, and persistency of yield. Lactation curve represents a graphical representation of the relationship between milk yield and lactation length, and it is useful for managers of cows in culling low milk producers and in planning for feed and farm resources (Anwar et al., 2009). Parameters of the lactation curve are estimated based on Wood (1967) Gamma function specification. The empirical technique employed for this study based on the Wood's Gamma model is specified as follows:

$$Y = \beta_0 n^{\beta 1} e^{-\beta_2 n} \quad (1)$$

Where Y is the average monthly milk yield in month n; β_0 is the scale parameter indicating Initial milk Yield; β_1 and β_2 are the shape parameters of the curve, for the increasing and decreasing phases of the lactation curve respectively; and e is the exponential sign. The gamma model is transformed logarithmically into a linear form for least squares regression analysis as follows:

$$\ln Y = \ln \beta_0 + \beta_1 \ln(n) - \beta_2 \text{n} \quad (2)$$

The log transformation of Y, β_0 and n are ln Y, ln β_0 and ln(n) in equation (2) above. Ordinary Least Squares (OLS) estimates of β_0, β_1 and β_2 can be used to calculate time to peak milk production, time to peak production and the persistence of the yield curve. Peak milk yield represents the maximum milk yield during lactation, and the lactation persistency expresses the ability of animals to maintain a reasonably constant milk yield after the lactation peak. Time to peak milk production is calculated by using the ratio of β_1 and β_2 coefficients whereas peak milk yield and persistence of the yield curve are estimated using the following formulas:

$$\textbf{Peak Milk Yield}^3 = \beta_0(\beta_1/\beta_2)^{\beta_1}\exp(-\beta_1) \quad \textbf{(3)}$$

$$\textbf{Lactation Persistency Index} = \frac{mean\ milk\ yield}{peal\ milk\ yield} \times 100 \quad \textbf{(4)}$$

$$\textbf{Estimated Total Milk Yield} = \beta_0\ (\beta_1 + 1)/\beta_2^{(\beta_1+1)} \quad \textbf{(5)}$$

In dairy cattle, milk production typically rises to a peak 2 to 8 weeks post-partum and steadily declines thereafter (Wood, 1969; Kamidi, 2005). This study focuses on peak yield, time to peak milk production and persistency in individual lactation curves. The lactation curve, based on the above-mentioned features, is analyzed by season of calving.

2.3 Sampling and data description

For this study, 80 households were sampled from different villages of BVG. Data on 89 mixed-breed lactated cows, calving between November 2008 and September 2010, were collected through semi-structured questionnaire. The summary of lactation data by season of calving is shown in Table 1. The mean monthly milk yield for all cows is 156.26 kg and the standard deviation is 49.26 kg.

Table 1. Summary statistics of milk yield of cows by season of calving

	N	Mean	Standard deviation	Minimum	Maximum
Overall	89	156.71	49.26	66.67	309
Season of calving					
Winter	53	169.91	50.1	66.67	309
Spring	26	132.35	34.92	78.4	196.25
Summer	3	112.78	25.24	88.33	138.75
Autumn	7	166.15	58	105.88	268.29

Period of calving is categorized into four seasons and they are winter (December to February), spring (March to May), summer (June to August) and autumn (September to November). From Table 1 above, most cows under this study calved in winter and spring. Mean monthly milk is higher among cow calving in autumn or winter and lower in spring and summer.

3. Results and Discussion

This section presents and discusses the OLS parameter estimates of the Wood's Gamma model. From Table 2 below, the overall estimates for initial milk yield (β_0), inclining slope (β_1) and declining slope (β_2) were 175.084±1.0396, 0.9464±0.0812 and 0.3174±0.0214 respectively. All parameters of the lactation curve are statistically significant. It takes about three months for monthly milk yield to reach its peak at 191.10kg. Overall, lactating cows have persistence after peak yield of 97.02% and total milk yield of 3,180.83 kg. The R-squared for the transformed logarithmic gamma function is 27.35%.

The estimated lactation curve together with actual curve is shown in Figure 1. Both actual and predicted monthly milk yields increase to reach a peak within few months and, thereafter, decline over several months, which is the defining characteristic of lactation curves. Over the entire duration of lactation, the predicted lactation yield curve lies below the actual lactation yield curve, indicating that the predicted milk yield underestimates actual milk yield of all cows considered under this study.

3.1 Effect of calving season

From Table 2 below, the values of initial milk production (β_0), the inclining coefficient of the lactation curve (β_1) and the declining coefficient (β_2) for all seasons together with their standard errors are presented. All the parameters of the lactation curve by season of calving are statistically significant at conventional levels. Initial milk yield is higher in autumn and winter as compared to spring and summer. The inclining (β_1) and the declining (β_2) slopes are lower for winter and spring calvers. The R-squared for the transformed logarithmic gamma function is 27.89%, 38.17%, 31.10% and 31.34% for winter, spring, summer and autumn respectively.

Table 2. Parameter estimates of lactation curve and other lactation characteristics by calving season

	β_0	β_1	β_2	Peak yield (kg)	Time to peak yield (kg)	Persistence index	Total milk yield (kg)	R^2
Overall	175.08*** (1.0396)	0.9464*** (0.0812)	0.3174*** (0.0214)	191.10	2.9817	75.83%	3180.83	27.35%
Season of calving								
Winter	188.84*** (1.0517)	0.9660*** (0.1036)	0.3176*** (0.0268)	288.38	3.0416	76.11%	3539.81	27.89%
Spring	151.12*** (1.0626)	1.0395*** (0.1290)	0.3524*** (0.0346)	221.54	2.9498	73.68%	2586.22	38.17%
Summer	133.14*** (1.1951)	0.9880** (0.4308)	0.3485** (0.1281)	196.24	2.835	73.20%	2151.92	31.10%
Autumn	221.89*** (1.1534)	0.8442** (0.3238)	0.3400*** (0.0909)	328.05	2.4829	71.21%	2992.21	31.34%

Notes: *** means significant at 1% and ** means significant at 5%; values in parenthesis are s the standard errors of regression estimates; peak milk yield and total yield are in kilograms while time to peak production is in months.

Milk production is largely dependent on the shape of the lactation curve. Relevant elements of the lactation pattern are the peak yield and the lactation persistency. Both higher peak milk and persistence of peak product tend to raise total milk yield. Higher persistence increases the area under the lactation curve thereby resulted in higher total milk yield. Thus, cows with persistent lactation tend to have flatter lactation curves. Calvers with high initial milk yield also tend to have higher peak milk and higher total milk yield (see Table 2). Cows calving in winter and autumn have high initial milk and peak milk levels (188.84 kg and 221.89 kg) as compared to spring and summer calvers. Winter and spring have slightly longer time to peak and strong lactation persistence as compared to summer and autumn. Efficiency of milk yield, in general, requires both peak milk yield and persistence. From Table 2, calvers for all seasons have similar peak milk persistence ranging from about 71% in autumn to 76% in winter. Peak milk yield, however, varies markedly across calving seasons. The ranking of peak milk yield, as can be seen in Table 2, thus tends to determine total milk yield in BVG. Winter and autumn calvers have higher peak yields and therefore higher total milk yield of 3,180.83 kg and 2,992.21 kg respectively as compared to 2,586.22 kg and 2,151.92 kg for spring and summer respectively.

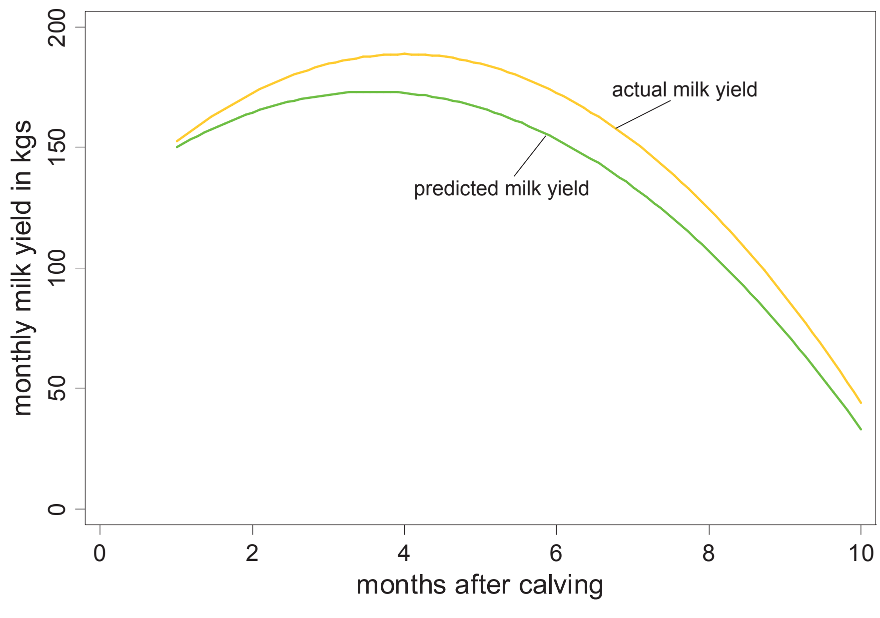

Figure 1. The predicted lactation curve and actual curve

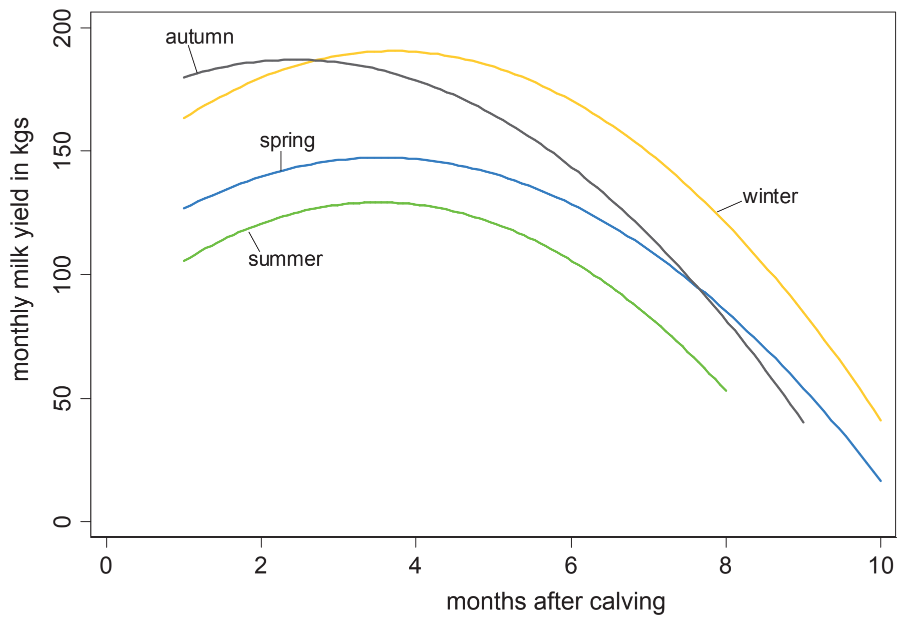

Figure 2. Lactation curves by season of calving

3.2 Effect of forage on the shape of lactation curve and total milk yield production

The effect of calving season is largely dependent on the availability of forage and management practices adopted to protect the animals against adverse climatic conditions. The cropping pattern in Kyrgyzstan is such that fodder is more abundant on cropland in autumn but there is an acute shortage during early spring and mid-summer due to dry and hot weather. Most households in BVG identify forage as the single most important factor in keeping livestock as shown in Figure 3. 57% of surveyed households perceive fodder and pasture forage shortage as the biggest problem. Other livestock management problems such as labor and skills among others are perceived as less serious problems.

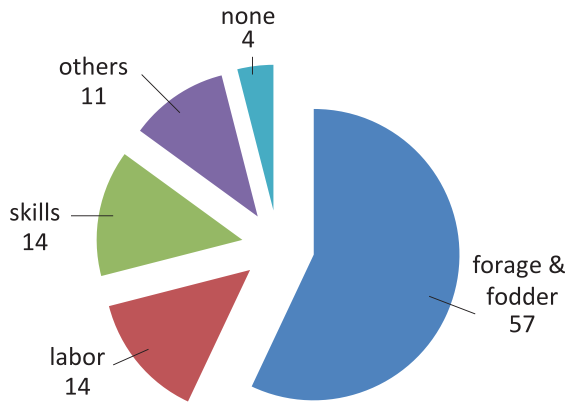

Figure 3. Perception of households on problems of livestock management in BVG
Source: Field survey, 2010

In BVG, serious forage scarcity occurs from March to May as can be seen in Figure 5. The pasture shortage in early spring is attributable largely to early movement to pastures when grasses have not yet matured as shown in Figure 4. Dry conditions or lack of water during growing season adversely affect quality of forage crops at this time of the year. In the rural areas, households store hay for winter feeding during which time heavy snow occurs. In BVG, moving from the "serious problem" to "no problem" stage takes about three months (from May to August). From August to December, there are no serious problems with forage to feed livestock. Cows feed on forage mostly in near-by cropland after harvesting wheat (major cereal) and this continues as crops are harvested one after the other. Forage shortage, in certain times of the year, is also attributable to lack of land for forage making, growing of cash crop which do not produce forage residue such as potato and sunflower or lack of finance to purchase forage from the market in winter when the prices are unusually high. The forage availability in BVG is comparable with Tashi et al, (2000) findings from Tibet, where most herders suffer a huge loss of animals because of lack of supplementary feed for animals during winter and spring. As a result, herders are caught in a vicious cycle of "weight increase in summer – fattening in autumn – loss of weight in winter – death in spring". Further, White et al. (1999) analyses the adverse effects of underfeeding on animal production in the study area and found underfeeding as challenge to meeting nutrient requirements in animals. At crucial stages of the life cycle, this can have major long-term effects. For young animals, restricted feeding is unlikely to be compensated by higher levels of feeding later in life, resulting in small-framed animals. Failure to meet target weights at mating may result in reduced ovulation rates, resulting in a failure to conceive or a lower proportion of multiple births. Poor feeding during pregnancy can result in substantial weight losses by the dam, low birth weights for the offspring and reduced milk yields in the ensuing lactation. Underfeeding in lactation causes lower milk yields and poorer growth rates in suckling calves. Loss of live weight in the dam will be recovered later in lactation at the expense of milk production.

Figure 4. Lactating cows grazing on nearby village pastures in summer and in winter in BVG.
Source: Field survey, 2010 and 2012

Based on above discussions, it can be discerned that efficient use of forage plays major role in milk production. However, the amount of milk yield depends on calving season among other factors, which affects feed sufficiency as shown in Figure 5 below. In the study area, majority of cows are calved during winter and spring. Only a few cows calve in summer and autumn. Efficiency of milk will be enhanced if more cows give birth in autumn rather than spring, which coincide with periods of forage availability.

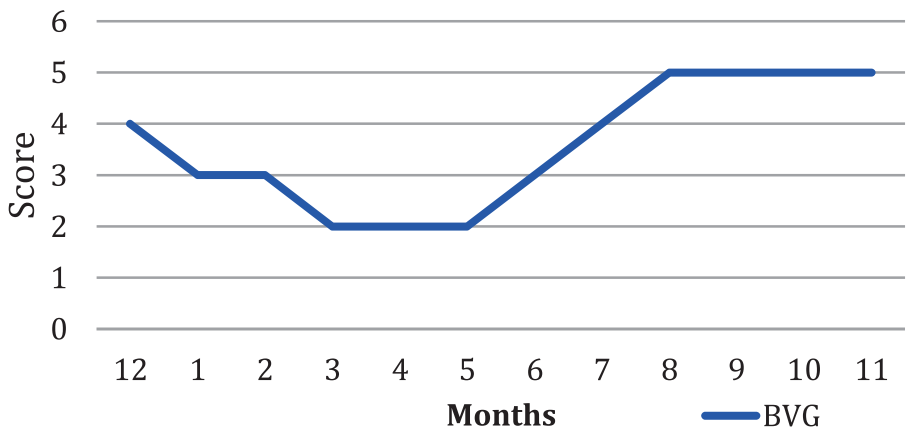

Figure 5. The rank of annual feed scarcity problem
Note: The score on the vertical axis ranges from 1 "serious feed scarcity" to 5 "no problem"
Source: Field survey, 2010

4. Conclusions

This study analyzes the effects of calving on the parameters of the lactation curve. The overall estimates for initial milk yield (β_0), inclining slope (β_1) and declining slope (β_2) were 175.084 (1.0396), 0.9464 (0.0812) and 0.3174 (0.0214) respectively with standard errors enclosed in parenthesis. All of the parameters of the lactation curve were significant at conventional levels of statistical significance. The R-squared for the transformed logarithmic gamma function is 0.27. Initial milk yield is higher among winter and autumn cows than spring and summer calvers. The inclining and the declining slopes are, however, lower in winter and autumn compared to spring and summer.

Two elements of the lactation curve, peak milk yield and lactation persistence, can serve as a guide to herders in selecting cows. In this study, peak milk yield is associated with total milk yield and can used as a criterion in selecting breeders. Peak yield is higher in winter and autumn, implying that herders should plan such that most cows calve in winter and autumn to maximize milk yield. The lactation persistence index, however, perform poorly in predicting total milk yield

It is imperative to note that seasons of calving affect milk yield through their impact on forage availability. Forage shortage during spring and summer tend to decrease productivity of cows. The sweltering heat in summer and drought conditions in spring do not also auger well for optimum milk production. The study recommends the manipulation of calving to match periods of forage availability and high milk demand. It also recommends protection of cows from adverse weather conditions to optimise milk production in BVG, Kyrgyzstan.

Endnotes

[1] The Ala – Too breed of cattle of meat-and-dairy direct has been developed in 1950. It is improved crossbred of local cattle with Swiss brown and Jersey blood and it make up about 85% of the total cattle number. This crossbreed is very suitable to the harsh, unpredictable climate condition and to complicated geographical landscape. Another local crossbreed is Oluya-Ata dairy direct breed which make up about 10% of the cattle in the republic are black and white graded up from Friesian / Holstein imports (Nogoev, 2008; Fitzherbert, 2005)

[2] Indigenous breed cattle size is small. The color is brown. Most of the poor households prefer to keep this breed, due to less labor requirement. The amount of milk also less than other breed, but fat content is high. Some of them can be milked all year round. This breed very well adapts to mountain climate and forage condition; it is easy to gain fat to them and to use that fat as energy during forage scarcity time (Zhumanova, 2011).

[3] The exponential function is used to model a relationship in which a constant change in the independent variable gives the same proportional change (i.e. percentage increase or decrease) in the dependent variable. The function is often written as exp(x), especially when it is impractical to write the independent variable as a superscript.

References

Anwar, M., et al. (2009), Factors Affecting the Shape of the Lactation Curve in Nili-Ravi Buffaloes in Pakistan, *Zoological Suppliment Services*, 9:201-207.

Beede, D. K., et al. (1985), Effects of warm climates on milk yields and composition (Short term effects), In A.J.Smith (Ed.), *Milk production in developing countries*, Centre for Trop.Vet.Med., University of Edinburg, 324-347.

Dijkstra, J., et al. (1997), A model to describe growth patterns of the mammary gland during pregnancy and lactation, *Journal of Dairy Science*, 80: 2340-2354.

Kamidi, R. E. (2005), A parametric measure of lactation persistency in dairy cattle, ILRI. *Livestock Production Science*, 96: 141-148.

Olori, V. E., et al. (1999), Fit of standard models of the lactation curve to weekly records of milk production of cows in a single herd, *Livestock Production Science*, 58: 55-63.

Pollot, G. (2000), A biological approach to lactation curve analysis for milk yield, *Journal of Dairy Science*, 83: 2448-2458.

Pollot, G. (2004), Deconstructing milk yield and composition during lactation using biologically based lactation models, *Journal of Dairy Science*, 87: 2375-2387.

Rook, A., et al. (1993), On the mathematical description of lactation curves, *Journal of Agricultural Science*, Cambridge, 121: 97-102.

Tashi, N., and Partap, T. (2000), Livestock Based Livelihoods in Tibet, China and Sustainability Concerns, In P. M. Tulachan (eds.), *Contribution of Livestock to Mountain Livelihoods: Research and Development Issues* 171-183, Kathmandu: ICIMOD

Tekerli, M., et al. (2000), Factors affecting the shape of lactation curves of Holstein cows from Balikesir Province of Turkey, *Journal of Dairy Science*, 83: 1381-1386.

Wood, P. D. P. (1969), Factors affecting the shape of lactation curve in cattle, Animal Production Science, 11: 307-316.

Wood, P. D. P. (1967), Algebraic model of the lactation curve in cattle, *Nature*, 216: 164-165.

Wood, P. D. P. (1970a), A note on the repeatability of parameters of the lactation curve in cattle, Animimal Production, 12: 535-538.

Wood, P. D. P. (1970b), The relationship between the month of calving and milk production, Animal Production 12: 253-259.

Wood, P. D. P. (1980), Breed variations in the shape of the lactation curve of cattle and their implications for efficiency, *Animimal Production*, 31: 133-141.

Zhumanova, M. (2011), *A Study on Livestock and Land Management in Kyrgyzstan*, higashihiroshima, Hiroshima, Japan: Hiroshima University, Graduate School for International Development and Cooperation.