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Dairy Cows under the Influence of Dietary Manipulations: A Review

Asad Ali Khaskheli*

Department of Animal Nutrition, Sindh Agriculture University, Tando jam, Pakistan

***Corresponding author:** Asad Ali Khaskheli, Department of Animal Nutrition, Sindh Agriculture University, Tando jam, Pakistan, Tel: +923123676239, E-mail: khaskhelias@gmail.com

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Abstract

This review study was carried out in order to understand the dietary influence on the dairy cows. The results obtained from review of already conducted studies revealed that dairy cow is significantly influenced by composition, quality, amount and regime of diet. Maximum daily milk production, milk protein, milk lactose, milk fat, total solids are recorded in dairy cow when ad-libitum feed and water is provided. Further, water is necessary for maintaining body fluids and proper ion balance, digestion, absorption, metabolization of nutrients, elimination and body cooling. Feeding and water frequency stimulates mammary functions, where milk synthesis is manipulated specifically by a non-invasive method. Reducing feeding frequency from 2x daily to 1x daily decreased milk yield from 7 to 38% in dairy cows, however changing feeding frequency from 2x to 3x resulted 18% increase in milk production. In conclusion, diet plays a key role in the life of dairy cow. Good quality feed and water with on ad libitum supports performance and production of dairy cow.

Keywords: Libitum; Diet; Performance; Production

Introduction

Dairy cow responses to various types of diets differently. Dairy farmers can use knowledge of animal behavior to improve cow well-being and yield. For instance, feeding and watering systems must be placed appropriately. Accessibility to feed and water may be more important than the actual amount of nutrients provided [1]. Efforts must be made to reduce the competition for feed, water, minerals, and shelter. Also, cow space, cow density, and distribution of feed and water are closely related factors. Feed intake and consequent milk yield are improved by provision of feed when cows need and want to eat [2]. When one cow eats, another might be stimulated to do likewise, whether she is hungry or not. This behavior is an example of social facilitation when cows eat in groups, they eat more than when they are fed separately [3].

Water is an essential component to sustain life and optimize growth, lactation, and reproduction of dairy cattle. The water requirement per unit of body mass of a high-producing dairy cow is greater than that of any other land-based mammal [4,5]. Total body water content of the body of adult dairy cattle ranges between 56 and 81% of body weight depending upon stage in the lactation cycle. Loss of only about 20% of total body water is fatal [6]. An other scientist reported that the reducing or decreasing watering had negative effect on milk production whereas free access to drinking water had a positive effect on milk yield [7]. Voluntary water intake of cows for optimum milk production depends upon frequent access, without discomfort and at a moderate temperature [8]. Most cattle normally consume 3 to 4 units of water for each unit of dry feed. Water requirements are directly related to dry matter intake i.e. increased consumption of dry matter will increase water consumption and vice versa [9]. Keeping in view the importance of diet in life of dairy cow current study were planned, whereby the main objective was to understand dietary influence on dairy cows worldwide.

Influence of Dietary Water on Dairy Cows

Water constitutes 60 to 70 percent of the body of dairy cow. Water is necessary for maintaining body fluids and proper ion balance; for digesting, absorbing, and metabolizing nutrients; for eliminating waste material and excess heat from the body; for providing a fluid environment for the fetus; and for transporting nutrients to and from body tissues. The water that dairy cattle need is supplied by drinking, by the feed that they consume, and by metabolic water produced by the oxidation of organic nutrients. Water loss occurs via saliva, urine, feces, and milk; through sweating; and by evaporation from body surfaces and the respiratory tract. The amount of water lost from the body of cattle is influenced by the activity of the animal, air temperature, humidity, respiratory rate, water intake, feed consumption, milk production and other factors [10].

The water requirement per unit of body mass of the high-producing dairy cow is higher than that of any other land-based mammal. This is because she produces a large amount of milk which is 87% water [11]. Water is required for digestion and metabolism of energy and nutrients, transport of nutrients and metabolites to and from cells in blood, excretion of waste products (via urine, feces, and respiration), maintenance of proper ion, fluid, and heat balance, and, as a fluid environment for the developing fetus [12]. Total body water content of adult dairy cattle ranges between 56 and 81% of body weight [13]. Cows in early lactation have more live body weight as compared with cows in later lactation (69.0 vs. 62.4%). Body water content of late pregnant dry cows was 65% of total body weight [14]. About two-thirds of water in the cow's body is in the intracellular compartment. The remaining one-third of water is in extracellular spaces around cells and connective tissues, in blood, and as transcellular water or water in the digestive tract. Water in the digestive tract accounts for 15 to 35% of body weight [15]. About 15% of body weight was as water in the digestive tract of dairy cows in early lactation; in late lactation and during the dry period about 10% of body weight was water in the digestive tract [16].

Another researcher determined that the residence time of a molecules of water in the rumen of lactating dairy cows was about 1 hour. Loss of about 20% of total body water is fatal. Loss of water from the body occurs through milk production, urinary and fecal excretion, sweating, and evaporative loss from the lungs [17]. Daily water losses via milk secretion (73 lb/cow per day) represented between 26 and 34% of total water intake (drinking water plus water in feed consumed) [18]. Water lost in feces of lactating cows ranged from 30 to 35% of total water intake, whereas loss in urine was 15 to 22%. Fecal water loss is increased by increasing dry matter intake (DMI), dry matter (DM) content of the diet, and with increasing forage content of the diet. Urinary water excretion is positively related with water availability, amount of water absorbed from the digestive tract, urinary nitrogen, sodium, and potassium excretion, and negatively related with dietary DM content [19]. Further it was calculated that losses associated with sweat, saliva, and respiratory evaporation accounted for about 18% of total water loss within the thermoneutral zone. However, amounts and proportions of water loss associated with these routes were highly dependent upon environmental temperature [20].

Several factors influence the daily water requirements and intake by dairy cows, including physiological state, amount of milk yield, amount of feed intake, body size, level and kind of activity, environmental factors such as temperature and air movement, diet composition including types of feedstuffs (e.g., concentrate, fresh forages, fermented forages, and hays) as well as nutrient composition (e.g., dietary sodium, potassium, and crude protein contents), and quality (or anti-quality) factors in a particular water source. Other factors affecting consumption may include frequency and periodicity of watering, temperature of the water, and social and behavioral interactions of animals. Water requirements of dairy cattle are met mainly from that ingested as drinking (free) water, that found in or on feed consumed, and, a small amount from metabolic oxidation (metabolic water). For all practical purposes drinking water intake plus that associated with the ration represent total water consumption. Seventy to 97% of total water consumption by lactating dairy cows was from drinking water [21]. Dry matter content of the diet is also an important factor affecting total water consumption.

Further it was found that, when dietary DM content declined from 50 to 30% (ration moisture content increased from 50 to 70%), drinking water intake declined by 42% [22]. Moreover, estimating drinking water intake of lactating dairy cows on pasture was studied and it was noticed that only 38% of total water consumption is free drinking water. Diets with high amounts of sodium-containing salts (e.g., NaCl, NaHCO3) or protein stimulate water intake [23]. In other study, it has been stated high dry forage diets may also increase water requirements because of higher excretion of water in feces compared with lower forage diets. There is a direct relationship between DMI and water intake in cattle. If water intake is sub-normal, feed DM intake typically will decrease. However, if water intake is normal and sufficient to meet the physiological needs of the animal for maintenance, growth, lactation and pregnancy, there is no evidence to suggest that increasing water intake (e.g., forced-hydration) beyond normal will result in greater feed DMI and performance [24].

Factors typically considered in water quality evaluation include odor and taste, physical and chemical properties, presence of toxic compounds, concentration of macro- and micro-minerals, and microbial contamination. These factors may have direct effects on the acceptability (palatability) of drinking water, or they may affect the animal's digestive and physiological functions, once consumed and absorbed [25]. Primary anti-quality factors known to affect dairy cattle include total dissolved solids, sulfur, sulfate and chloride (both being anions), nitrates, iron, and fluoride. Many other potential factors typically listed in water analyses reports and listed as potential risks for humans have not been well-documented in the research literature or under practical conditions to affect dairy cattle performance or health; examples include pH of water (pH between 6 and 9 is assumed acceptable and has very little influence on ruminal pH due to the highly reductive environment in the rumen), total hardness, calcium and magnesium contents [26]. It is always possible that isolated cases of higher than normal concentrations of mineral elements, microorganisms, or other toxic compounds may be present and deleterious to cattle. However, typically these cases are extremely difficult to identify and to prove cause and effect [27].

Influence of Feeding on Dairy Cows

Regular and complete milking is one of the requirements for continuance of lactation. The effect of changes in feeding frequency on milk yield varies widely between individual species. Reducing feeding frequency from 2x daily to 1x daily decreased milk yield from 7 to 38% in dairy cows [28]. However increasing milking frequency from 2x to 3x increased milk yield by 7 to 20% [29]. The mechanisms responsible for the increase in milk yield have not been identified but some researchers suggest an increase in mammary epithelial cell (MEC) number, reduction in MEC apoptosis, increased cell activity and frequent removal of feedback inhibitor of lactation (FIL) from the glands [30]. Feeding frequency stimulates mammary functions, where milk synthesis is manipulated specifically by a non-invasive method. These increases are achieved with little loss of body weight or condition, the extra nutrient requirement being met by an increased feed intake. Significant increase in milk yield with increased feeding frequency [31-32]. The mechanisms responsible for the increase in milk yield include, increase in mammary epithelial cell (MEC) number, reduction in MEC apoptosis, increased cell activity and frequent removal of FIL from the glands. Milk yield for 1x daily milking was significantly lowered ($p<0.05$) observed with 2x and 3x daily milking [33-34].

While another scientist reported that changing feeding frequency from 2x to 3x in cattle resulted in 18% increase [35]. Some other reported an increase of 10- 20% in cows' milk when daily feeding frequency was changed from 2x to 3x. Further it has been studied that diet during lactation had significant effect ($p<0.001$) on milk yield. Yield declined by 2.5 mL for each additional day of lactation [36,37]. This result agrees with that of another scientist who reported that milk production in cows gradually declines after reaching its peak [38]. This decline was mainly due to the loss of secretory tissue and decrease in rate of secretion per cell [39]. Similarly, in non-pregnant cows, the decline in milk yield after peak lactation was very gradual, with each month's yield being 95% of preceding month. The study revealed that feeding frequency had significant on milk yield [40]. This decline was mainly due to the loss of secretory tissue and decrease in rate of secretion per cell. Similarly, in non pregnant cows, the decline in milk yield after peak lactation was very gradual, with each month's yield being 95% of preceding month. It was also reported that cows milked 6x daily consumed higher dry matter than the cows milked 3x daily.

In another study a researcher stated that a measurable increase in dry matter intake in cows accompanied the rise in milk production from higher milking frequencies. It was noticeable that as the day of lactation progressed, most of the animals did not gain weight. In fact, some actually lost weight during the milking period (especially animals on 3x daily milking) indicating higher demands for dry matter intake at higher milking frequency [41]. This result corroborates the findings of another researcher who reported that increased dry matter intake by cows milked 6x daily did not compensate for the increased energy demands, thus these cows lost BW, had a lower body condition scores during the initial lactation period and displayed a longer recovery period than did cows milked 3x daily [42]. It has also been reported that cows milked 3x daily tend ($p<0.1$) to be lighter than their counterparts milked 2x daily during lactation. They observed further, that dry matter intake increased by approximately 15% and cows on 2x and 3x daily milking consumed 10 and 11% more dry matter than controls during lactation respectively [43]. Although, a researcher reported that increased dry matter intake was too small to be measurable or nonexistent. Further it was reported that cows milked 3x daily actually had lower dry matter intake than those milked 2x daily [44].

In another study a researcher has reported that milking 3x daily reduced body weight gains in cows and there was a tendency for cows milked 3x daily to lose weight in the present study. Even though, cows were allowed ad libitum dry matter intake, the cows milked 3x daily did not respond to the increased energy demand associated with increased yield by consuming more ration. It appears that increasing feeding frequency results in either preferential utilization of nutrients for milk production or a higher rate of tissue catabolism [45]. Another researcher suggested that increased milk yield and milk yield: feed intake occurs only as long as tissue reserves are able to subsidize the nutrient needed for milk yield. Day of lactation had significant effect ($p<0.001$) on dry matter intake increasing by 3.73 g for each additional day of lactation [46]. These results agree with those of scientist who reported that the onset of lactation results in a dramatic increase in the requirements of nutrients, for example glucose, amino acids and fatty acids. This increase in requirements is met partly by increased voluntary intake partly by an array of metabolic adaptations [47].

According to another scientist, changes which are of major importance for the establishment and maintenance of high milk production include hypertrophy of the gastro intestinal tract, increased fatty acid metabolism from adipose tissue and an increased rate of gluconeogenesis. The efficient utilization of feed by the animals could be attributed to the breed, physiological status of the animals and the quality of the feed offered [48]. This observation agrees with the findings by other researchers who reported that feed efficiency for milk production depends on diet, environmental factors and on genetic ability of the animal to utilize these inputs to produce milk [49]. Moreover, few others noted that efficiency of carbohydrate utilization (carbohydrates being the major nutritive portion of ruminant animal feed) can be increased by treatments which encourage the animals to produce propionate rather than acetate or butyrate from carbohydrates. Consequently, if the animal is making more propionate, it will be found to be using its feed more efficiently. The elephant grass offered to the animals was chopped and fresh thereby increasing the surface area of the roughage. This may therefore, contribute to its efficient utilization by the animals.

According to some other scientists, the hormones (e.g. growth hormone, insulin, prolactin) interact to control partitioning of dietary energy into milk and body tissue; this interaction is associated with genetic differences for milk within and between breeds. Further it has been stated the animals could also be under favourable hormonal interaction [50,51]. The result also revealed that the higher the milking frequency, the higher the efficiency of feed utilization for milk production [1x (0.237), 2x (0.412) and 3x (0.431)]. Animals on 3x milking frequency utilized their feed better than 2x and 1x milking frequencies. This result agrees with those of Barnes, *et al.* [26] who reported that cows milked 3x daily had efficiency ratios approximately 14% greater than for cows milked 2x. In the present study, animals on 3x daily milking frequency had efficiency ratio of 4.6% greater than 2x milking frequency. Therefore, animals on 3x milking frequency could have performed better if they were fed according to yield. This could probably explains the non significant difference recorded between 3x and 2x milking frequency in this study [52].

Conclusion

On the basis of current review it is concluded that the water and feed supply play a critical role for normal physiological processes, performance and production of dairy cows. The dairy cow perform excellently when high quality feed and water is provided on ad-libitum.

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