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Review
Adjusting Milk Production Records for Calving Age

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ABSTRACT

Age at calving is an important source of variation in milk yield records of cows and buffaloes. Production records are usually pre-adjusted for this environmental factors for the estimation of breeding values. Various aspects of age adjustment including how it is defined and the procedures of adjustment are reviewed for cattle and buffaloes.

Key Words: Age at calving; Cattle; Buffaloes; Milk Yield

INTRODUCTION

Milk yield in dairy animals is influenced by many environmental factors including age at which cows calve. Increase in milk yield at a decreasing rate until the mature age is reached, and decline thereafter has long been recognized. Most of the studies agree that age at calving is an important source of the variation in milk yield. The magnitude of this effect however, varies depending on the species, breed, actual age studied (early or late), and the way the age is defined, and other factors taken into account while documenting its effects. Various aspects of calving age adjustment of milk yield records in dairy cows and buffaloes are reviewed.

Age as important environmental factor. Lush and Shrode (1950) estimated that age at calving caused 14–16% of the variation in milk yield. The bias in age correction factors, which culling of cows may cause, was discussed and multiplicative age-correction factors were presented for cows milked twice and thrice daily. Syrstad (1965) estimated that age of calving accounted for 12% of within herd variance in yearly milk yield. Gacula *et al.* (1968) reported variation in milk yield associated with age to be 17, 12, 25, 14, and 18% for Ayrshire, Guernsey, Holsteins, Jersey, and Brown Swiss cows. Average variation in milk constituent yields and percentages, explained by age at calving was 14.6 and 7.3% in the five breeds. Age explained 20 to 40 % of the total sums of squares in the studies of Auran (1973), Dommerholt (1975), and Cooper and Hargrove (1982). Auran (1973) also reported that effect of age on monthly milk yields decreased with advancing lactation, accounting for about 41% of the total variation in first monthly test and about 2% in the last monthly test. For cumulative monthly records age accounted for about 45% of the variation in three cumulative records and about 23% in 10 cumulative records.

In the study of Chauhan (1985) on Jersey cows, about 10% of variation in milk yield was explained by age-parity classes. Contribution of age in total variation in milk yield varied between 1 to 17% for the three herds studied by Papajcsik and Bodero (1986). Age at calving was also an important source of variation in the studies of Chauhan (1988), Saxena *et al.* (1991), Rege (1991), and Djemali and Berger (1992). Martinez *et al.* (1992) reported that variation in production due to age at calving could be best explained by a third degree polynomial in Gir cattle. Heifers calving between 34 to 38 months and those calving from 54 to 56 months differed by more than 20% in milk yield. Age effects were most important in first lactation in the study of Sobczynska and Dymnicki (1992).

Studies are available in the literature that show that age was not an important variation source for milk yield. Fisher *et al.* (1983) studied 400 first lactations to examine relative importance of age and weight at calving for first lactation milk yield. Although, both were reported of nearly equal importance for explaining variation of total yield of first lactation, age was found to be of little value in explaining variation of milk yield of 60-day intervals. Correction for weight, rather than age at first calving was suggested to prevent bias in favor of sires producing larger heifers.

Age by season of calving subclass at the start of productive life of cows did not affect milk yield significantly in the study of Aleandri *et al.* (1984). Increase in milk yield with increased age was, however, reported for all three seasons studied. Age from 24 to 50 months of calving was divided into nine classes to study these effects. Age at first calving was also reported not related to milk yield in the study of

Van Dam *et al.* (1988). A total of 1161 animals were involved in the study. First available lactation record initiated between 20 and 31 months of age was defined as first lactation. Heifers with higher age at first calving were reported to produce more milk but the increase was not statistically significant. Weight was reported to be better predictor of first lactation fat and protein corrected milk production than age in the study of Stassen *et al.* (1991) involving 1081 animals. Effect of age on fat and protein corrected milk yield was reported significant when used alone, but became non-significant when weight was also included as a predictor.

Age vs parity. Reports in the literature have conflicted on whether records should be corrected for age at calving alone or if parity effects, should also be taken into account. Syrstad (1965) reported that the effect of lactation number on milk yield, independent of age, was of minor importance. Mao *et al.* (1974a) analyzed 113,918 milk and fat yield records on the first two consecutive lactations of Holsteins in Canada. These records were part of a larger data set (n=696,682) that could meet restrictions for parity identification. The overlapping period from 31 to 37 months of age at calving included 24,479 records and was grouped into three age classes (31 to 33, 34 to 35, and 36 to 37 months) to examine the joint effect of age and parity. Average production of second lactation cows at a particular age was reported to be greater than first lactation cows of the same age. Interaction between age and parity, observed graphically both for unadjusted solutions and solutions adjusted for herd-year-season effects, did not reach statistical significance for milk yield. Parity was suggested unimportant to adjust for age at calving for first and second lactation records. For fat yield however, interaction between age and parity interaction was statistically significant. Leroy *et al.* (1980) concluded that for Herve Black Pied cattle, correction for age at calving can be applied independently of that for lactation number. Data on 41,709 lactations (first 3 parities) were analyzed by fixed effect linear model in this study. Kennedy *et al.* (1981) suggested the need to consider parity in addition to age and season in developing age correction factors in dairy goats.

Chauhan (1985) reported that for Jersey cows (2276 lactations), age accounted for more variation in milk yield than parity. Out of total variation accounted for by age, parity, and age by parity effects, age ignoring parity accounted for 79%, and parity after age accounted for 8% of the variation. Fitting the effect of parity ignoring age accounted for 66% and age after parity 21% of variation. Age by parity effect was reported to be significant and accounted for 12% of the variation. It was thus suggested that records should be jointly corrected for age and parity rather than for age alone. Kafidi *et al.* (1990) estimated age effects within the first three parities in Belgian Black Pied cattle. Ptak *et al.* (1993) has also suggested defining age classes within parity to account for variation in milk yield of cows calving in different parities at the same age.

Defining age for adjustment. Age at calving has been studied both as a classification variable and as a continuous variable to develop correction factors for age. When age is used as classification variable, the estimated constants are either used as such or are smoothed to eliminate fluctuations in yield that result from small numbers of records in some of the age classes.

Lee (1974) utilized first lactation records of Canadian Holsteins to study adjustment of milk yield for age at calving. The months of age at calving and calendar month of calving were combined to form a single age-month classification for deriving least squares constants. The fitted curve, with a linear coefficient of 213 ± 21 kg and quadratic coefficient of -2.7 ± .4 kg was recommended for age adjustment of first lactation milk yield. Mao *et al.* (1974) divided age at calving from 18 to 200 month into 23 age classes and grouped them into six age groups to estimate age-month constants. Group 1, for example, consisted of six age-classes. The first age class included cows calving between 18 to 21 months and last age class of 27 to 28 months. Groups 2, 3, 4, and 5 had three, one, one, and two age-classes while the last age group had 10 age classes. Similar definitions were used by Norman *et al.* (1978) for calculating adjustment factors for SNF and protein and by Powell *et al.* (1990) for age-season adjustment of milk yield records of Holsteins in Ecuador.

Everett *et al.* (1982) estimated 149 age (20 to 168 months) month effects for six breeds in Australia. Solutions were smoothed to obtain correction factors for milk and fat yield adjustments. Age classes were defined across parities by Keown and Everett (1985). Age-month adjustment factors were estimated in this study for Northeast region of U.S. All cows calving before 24 months were grouped into one category in defining 26 age groups. Similar grouping was done in the study of Duraes and Keown (1991). Age groups were also defined across parities in the study of Lee and Ohh (1985). Thirteen age class solutions were obtained for the two seasons of calving and were smoothed to obtain correction factors for cows calving between 19 and 138 or more months of age.

Martinez *et al.* (1990), while comparing different age adjustment procedures, classified age into 18 classes for cows calving between 20 and 96 months of age. Solutions were smoothed by a second degree polynomial model to develop correction factors. Rege (1991) fitted age at calving (22.5 to 112 months) as a classification variable along with lactation length to get age class solutions in Kenyan Friesian (n=28,890). Age was divided into 30 age classes at 2.5 month intervals for a model having fixed effects of herd, year, and season, and random effect of sire. Age class solutions were smoothed by a cubic function to get adjustment factors. Age at calving in Sahiwal cows was classified into 29 classes of two months each for studying additive and multiplicative adjustment factors in the study of Saxena *et al.* (1991). Djemali and Berger (1992) used age as classification variable along with linear and quadratic regressions of lactation length to document yield characteristics of Friesian cattle under North African conditions of Tunisia. Age at calving from 21 to 105 months was divided into 3-month intervals in this study and the curve was smoothed to obtain multiplicative adjustment factors.

Larger age classes have been used in a few studies. Data were classified into three age classes i.e. 1 to 2 years, 3 to 5 years, and older cows in the study of Papajcsik and Bodero (1986). Seven age classes defined by Chauhan (1985) were also ≥1 year interval.

Age effects have been defined within parities in some studies (Buchsteiner, 1978; Skjervold, 1978; Morales *et al.*, 1989; Kafidi *et al.*, 1990; Ptak *et al.*, 1993; Dahlin et. al., 1998). Skjervold (1978) studied 312,422 lactation records of cows in Norway while Buchsteiner (1978) utilized 345,569 records of Simmentals to study age effect on milk yield. Morales *et al.* (1989) used age-parity-season subclasses to develop correction factors for Carora cattle and Brown Swiss crossbreds in Venezuela. Thirteen age classes ranging from 18 to 168 months of calving within first to fourth and higher parities were defined for each of dry, rainy, and transitional seasons. Kafidi *et al.* (1990) estimated age effects from data on 115,774 first, 74,884 second, and 46,436 third lactations of Belgian Black Pied cattle. Age at calving varied from 22 to 37 months for first, 34 to 51 months for second and 45 to 70 months for third parity. A fixed effect linear model was used and ages were not grouped. Definition of age groups in the study of Ptak *et al.* (1993) and Dahlin *et al.* (1998) was also within first, second and third parities. Dahlin *et al.* (1998) reported that under a trivariate animal model analysis of Sahiwal cows, milk yield increased with increase in age at calving within parity. Maximum difference between age at calving across lactations was 180 kg.

Linear regression of milk yield on age at calving has also been used to adjust milk yield for age at calving. Lee and Hickman (1972) used within herd regressions of first lactation milk yield on age at calving to adjust milk yield records. Cooper and Hargrove (1982) estimated linear and quadratic regressions of milk yield on age at calving from Pennsylvania DHIA data to develop age correction factors. Age at calving was also used as a covariate (linear, quadratic and cubic terms) along with lactation length in developing age correction factors for Pitangueiras cattle in the study of Lobo *et al.* (1984). Chauhan (1987) used linear and quadratic regression of milk production on age at calving in studying variation in milk yield due to herd, year and seasons. Age at calving was treated as a covariate in studying its effect on reproduction, milk production, and disease incidence in Friesian heifers in the study of Van Dam *et al.* (1988). Ko *et al.* (1989) reported separate linear regressions of milk yield on age at calving for the first four parities to adjust records. Parity adjustment factors were also reported to adjust records to first parity equivalent.

Adjustment Procedures

a) Computing methods. Basic problems related to age adjustment have been reviewed by Freeman (1973). Prior to the introduction of the maximum likelihood (ML) method, records were either corrected by gross comparison (GC) or paired comparison (PC) methods. Contemporary records are grouped in classes by age or lactations and correction factors are calculated from the means of these classes in GC method. In PC, records of the same cows in successive years are compared. The age effect is measured by the change in mean yield from previous to the next year. Both of these methods of computing age adjustment factors have been reported to be biased due to within herd selection of cows. The ML method eliminates such bias due to selection. Method accounts for culling by considering cows as random. Perfect repeatability of cow's records (assumed in least squares procedure) is also not assumed. Henderson (1949) showed that when repeated observations are used and selection is practised on the records earlier in life, the ML methodology is appropriate. Age factors tend to be biased upward in the GC method by r(m'-m) and biased downward in PC by (1-r)(m'-m), where r is repeatability and m, m' are means of lactations before and after selection (Henderson *et al.*, 1959).

Miller *et al.* (1966) compared ML factors with GC and PC using 24,636 lactations. GC factors, particularly at older ages were reported more similar to ML factors than were the PC factors. ML factors were recommended due to minimum variance and unbiasedness. Miller and Henderson (1968) compared age-season correction factors derived from ML, GC, and PC methods using 1,340,302 Holstein records. The ML factors were intermediate between GC and PC (adjusted for year) factors. Factors by GC were reported to substantially over adjust second and third lactation records. Miller *et al.* (1969) also reported that age factors based on GC were seriously biased when season and age are confounded with herd production. Age-month factors derived from ML procedures were later published for adjusting milk yield of Holsteins in the Northeastern U.S. (Miller *et al.* (1970).

Reddy and Mishra (1983) reported that simple regression method of estimating lactation length adjustment factors should be preferred over GC method for predicting 305-day yield from cumulative yields for Murrah buffaloes. Das and Balaine (1985) compared first lactation equivalent age adjustment factors obtained by least squares (LS), GC, PC and multiple regression (MR) methods. Lactation records of all lactation lengths were included in the study and were corrected for significant effects of lactation length, body weight at calving, farm, period and season of calving. Higher coefficient of variation, higher estimate of repeatability and better reduction of variance among lactations after adjustment were true for factors derived by LS method and this method was recommended for genetic evaluation programs of buffaloes. Martinez *et al.* (1990) compared multiplicative age-season adjustment factors obtained from ML, GC, and PC procedures. Complete lactation records (n=24,881) from 7,753 Holsteins in Brazil were used in the study. Factors were reported to be almost identical from ML and PC and were about .04 smaller than GC adjustment factors for cows calving in dry season and up to 45 months of age at calving. ML methodology was found to be robust with respect to repeatability estimates chosen. Schutz and Norman (1994) reported that under US production set up adjustments to standardize milk yield traits for calving age and season needed revisions. Use of more recent data under animal model was suggested for more precise adjustments.

Khan and Shook (1996) examined age effects among 1.6 million records of Holsteins. Data from 24 years at Wisconsin Dairy Herd Improvement Association were used for this study. Multiplicative, additive, and a combined method of adjusting records for calving age were evaluated. The combination of multiplicative and additive adjustment that minimized variation among within age class standard deviations was considered optimum. The increase in yield associated with advancing age and parity was found to be greater in recent than earlier years. Age effects were more pronounced for younger cows while season effects were greater for later parities. Heterogeneity of within age class variation was near minimum by additive adjustment in the first three parities while heterogeneity in 4th and 5th parities was not sensitive to method of adjustment. Although multiplicative adjustment was near optimum in these two parities. Yearly averages of estimated breeding values from models with additive adjustments were similar to those derived under optimum adjustments and were quite different from multiplicative adjustments. This was especially true for the recent years. Genetic trends were similar between even and odd herds both for additive and multiplicative adjustments. Multiplicative adjustment of records for age at calving inflated the estimates of genetic trend. Based on both heterogeneity of variance and genetic trend estimates, additive adjustment was recommended.

b) Herd-level correction factors. Although age effects are estimated across different months or seasons of calving, many earlier studies (Searle & Henderson, 1959, 1960; Searle, 1960, 1962; Syrstad, 1965; Hickman & Gravir, 1968; Hickman, 1973; Dempfle & Hagger, 1979) and some more recent studies (Everett *et al.*, 1982; Wilmink, 1987; Chauhan, 1988; Sobczynska & Dymnicki, 1992) have examined age corrections at different herd levels of milk production. Searle and Henderson (1959) developed additive age correction factors based on the level of herd production. Factors were expressed as regressions on the age-corrected herd average and were termed as within-herd additive gross comparison factors. It was found that age corrections should be larger in herds of high production than in herds of low production, independent of the actual production of young cows. Factors expressed as regressions on the age-corrected herd averages were reported to take into account the between-herd differences in age effects. Searle (1960) presented a simplification of the method and developed multiplicative factors for herd-level age correction. Searle and Henderson (1960) again compared herd-level method of age correction with multiplicative and additive adjustments (across herds). Results were similar for herd-level and multiplicative adjustments. Later, Searle (1962) however, found herd-level factors to be better over multiplicative factors. Syrstad (1965) showed that increase in milk yield with advancing age, expressed in per cent, was similar for high or low producing herds. Hickman and Gravir (1968) and Hickman (1973) recommended herd-level procedure for age adjustment. A large discrepancy between total and intra-herd regressions was attributed to confounding of age at calving with level of herd production in the study of Miller *et al.* (1970). Dempfle and Hagger (1979) reported significant differences between age effects in low and high producing herds. The multiplicative age correction factors were, however, reported to be similar for any age class. It was suggested that a single set of these factors would be more useful than correcting age effects additively.

Wilmink (1987) studied influence of age at calving on 305-day milk yield in relation to level of herd and population level of production. A repeatability model was used for 49,669 lactation records of 27,965 Dutch Friesian cows. Age differences were proportional to herd level of production. Consequently, one set of age factors were recommended to be used for all levels of herd production. Chauhan (1988) used 168,480 first lactation records to study the effectiveness of additive and multiplicative correction factors in estimation of breeding values of dairy sires. Data were split into low, medium, and high producing herds. Estimates of age effects at calving showed nearly parallel lines for the three production levels. It was implied that as long as the herd effects or the herd production effects are fitted in the model, separate sets of additive correction factors for different herd production would not be needed.

Age adjustment in buffaloes. Parity has been the most common alternative for removing differences in production due to age at calving in buffaloes. This assumes that there is no difference in yield within a parity or difference is not important enough to use age instead of parity. Another reason for the preference of parity over age has perhaps been the use of analysis of variance or simple regression analyses instead of the more sophisticated mixed linear models. It may also be due to unavailability of date of birth records especially in field situations where farmers remember the parity of the animal far more correctly than date of birth. In studies involving single parity only, correction for actual age at calving is usually ignored. Some researchers have also reported separate analyses for different parities to study the effects of different factors on milk production (Patro & Bhat, 1979; Das & Balaine, 1985).

Significant differences in milk production due to parity has been reported by Sane *et al.* (1972), Jawarkar and Johar (1975), RoyChoudhury and Deshmukh (1975), Basu and Ghai (1978), Kumar and Bhat (1978), Garcha and Tiwana (1980), Das and Balaine (1982), Cady *et al.* (1983), Swain and Bhatnagar (1983), Ulaganathan *et al.* (1983), Farrag *et al.* (1984), Gogoi *et al.* (1985), Vij and Tiwana (1986), Tailor and Jain (1987), Dutt and Yadav (1988), Ashmawy (1991), Kawthar *et al.* (1991), Iype and Nagarcenkar (1992), and Juma *et al.* (1992). Effect of parity on the other hand was not significant in the studies of Gurnani *et al.* (1976); and Khanna and Kanaujia (1981). In some of these studies however, the adjustments due to other factors such as lactation length was ignored.

As far as the extent of difference among different parities, few studies have compared the solutions. Dutt and Yadav (1988) reported that the least squares mean of 1st lactation milk yield was lower than 2nd and 3rd lactation means but the same as those of 4th and 5th lactations. In the study of Farrag *et al.* (1984), 1st lactation yield (1350 kg) was significantly different from 2nd, 3rd, 4th and 5th lactation yields (1724 to 1898 kg) while means of lactations other than 1st lactation were statistically the same. Lactation milk yield of 1st lactation was also statistically lower than 2nd, 3rd and 4th lactations in the study of Gogoi *et al.* (1985). Least squares means of milk yield were, however, similar for 3rd and 4th lactation in this study. Juma *et al.* (1992) reported that least squares means of 1st lactation milk yield (1079 kg) were statistically different from those of later lactations in Iraqi buffaloes. Least square means of 2nd and later lactations (1296 to 1428 kg) were reported to be similar in their study. Das and Balaine (1994) reported mature equivalent age adjustment factors for lactation milk yield in Indian buffaloes. The multiplicative adjustment factors for converting the milk yield record of a particular lactation to mature equivalent (4th) lactation basis derived by the least-squares method were reported to be the most efficient. Swain and Bhatnagar (1983) on the other hand reported that least squares means of 2nd to 9th lactation were similar but higher than that of 1st lactation in Murrah buffaloes. Difference between first lactation and later lactations for milk yield was also true in the study of Kumar and Bhat (1978). Milk yield for 1st and 2nd lactation (1405 and 1520 kg) was not different from each other but were lower than other lactations in the study of Ulaganathan *et al.* (1983).

Difference in milk production due to age at calving within a lactation has not been extensively reported except for age at first calving. Ashfaq and Mason (1954) found that lactation number and not the age to be an important factor influencing milk yield. This was based on comparison of simple means of 296 milk yield records of 1st and 2nd lactations of Nili-Ravi buffaloes. The model used by Cady *et al.* (1983) included parity as well as age, and both were reported to have a significant effect on milk yield.

Correction factors reported by some of the researchers for adjusting lactations are given in Table I. In most of these studies, first parity has been used as base for estimating the correction factors, except by Basu *et al.* (1978) and Khan (1986), where base was third parity (parity of maximum production). The correction factors differ in magnitude because of the different samples of the populations of different breeds have been used and also because the effects of other factors causing variation in milk yields have been removed differently by different scientists.

Effect of age on milk yield in buffaloes has also been expressed in terms of regression equations or as covariables when other factors causing variation in milk yield are in the model. Regression of 300 day milk yield on age at calving was positive and significant up to third lactation (0.25 ± 0.06, 0.42 ± 0.07 and 0.25 ± 0.07 kg per day respectively for first three lactation) in the study of Bhat and Patro (1978). Data used were from 11 military farms (n=4963) of Northern India. Records were adjusted for farm, period and season of calving in this study. Prakash *et al.* (1988) also reported partial regression coefficient of milk yield on age at calving (keeping body weight constant) to be 0.392 ± 0.10 kg per day ($P < 0.01$) for first five lactations in Murrah buffaloes.

Studies on Pakistani buffaloes (Khan, 1986; Salah-ud-Din, 1989) have reported multiplicative age correction factors. Khan (1986) used a quadratic regression equation to estimate milk yield and then computed factors as a ratio of estimated yield at 119-130 months of age and any age for which correction was required. Records having lactation length of more than 305 days were pre-adjusted to 305 days. Salah-ud-Din (1989) developed separate correction factors for first and later lactations by least square mixed model procedures. Records with lactation length of more than 300 days were adjusted to 300 days. Base age used in this study was 124-128 months. Age was defined within parity in the recent studies (Iqbal, 1996; Akram, 1997; Khan *et al.*, 1997; Chaudhry, 1998) on Nili-Ravi buffaloes. It was concluded that the age at calving was a significant ($P<0.01$) source of variation at all stages of lactation curve (Chaudhry, 1998). Multiplicative adjustment to 60 months of age at calving was suggested (Khan *et al.*, 1997). For Italian buffaloes also, age at calving within parity affected milk yield traits significantly (Rosati, 1997).

It can be concluded from the above reviewed studies in cattle and buffalo that age at calving is an important source of variation in milk yield. Milk yield records should thus be adjusted for comparison of animals for herd management decisions and genetic evaluation. Although, correction of records for this factors depends on the amount of information recorded or available, removal of age effects within parity through maximum likelihood methodology is the method of choice. Although, records are mostly pre-adjusted by multiplicative adjustment factors for genetic evaluations, information on the effects of such adjustments on genetic trends in lactation and test day milk yield is still scarce especially for buffaloes.

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