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Review Article

THE EFFECTS OF HEIFER GROWTH ON MILK PRODUCTION AND EFFICIENCY

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ABSTRACT
The effects of heifer growth on milk production and efficiency depends upon its reproductive efficiency, nutrition, genetics, environmental factors and other related factors. Reproductive efficiency is the primary factor affecting productivity in female calves and greatly affected by slow growth rate, delayed puberty & age at sexual maturity. Strategies for optimizing growth and maturity may include proper feeding, housing, health management and regulation of hormone like bGRF and GnRH. Protein and energy are the most critical nutrients affecting the weight and consequently age at puberty in heifers. Heifers can be bred when they have attained 60% of their matured adult body weight. Sexual puberty is directly associated with body weight than age of the animal. Early weaned calves grow faster later on compared to those unweaned. Effective summer and winter management reduces stress and thereby enhances early maturity in the animal. Forage along with adequate concentrate and performance modifiers can be supplemented to gain faster growth rate for early puberty on cost effective basis. Reducing the age at maturity and improving the reproductive efficiency is required to augment the milk production of India at a low input to meet the future requirements.

KEY WORDS: Growth, maturity, optimization, Heifers.

INTRODUCTION

The success of any dairy industry depends upon proper management of heifers. Unfortunately, this is the most neglected area. During this period, heifers are not generating income directly. The significance of adequate nutrition and management of replacement heifers is often ignored and production losses linked with slow growth rate are not realized. The right approach to decrease this cost is to decrease age at first calving. The shortening of rearing period (non-productive time) would lead to cost reduction. This can be achieved by faster heifer growth, earlier onset of sexual maturity, breeding and calving. Various experiments have been conducted to reduce the age of puberty by various methods like nutritional & hormonal treatments etc. By optimizing age of puberty, cost of raising heifer can be economized for dairy farmers. Adequate protein or energy helps in the early onset of puberty and can significantly reduce the sexual maturity. Fertility is more associated with body weight rather than age of the animal. Adequate level of nutrition is necessary for the proper functioning of endocrine system since it influences synthesis as well as release of the hormones necessary for attaining high body weight and sound reproduction. The need of the hours is to explain the effect heifer management on attaining early sexual maturity and growth rate. Therefore, keeping in view of importance, the present review has been done to study the effects of heifer growth on milk production and efficiency. Besides, study is also stressed on optimization of body weight for efficient milk production without sacrificing health and efficient use of scarce feeds and fodder available in the country. Moreover, optimising body weight for potential milk production keeping in mind the scarcity of feeds and fodder of our country, meeting the requirement of large cattle population (199 million) and hereby, meeting our targeted milk production for 121 cores human population is the objective of this review.

Importance of Heifer Growth

Every farmer aims to achieve maximum profit. Healthy and well- fed calves are the first prerequisite for excellent performance later in their lives (Zeman *et al*., 2006). Several studies have been conducted to determine whether or not older and larger heifers produce more milk when compared to their younger and smaller herd mates. There was no relationship between production and percentage increase in weight, wither height, and chest girth from birth to 2 year (Holtz *et al*., 1961). There is report of low correlations ($r < 0.2$) between weight, gain, and feed intake to subsequent milk production (Lee, 1997). There are no strong associations between heifer rearing traits and first lactation yield traits (Lee, 1997). Most published reports indicate that heifer growth plays an important role

in milk production. Increasing calving weight has a positive effect on first lactation milk yield (Harville and Henderson, 1966, Heinrichs and Hargrove, 1987, Hoffman and Funk, 1992, Keown and Everett, 1986, Lin *et al*., 1985, Miller and Mcgilliard, 1959). The positive relationship between BW at calving and milk yield is mainly due to a positive relationship between growth rate capacity and milk yield (Sejrsen *et al*., 2000). Most dairy operations with higher production levels demonstrated greater growth in their dairy calves (Heinrichs and Losinger, 1998) helping to maintain the production cycle. Larger cows produce more milk and the most profitable cows are those that calve around 2 yr of age. Recent research has determined that more specific parameters for growing dairy replacement heifers should be targeted to maximize lactation production. First, ADG for dairy heifers weighing 150 to 320 kg should be 0.8 kg/day, to maximize milk production in the first lactation (Zanton and Heinrichs, 2005). On the contrary, Zanton and Heinrichs (2005), also point out that other researchers believe that pre-pubertal gains should be less than 0.8 kg, around 0.6 to 0.7 kg/d to maximize milk production for larger breeds of dairy cattle (Foldager and Sejrsen, 1987, Sejrsen *et al*., 2000). However, Holtz et al., (1961) suggested that heifer ADG has no significant effect on milk production in the second and subsequent lactations.

Cross breeding will decrease the weight, height and gain of heifers. By having a smaller female milking such as the JH, a dairy producer is able to lower his or her maintenance costs (Heins *et al*., 2008). There are substantial additive genetic differences between dairy breeds and sire groups within a breed for size and growth rate of replacement heifers (Lee, 1997, Lee *et al*., 1988). Heifers do not have constant growth rates and the most usual pattern generally observed is a faster growth between the birth and onset of puberty (6-10 months of age), followed by a slower growth period. Therefore, the most efficient way of increasing heifer growth potential is to improve nutrition in the per-puberty phase (Heinrichs and Gabler 2003). The heifer rearing period (particularly in terms of nutrition and feeding management) should be divided into two consecutive phases, i.e. before and after the onset of sexual maturity (Mourits *et al*., 1999a, Abeni *et al*., 2000 and Shamay *et al*., 2005). Prenatal feeding management has an impact on future performance and profitability of heifers (Le Cozler *et al*., 2008).

Effect of growth on early sexual maturity in heifer

Sexual maturity is more influenced by body weight than the age of the animal (Wattiaux 2011). Growth refers to an increase in linear size, weight, accumulation of adipose tissue and retention of nitrogen and water. Growth is a highly complex and integrated process that involves increase in cell number, increase in cell size and the deposition of substance within cells. It involves interaction between nutrients environment, genotype, hormone and the receptors for these hormones of different tissues. It is additionally influenced by age, sex and difference in the tissues that are growing. The growth rate and age at maturity are directly linked with productive and reproductive performance of a female. A cow maturing at an early age will also calve at an early age, give more number of calves, complete more number of lactation and thus will produce more milk in her life time. The sexual maturity is highly dependent on growth rate, since it is a function of body weight rather than age.

Higher growth rate helps in an early achievement of the target weight that is essential for early sexual maturity. Attainment of a particular body weight is reported to be essential for the sexual maturity. Target growth rates or optimum body weight are needed to maintain economically efficient growth of individual animals so that breeding and first calving occurs at the ideal age and weight. Puberty occurs when heifer's weight is between 40-50% of mature body weight, regardless of age. Breeding should occur when heifers reach 50-60% of mature body weight. Growth rate should be sustained during pregnancy such that heifers weigh 80-85% of mature body weight at first calving. A lesser rate of growth is associated with a delayed onset of puberty and thereby disrupts reproductive cycles. Thus, growth rate considerably influences age at puberty and ultimately age at first calving. The faster growth rate of animal is, therefore, desirable in dairy enterprise to produce high quality dairy heifers, which exhibit sexual maturity at minimum cost. Thus, at present time, optimisation of growth of dairy animals has become an area of research interest.

Importance of early sexual maturity in Heifer management

Heifer rearing period requires considerable capital expenditures including feed, housing and veterinary expenses. Raising replacement heifers incurs one of the highest cost of the dairy operation and represents 15-20% of the total milk production cost (Stelwagen and Grieve, 1992 and Heinrichs, 1993). Following the cost of feeding the lactating herd, heifer rearing is the second largest expense in dairy operations; accounting for approximately 20% of the total cost (Gabler *et al*., 2000). A basic approach in reducing heifer rearing costs is to shorten the non productive rearing period by lowering the parturition age. Age at first calving (AFC) has a significant influence on the total cost of raising dairy replacements with older calving heifers being more expensive to raise than younger and lowering the age of maturity by one month lowers the cost of farm by 4.3% (Tozer and Heinrichs, 2001).Besides, reducing AFC can also improve the profitability of the enterprise by increasing life time milk production per year of herd life (Lin *et al*., 1988). The AFC can be reduced by a combination of increasing pre-pubertal average daily gain and decreasing age at breeding (Radcliff *et al*.,2000) or by reducing age at breeding alone (Ettema and santos, 2004). So, early maturity in heifer is a good managemental tool for profitable dairy enterprise.

Management of Puberty and sexual maturity in dairy heifer

Management of dairy heifers for productive and reproductive success, both before and after puberty, play a major role in determining the efficiency of any dairy production system. The prepubertal and postpartum periods management are the two most critical physiological periods associated with female reproduction. Therefore, a general understanding of the processes that underlie developmental changes in the heifer during pubertal development and in the sexually mature females

during and after calving can aid in understanding the basis of established management protocols. Many researchers have defined puberty in many ways. Generally, puberty in female animal is defined as the age at which ovarian cyclicity commences. Puberty is best defined as the age at which ovulation is first occurred and is followed by characteristics estrus cycles in cattle. The onset of puberty occurs between 6 and 24 months of age depending on genetic and environment factors. Puberty in heifers at first ovulation is characterised by increase in plasma progesterone concentration above 1 ng/ml (Madgwick *et al.*, 2005).

Sexual maturity is an important factor in deciding the productivity and fertility of dairy cows. Sexual maturation of heifers involves an increase in ovarian circumference as well as increase in LH secretion while no change in FSH secretion with age. Sexual maturation involves a complex interplay of endocrine factors which bring about development of the reproductive tract and is dependant to a large extent on genetic and environmental factors. On average, zebu cattle reach puberty 6-12 months later than exotic cattle. *B. Indicus* cattle do not appear to achieve puberty until they reach 60% of adult body weight whereas *B. taurus* dairy and beef breeds reach puberty at 30-55% of their mature body weight.

Nutrition plays a significant role in attaining the proper weight at proper time required for sexual maturity. Age at puberty is negatively correlated with plane of nutrition. Protein and energy are most critical nutrients influencing the growth of calves to become heifers. Besides, minerals and vitamins are also important. Balanced feeding, improved management and minimum disease prevalence can be helpful in reducing the age at first calving (Heinrich *et al.*, 2005). Now-a-days the use of hormones like GnRH and GnRH analogues is becoming common in domestic animal production systems since they are most commonly being used to control the fertility and reproductive health of the dairy cows.

Effect of nutrition on heifer growth

Heinrichs and Gabler (2003) suggested that the age at first calving is influenced not only by circumstances around calving, but also by nutrition, health and environmental factors in the first 4 months of life. Nutrion has a major role in the skeletal development and BCS in dairy cows. The dairy heifers skeletal growth is usually measured by heart girth, wither height, length, hip width and hip height.

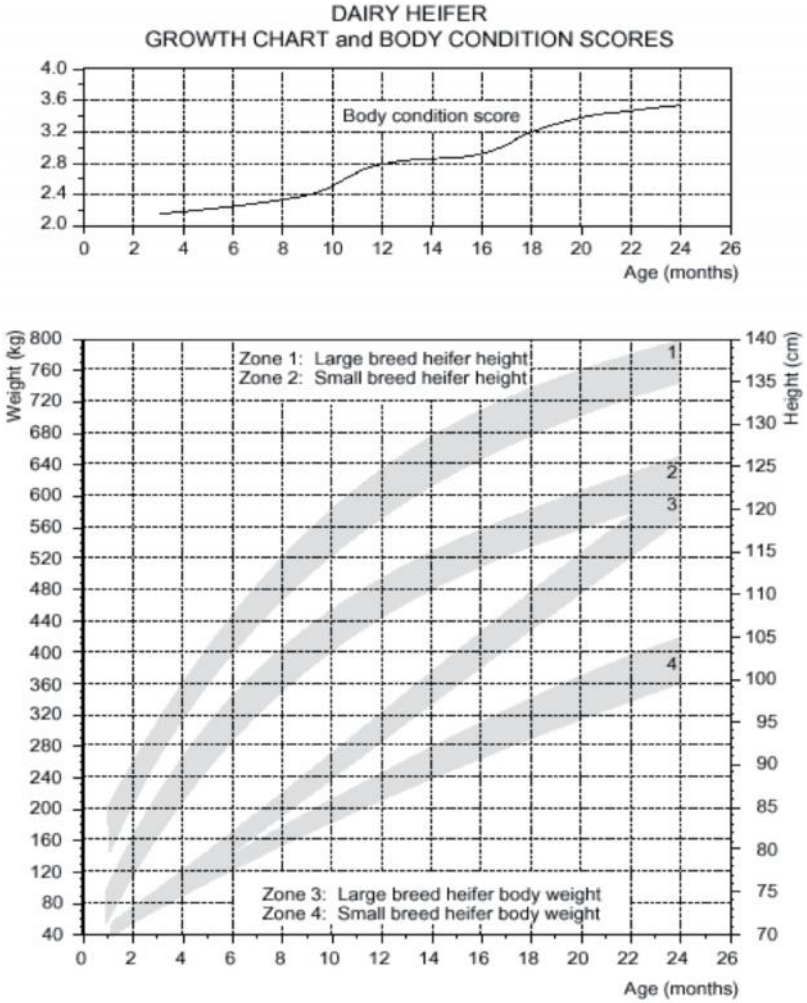

FIGURE 1: Body weight (kg), height (cm) and body condition scores (points) in different months of heifer rearing period for small and large breeds (Wattiaux, 2011).

Wither height of a cow is considered to be important because tall animals have longer bodies and therefore have more body capacity. Tall cows also have udders higher off the ground which is important for injury prevention and ease during milking operations. A body condition score (BCS) is based on the amount of fat and muscle tissue covering the skeletal frame and is indicative of the animal's nutritional status. Body condition score (BCS) is the best method of assessing body reserves and carcass composition. Body conditions are reflection of the fat reserves carried by the animal. The BCS is determined largely by the amount of fat covering the rump and tail head area. The loin area also is evaluated. Changes in BCS of cow indicate likely levels of subsequent reproductive performance. Management of body condition score is a critical component of nutritional management of cow for high fertility. Major increases or losses in BCS are undesirable. Over conditioned heifers will not breed easily and will have a higher incidence of calving difficulty and also delayed mammary development that decreases lifetime milk production potential (Keown, 2005, Zeman *et al*., 2006; Nor *et al*., 2013). There is no simple relationship between BCS and live weight, but as a rule of thumb, a loss of one point in BCS is equivalent to a loss of approximately 50 or 60 kg or 10% of body weight. At first service and at first calving BCS should be 2.0 - 2.5 to 3.0 - 3.5, respectively. BCS has useful application for raising heifers. Excessive BCS of young heifers often causes fat deposition of the udder and inhibit milk secreting cell formation in the immature mammary gland. Thus, a BCS of 2.0-2.5 is desirable for heifers up to breeding age, after the breeding of heifers, their body condition score may be increased to 3.0-3. The ideal body condition score of heifers around calving is 3 (Shamay *et al*., 2005). Over-conditioned heifers have a higher risk of dystocia and postparturient metabolic disorders (Wattiaux 2011).

Herd nutrient and energy balance can be effectively monitored by measuring BCS. Proper feeding of energy, protein minerals and vitamins as per requirement is very much essential for maximization of lifetime reproductive and productive performance of dairy animals. It is important to feed balance protein and energy so that heifers grow in stature as well as body weight. Besides, adequate minerals, vitamins should be fed for normal and healthy bone, teeth and other tissues. Increased nutritional level in young heifers may help to improve physiological process, thus leading to early maturation of hypothalamic hypophyseal axis thus leading to early initiation of ovarian activity and reproductive function. Dietary mistakes made in the second year of heifer rearing period lead to impaired lactation performance, i.e. reduced daily milk yield and compromised fertility (Meyer *et al*., 2004). Poor feeding management from 12 to 18 months of age resulted in impaired cow fertility (Roche *et al*., 2000). So, nutrition plays a significant role in the growth of heifer.

Inadequate feeding can worsen fertility and increase early embryonic death. After breeding, it is necessary to adjust the diet to weight gain over 800 g/day to support the body frame growth and suppress fat deposition. Similar body weight gain values of 816 g/day were also recommended (Meyer *et al*., 2004). The target adult body weight of 630-820 kg was recommended for Holstein cows (St-Piere, 2002). Heifers should reach 55% of target body weight during the first pregnancy, 85% at the first calving, 92% at the second calving and 96% at the third calving. In the older heifers, a large proportion of protein supply is provided by ruminal microflora (Spiekers *et al*., 2009). Carbohydrate supply in older heifers should be well balanced to prevent fat deposition.

What is Target weight concept in dairy heifer management?

Body weight is an important factor in the attainment of puberty in heifers, a management method referred to as the target weight concept is widely used, where it is recommended that heifers reach approximately 65% of their estimated mature body weight by the beginning of their first breeding season. Target weight is simply an estimation of the weight at which individual heifer will reach puberty. Moderate daily gains in the range of 0.5 kg/d will usually be adequate to ensure that heifers reach their first calving. Normal pre-breeding weight should be close to 60-65% of the heifer's expected mature weight. Selection of the target weight may be based on the average weight of the heifer group, a percentage of the expected mature weight, or extrapolated from the average frame score. Heifers will normally reach puberty at 60-65 % of their mature weight, but this will be affected by the genetics, season of birth, and rate of post weaning gain (Engelken, 2008). Based on a genetics and expected mature size, a target weight can be selected and the feeding program tailored to meet the needed average daily gain. Relative body weight has been applied with the use of the target body weight concept in heifers, where heifers are fed to reach a particular percentage of their estimated mature body weight by a particular time such as the start of breeding. The mature body weight is generally estimated from the average BW of mature cow in the herd, which is subject to many factors such as physiological and nutritional status, but the target body weight concept provides a valuable rule of thumb method of managing heifers. So, target weight concept is one of the best Managemental tools for raising dairy heifers.

Young heifer production performance

Young heifer management strategies depend on breed, genetic potential of animals and target first calving age. The management strategy strongly influences future performance and profitability of the herd (Mourits et al., 1999a). The age at first calving has an impact on heifer raising cost and consequently on depreciation of production cows. Besides, it affects lifetime performance and longevity of cows. The aim of the heifer rearing is to raise dairy cows so that it will give maximum performance during their productive life at the lowest possible cost of production (Stevenson *et al*., 2008 and Le Cozler *et al*., 2009a).

Impact of heifer's growth on later milk yield

Most researchers found a negative impact of high average daily weight gain in young heifers on first lactation milk yield. Particularly the pre-puberty period is critical because mammary parenchyma reduction may occur (Capuco *et al*., 1995; Sejrsen and Purup, 1997; Silva *et al*., 2002; Ettema and Santos, 2004; Daniels, 2010). In some experiments no such effects were found (Kerzt *et al*., 1987; Waldo *et al*., 1998; Pirlo *et al*., 2000) and in some

mammary parenchyma was reduced only if ADG was over 0.7 kg/day (Abeni *et al*., 2000), 0.9 kg/day (Knight and Sorensen, 2001), and 1.0 kg/day (Mourits *et al*., 1999a). The proposed upper ADG limit for smooth mammary gland development was 0.7-0.8 kg/day (VanAmburgh *et al*., 1998; Zanton and Heinrichs, 2005). It was suggested that both the low (up to 400 g/day) and high (over 800g/day) ADG before puberty leads to a reduction in milk yield in subsequent lactations by 10 to 40 % (Van Amburgh *et al*., 1998). It was reported that ADG of about 0.7 kg/d is optimal for achieving maximum performance (Shamay *et al*., 2005). An accelerated growth of Holstein heifers during puberty, enhanced by higher protein levels in the diet, does not depress future milk production and they suggested that heifers growing faster before puberty show an impaired mammary gland development, but the first lactation milk yield was not adversely influenced due to a better body development (Madgwick *et al*., 2005 and Macdonald *et al*., 2005). Increasing ADG in young heifers from 0.4 to 0.6 kg/day milk yield and mammary gland size were increased by 10 % and further increase in ADG, up to 0.8 kg/day, did not have an effect on mammary gland volume or milk yield (Foldager and Sejrsen, 1991). ADG of 0.9 kg/day in young heifers significantly reduced milk fat in the first lactation (Abeni *et al*., 2000). The relationship between ADG and milk yield depends on the breed (Hohenboken *et al*., 1995). Small breeds are more sensitive to negative consequences of intensive rearing in terms of the first lactation milk yield (Sejrsen *et al*., 2000). Heifers with high milk production potential seem to be less sensitive to intensive nutrition. Holstein heifers can achieve higher ADG without marked undesirable effects. Moreover, higher ADG has an accelerating effect on the puberty onset (Le Cozler *et al*., 2008).

Effect of age at first calving on future milk yield

The length of heifer rearing period depends mainly on growth rate and conception at optimum live weight and age. As soon as a heifer reaches body weight considered as ideal for conception, she should be successfully bred. Any prolongation of the empty time leads to mostly undesirable increase in age and body weight at the first conception and calving (Britt *et al*., 1998; Stevenson *et al*., 2008). Heifers which calved at earlier ages had lower first lactation milk yield but better lifetime performance (Ettema and Santos, 2004; Dawson and Carson, 2004). Late calving heifers produced by 11 % milk more in the first lactation. Early calving heifers had greater weight losses during early lactation and longer calving-to-calving interval. However, the first calving live weight did not affect milk yield in the second and third lactations (Shamay *et al*., 2005). It is recommended that the first calving age to be 23 to 24 months in Holsteins, to achieve the most profitable milk production (Mourits *et al*., 1999a, Heinrichs and Gabler, 2003), Ettema and Santos, 2000 and Shamay, 2005). It is seen that heifers that calved at 22-23 months of age showed the best performance and longevity because highly fertile heifers keep their good fertility to higher ages. reported that the first calving ages higher than 24.5 months did not improve fertility, lactation performance nor the health of heifers (Ettema and Santos, 2004). Medium calving (23-24 months) heifers brought by $138.33 and $98.81 higher profit than early calving (before 23 months) and late calving (over 24.5 months) ones, respectively. Hoffman (1997) concluded that mean first calving ages higher than 24 months are not profitable and indicate an uneven herd. Mourits *et al.* (1999b) suggested to take into account and compare possible benefits of lower first calving ages such as lower feed cost, higher cumulative production per month of age, shorter generation interval and lower overheads, and disadvantages such as reduced conception rate, impaired calving ease, reduced milk yield per lactation, reduced longevity and increased cost of nutrients required in later diets. The optimum calving age is 24 months and every day older than 24 months increases the raised heifer cost by $1.50 - $3.00 (Fricke, 2003). It can be concluded that early calving ages less than 23 months are associated with lower milk yield in the first lactation, lower milk fat, higher milk protein due to a reduced milk production but with no adverse effect on subsequent lactations.

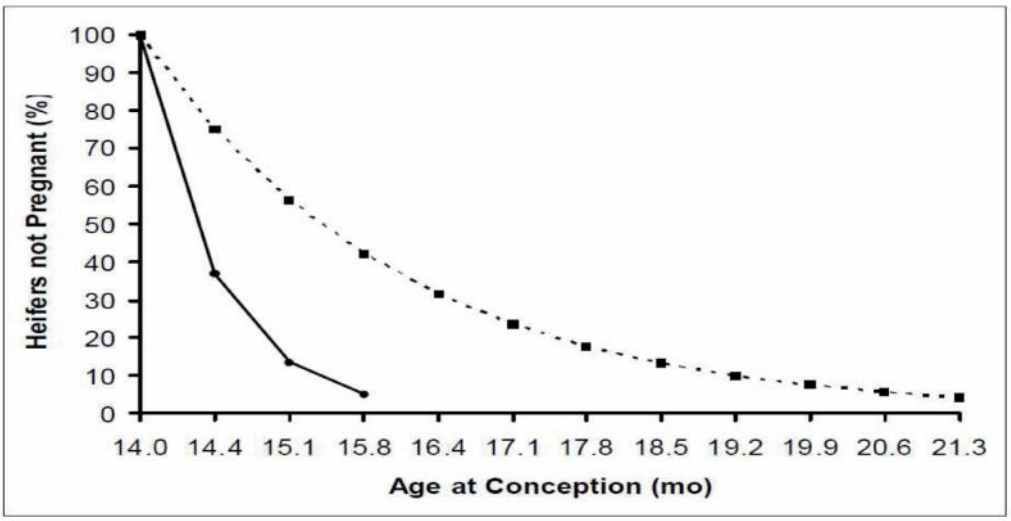

FIGURE 2. Reproduction management of heifers (Fricke, 2003)

Consequences of Excess Growth

Dairy producers strive to be effective and efficient by maximizing dry matter intake and milk production in dairy cows and maximizing growth of dairy heifers. However, it is important to realize that in heifer growth and development, excessive growth may be detrimental in the productivity of a dairy heifer. The pre-pubertal phase is a very critical time in the dairy calf's life. During this time, the mammary system is growing all metrically (Sinha and Tucker, 1969). The most critical period of mammary gland growth is likely to be 3 to 9 mo of age, prior to puberty (Heinrichs, 1993). The NRC (2001) recommends that ADG for 10 to 67 wk old dairy heifers be 0.7 to 0.8 kg/d. The dairy calf must be fed in a restricted manner to result in adequate ADG so that mammary gland development occurs uninterrupted and subsequent milk production is unaffected (Sejrsen *et al*., 2000). Mammary gland development can be inhibited due to fat deposition in the glands as a result of overfeeding heifers. The type of diet and protein level can be modified to maximize efficiency of growth and mammary duct development (Sejrsen and Purup, 2000). ADG in post-pubertal dairy replacement heifers becomes less important because increased ADG, at this time period, does not affect mammary development (Sejrsen *et al*., 1982), and subsequent milk production in the cow (Hoffman *et al*., 1996, Zanton and Heinrichs, 2007). There are few studies on post pubertal heifer growth and its effects on milk production (Bagg *et al*., 1985). Undesirable over-conditioning of pre-puberty heifers can have a long lasting negative impact on cow performance (Le Cozler *et al*., 2009b)

CONCLUSION

Dairy herds need enough replacement heifers for efficient productivity and profitability of the farm. So, proper rearing management has a considerable impact on farm profitability. Economics and dairy replacement heifers are very much important for the progress of the dairy farm. Dairy producers can maximize lifetime profitability of heifers by decreasing the age of onset of puberty and first calving, by providing a diet that insures proper protein intake. Heifers normally do not become profitable until their second lactation. An earlier age at first calving (AFC) can reduce rearing costs due to decreased feed, labour and building costs.The bovine begins growth and development immediately after conception. Heifers will normally reach puberty at 60-65 % of their mature weight body weight. However, puberty and maturity will be affected by the genetics, season of birth, and rate of post weaning gain. Based on genetics and expected mature size, a target weight can be selected and the feeding program tailored to meet the needed average daily gain for efficient milk production. There is a need for more research to be done in this area to determine a strategy to accelerate lean growth of dairy heifers without subsequently reducing lactogenesis of the cow and keeping in mind the scarcity of feeds and fodder resources in the country.

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