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Review on: How Does Pre-Calving Nutrition Interact with Post-Calving Nutrition to Affect Milk Production and Changes in Body Condition of Cows?

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Abstract: Most of nutritional researches regarding transition cows has involved the feeding of total mixed rations or pasture silage and concentrate to cows before and after calving. The nutrition of dairy cows is believed to affect productivity early in lactation. Pre-calving nutrition has impact on body condition score (BCS) at calving. It has been suggested that increased level of feeding prior to calving is associated with increased BCS at calving and increased milk yield after calving. The effect of pre-calving feeding may be less evident in cows fed well post-calving. Over conditioned cows, unlike thin cows, produce milk with the expense of their stored fat and as a result they are in negative energy balance and they have low dry matter intake (DMI) during early lactation. It is better to achieve high energy concentration by the use of high-fiber concentrates with a fat supplement and optimum performance in cows that are fat at calving may be achieved with higher level of undegradable dietary protein, whereas cows that are thin at calving perform best with higher levels of energy diet. This review explores pre- and post-calving nutrition and milking frequency and their effect on production parameters. In addition, I review the interaction between BCS at calving and nutrient intake during early lactation.

Key words: BCS · DMI · Milk Yield · NEB · Pre-Calving · Post Calving

INTRODUCTION

The feeding management of dairy cows during dry period has involved offering of total mixed rations or pasture silage and concentrates. Whilst the nutritional management of dry cows is extremely varied, pasture will generally be the most important source of feed for most cows after calving [1]. Feed shortages can occur in pasture-based dairy systems when the quality or availability of pasture is negatively affected by weather conditions or poor grazing management [2]. In pasture based dairy system, once daily milking is used as a management strategy during early lactation to reduce the heavy work load associated with seasonal calving or to alleviate feed shortage when pasture quality or quantity is reduced [3]. Once daily milking is used in some dairy system as a short to medium-term management strategy in early to mid-lactation, typically to alleviate a temporary feed shortage [4]. However, most dairy cows throughout the world are milked twice a day.

The nutrition of dairy cows is believed to affect productivity early in lactation [5]. The transition period is generally defined as " 3-4 weeks pre-partum to 3-4 weeks post-partum and coincides with a time when the dairy cow is undergoing significant hormonal and metabolic changes as the cow moves from a period of net tissue deposition (pregnancy) to one of net tissue mobilization (lactation)" [1, 6]. This period is characterized by a number of physiological changes that may be important, including feed intake, the type of energy and protein and adaptation of the rumen in preparation for post-calving feed. During early lactation, the energy requirements for maintenance and milk production exceed the amount of energy obtained from dietary sources. Hence, the high energy requirement at the onset of lactation results in a negative energy balance (NEB) that begins a few days pre-partum and usually reaches its maximum two weeks post-partum which may adversely affect post-partum health and fertility [7]. Therefore, supplementation of dairy cows with high energy diet during early lactation is necessary to

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avoid NEB and to improve the health status of the cows. Moreover, grain supplementation during late gestation is believed to prepare the rumen for the consumption of high energy concentrate that the cow will be expected to utilize when lactation commences [8]. However, the types of supplements might be taken in to account in relation to body condition score of the cows at calving. The intent of this review is to assess the interaction between pre and post- calving nutrition and its effect on milk production with regard to changes in body condition score of dairy cows.

Pre- and Post-Calving Nutrition and Their Effect on Production Parameters: Nutrition can affect reproduction through its effect on body condition score (BCS) at calving. Cows calving at BCS 4 compared to 5 have an extended post-partum anestrous interval (PPAI), reducing the potential number of breeding events the cow can undergo, particularly for later calving cows [9].It has been reported that underfed cows in early lactation can prolong periods of anestrous, although short periods (5 weeks) of underfeeding didn't affect PPAI [10]. Net energy balance caused by feed restriction would be expected to reduce fertility. Supplements can be used effectively in such situation to increase BCS pre-calving or to meet cow demand in early lactation [11].When metabolisable energy is restricted in lactating cows, fat and protein in body tissue are mobilized to supply energy which is used for milk synthesis [12].

Pre-calving nutrition has impact on BCS at calving. Reduced pre-calving nutrition results a reduced BCS [6, 13]. Roche and Roche et al explained that pre-calving feed restriction reduced milk fat production during the first 5 weeks post calving, but differences were not significant afterwards. However, feed restriction during early lactation has a significant carry over effect on subsequent milk production (fat corrected milk, fat, protein), even after the feed restriction is removed. Roche *et al*. [13] reported a small and transient effect (5.25 kg MS) of pre-calving feed restriction on post calving milk production in cows that were well fed post calving. Overton and Waldron [14] suggested that increased level of feeding prior to calving is associated with increased BCS at calving and increased milk yield after calving. The effect of pre-calving feeding may be less evident in cows fed well post-calving [15]. Furthermore, Roche [6] argued that high pre-calving feed allowance increase the likelihood of hypocalcaemia and ketosis, especially in cows that underwent a feed restriction post calving and also the author emphasized the pre-calving feed restriction lowered the risk of milk fever during the peri-partum period. Cows that are conditioned pre-calving are more likely tending to mobilize body reserves unless they are offered sufficient energy feed post calving.

Lack of effect in feeding of additional energy and protein diet before calving on post-partum milk production has been reported [8]. Likewise, there was no interaction with BCS. But, cows in good (3.0 to 3.5 on a 5 point scale) BCS at calving have higher milk yield post-calving than cows in poor BCS [5]. Feeding additional protein pre-calving, particularly rumen undegradable protein, may minimize the use of body protein reserves for the development of fetus and the reserve will be available to support milk protein production in early lactation [16]. Low intake of protein during pre-partum will lead to mobilization of body protein to meet the requirements of the fetus. Late gestation protein diet appeared to result in greater proportion of cows cycling earlier than cows offered energy diet [8]. However, lack of effect of pre-calving feeding level on post calving feed intake had been reported by the (Stockdale, 2005). The assumed benefits achieved through feeding concentrates before calving are likely to be the result of microbial adaptation to the highly fermentable carbohydrate diet offered in early lactation and the ability of concentrate to stimulate ruminal papillae development [16]. There is evidence that when cows are put on a low energy density diet in the dry period, the cross sectional area of ruminal papillae decreases [17]. This could reduce the absorption of volatile fatty acids, the end-products of ruminal fermentation. Furthermore, Dirksen *et al*. [17] showed that introducing a high energy diet 2 weeks before calving could increase the cross-sectional area of the ruminal papillae. Thus, the presumption is that cows adapted to concentrates pre-calving will be better able to cope with a high concentrate post-calving diet.

Body condition at calving may affect subsequent reproductive performance. This is due to its association with the degree of negative energy balance occurring in early lactation and because fat cows may be more susceptible to metabolic disease [18]. Improving BCS at calving increased average milk production and milk fat concentration in cows supplemented with protein and energy rich diet pre-calving and grazed pasture after calving (for 10 weeks) [8]. The author further indicated improved response of 1.1 kg milk/ day for each additional BCS after using the regression analysis of the average milk yield data. Stockdale [18] reviewed the advantage of having higher BCS at calving is dependent on level of feeding post calving. There is interaction between calving BCS and level of concentrate supplementation post calving [19]. The interaction between diets offered pre- and post-calving for BCS and blood non-esterified fatty acid (NEFA) indicates that the higher degree of mobilization by cows offered diet high pre-calving can be limited by feeding an energy rich diet post-calving. Thus, cows in a good condition at calving should be fed well an energy rich diet in order to reduce the mobilization of body reserve and increase milk yield [20, 13]. Similarly, Roche *et al*. [13] reported that the effect of pre-calving nutrition is dependent on level of feeding post calving.

The Effect of Milking Frequency on Milk Yield: Most dairy cows throughout the world are milked twice a day. Reducing milking frequency is much less common; however, once daily milking of dairy cows, practiced either strategically during certain parts of the lactation and it is common in key dairying countries where less emphasis is placed on milk production per cow [21]. The effect of once daily milking is that it reduces milk yield by approximately 22%, depending on stage of lactation, breed and parity and it may adversely affect lactation length and persistency. Furthermore, a loss of 35-50 % milk yield has been reported in full lactation experimental studies [22]. An immediate reduction in milk yield is the most common and consistent observation when cows are milked once daily, regardless of the duration of once daily milking [4]. Marked physiological changes occur within the mammary gland during 24 hrs of an extended milking interval. Once daily milking results in changes in mammary permeability which leads to changes in milk composition through increased influx of serum protein and ions and increased efflux of lactose and potassium [22].

The effect of once daily milking is more on primiparous cows, as their udder capacity is smaller [23]. Primiparous cows showed a greater decrease in milk yield compared with multiparous cows when milked 1 × over a whole lactation [24]. It has been reported that the milk yield loss due to full-lactation once a day milking was greater in 2- and 3-year old Holstein-Friesian cows compared with those aged 4 year and older [3]. A reduction in milking frequency (MF) from 2× to 1 × increase in concentration of milk protein, milk fat, serum albumin, sodium, chloride and somatic cell count and resulted in a decrease in the concentration of lactose and potassium [22]. Similarly, Kay *et al*. [25] reported that yields of milk, fat, protein and lactose decreased with reduced MF and feeding level during the first 1-3 weeks of lactation. In consistent with this, Davis et al.[23]found that cows milked 1 × for 3 or 6 weeks post-partum have lower lactose content, a greater protein: fat ratio than those milked 2 × from calving. The lower milk fat content might be explained as reduced activity and transcription of mammary enzymes involved in milk fat synthesis and the lower circulating NEFA concentration in cows milked 1 × [26]. It has also been reported that during the first 3 weeks of early lactation, cows that were milked 1 × had consistently greater plasma glucose concentration compared with those milked 2 ×, whereas NEFA concentrations were lower in cows milked 1 × relative to 2 × [26’ 25]. This indicates that MF has its own impact on the energy status of milking cows. Cows that were milked 3 × for 1- 3 weeks early lactation had lower serum glucose, but greater NEFA concentration compared with cows milked 2 ×. Increasing the MF induced a greater degree of a negative energy balance during the first 3 weeks of early lactation [26]. In addition, the authors further explained the presence of interaction between MF and duration for glucose and NEFA concentration during week 4 to 6. The interaction has resulted in a better BCS when cows are milked 1 × for 6 weeks compared with 3 weeks; however there was no interaction afterwards.

Greater milk production loss occur when well fed grazing cows are switched to 1 × milking than when cows on a restricted diet switched to 1 × milking. In addition, Loiselle *et al*. [27] reported milking 1 × for 1 week post-partum caused a long term reduction in milk yield. The interaction between MF and feeding level may be due to well-nourished cows produce more milk and the udder reaches its maximum capacity earlier [4]. Hence, if MF is switched to 1 ×, the udders are subjected to longer periods of negative feedback mechanism, resulting low milk production by the milk secretary cells [22].

Cows that had been offered a restricted diet and exposed to 1 × milking for three weeks produced the least milk as compared to cows with unrestricted feeding level and milked 2 × [25]. This indicates that feeding level and MF have a negative effect on milk production. It might be obvious that feed restriction reduces energy intake and available nutrients, resulting in reduced total cardiac output and decreased mammary blood flow via local rather than systemic circulation [22]. When cows are returned to 2 × milking from 1 × milking, there is negative carry over effect. This might be due to the combination of reduced epithelial cells number and activity in the mammary gland [25]. Furthermore, the authors elaborated that grazing cow that are subjected to a severe, but relatively short (3 weeks) feed restriction in early lactation, the cows will continue to mobilize body reserve even when energy demand for milk production is reduced by 1 × milking. In addition, the effect of reduced MF or feeding level on milk solid production continue to after cows are switched back to normal intake and 2 × milking [25].

Interaction Between BCS at Calving and Nutrient Intake During Early Lactation: Body condition score is a management tool for evaluating body energy reserve and mainly used for evaluating nutritional status in farm animals [28]. BCS may be assessed visually and/or by feeling the amount of body fat over the backbone, hips and ribs and around the base of the tail and taking some account of the prominence of the pin bone [18].

Many researchers reported different results on the response of dry matter intake (DMI) to condition score at calving. The difference might be explained by the difference in the composition of the diet fed to cows in early lactation in different trials.

As body condition at calving increases, there is a reduction in DMI after calving [29]. Similarly, Garnsworth and Jones [30] argued that as BCS at calving increases, the rate of increase in feed intake after calving decreases and the delay between peak milk yield and time of maximum food intake becomes greater. This indicates that overfed/fat cows might take more time to attain maximum intake than thin cows. Cows restrictively fed during dry period/late gestation have a higher DMI in lactation and a lower mobilization of body fat [31, 15]. On the contrary, generous feeding during late gestation is responsible for gaining large quantities of body fat and the cows have lower DMI along with the propensity of mobilizing body reserves in lactation. As a result, over conditioned cows will be in negative energy balance during early lactation as they mobilize a great deal of body reserve to support milk production [32]. But, cows with lower condition scores at calving produce a higher percentage of milk directly from feed rather than via body fat and reach positive energy balance earlier in lactation and are more efficient over the total period than cows with higher condition score [30]. However, thin cows need high-energy diets to milk well in early lactation. This is because thin cows don't have sufficient body reserve to support milk production and as a result large reduction in milk yield might be observed. Caution is, therefore, needed when we formulate and offer diet to the cows during late gestation and early lactation. Furthermore, Kunz *et al.* [33] asserted that cows fed only 75% of their requirements during the final 70 days pre-calving showed faster increase in DMI immediately after calving, compared with cows fed *ad libitum*. Similarly, Remppis *et al.* [31]showed high grain consumption during early lactation for cows that were subjected to energy under feeding prior to calving compared with cows fed above requirements in the dry period.

Mammals have the ability to regulate feed intake. The regulatory mechanism helps the cows to reduce feed intake as body reserve increase, in an attempt to prevent excessive fatness [34]. In this regard, the hormone leptin might play a great role in modulating feed intake. The adipose hormone leptin is anorexigenic and acts in the hypothalamus to reduce appetite and increase energy expenditure in response to a meal in a healthy animal [35, 36]. Overfed/fat animals have elevated leptin levels due to their greatly increased adipose tissue mass [35, 37]. Increased leptin level, which is associated with increased body fat, results in a negative energy balance [35, 38]. It had been contended that oxidation of NEFA in the liver may reduce intake [34]. This most likely explain the lower intake often observed in high conditioned cows mobilizing more body reserves compared with thin cows in early lactation. Generally, the decreased feed intake of overfed/fat animals thought to be a mechanism for regulating adipose tissue depots or physiological feedback mechanism [39].

Apart from leptin, acetate is believed to play a role in feed regulation in mammals. Stockdale [18] reviewed the presence of higher rate of fatty acid synthesis in the adipose tissue of thin cows which could result in lower blood concentration of precursors such as acetate which in turn affect appetite and food intake. Higher oxidation of acetate to CO_2in the adipose tissue of thin cows throughout the early post calving has been reported by Treacher *et al*. [40]. Acetate oxidation is probably the major energy source for adipose tissue in the cow and may play a role in regulating food intake by influencing acetate utilization rate. Dalley *et al*. [41] infused a 2 year old sheep through terminal ileum and proximal colon with volatile fatty acid at a ratio of 0.80:0.15:0.05 (acetic, propionic and butyric, respectively) and found a depressed feed intake. Similarly, infusion of sodium acetate in the rumen of sheep depressed feed intake [42].

For better performance of thin and fat cows during early lactation, it has been suggested that it is better to achieve high energy concentration by the use of high-fiber concentrates with a fat supplement, rather than high starch concentrate [18]. Likewise, optimum performance in cows that are fat at calving may be achieved with higher level of undegradable dietary protein in the diet, whereas cows that are thin at calving perform best with higher levels of energy and generally don't respond to undegradable dietary protein. Generally, Garnsworth and Topps [43] contended that there are no benefits from feeding cows to achieve a condition score at calving greater than 1.5- 2.0 on the 4 point scale (3.0 – 4.0 on the 8 point scale) if high energy complete diets are offered at *ad libitum* levels in early lactation.

CONCLUSIONS

Increasing the energy density of the pre-calving diet improves subsequent milk production if it alleviates a low BCS at calving and if it is accompanied by high post calving feeding. The health status of dairy cows in early lactation and their reproductive performance can be influenced by feeding pre- and post-calving through effects on body reserves at calving and negative energy balance post calving . Reducing milking frequency to 1 × milking in early lactation may provide benefits in labor management and farmer life style, but will result in decreased daily and total milk production. In general, temporary 1 × milking has lactation long negative effect on milk and milk components yields but improved cow energy status and BCS.

Thin cows have better DMI during early lactation than over conditioned cows. The lower intake by fat cows is believed to be as a result of physiological feedback mechanism. It is better to achieve high energy concentration by the use of high-fiber concentrates with a fat supplement and optimum performance in cows that are fat at calving may be achieved with higher level of undegradable dietary protein, whereas cows that are thin at calving perform best with higher levels of energy.

REFERENCES

1. Stockdale, C.R. and J.R. Roche, 2002. A review of the energy and protein nutrition of dairy cows through their dry period and its impact on early lactation performance. Australian Journal of Agricultural Research, 53: 737-753. doi: 10.1071/AR01019
2. Grala, T.M., J.R. Roche, C.V.C. Phyn, A.G. Rius, R.H. Boyle, R.G. Snell and J.K. Kay, 2013. Expression of key lipid metabolism genes in adipose tissue is not altered by once-daily milking during a feed restriction of grazing dairy cows. Journal of Dairy Science, 96: 7753-7764.doi: 10.3168/jds.2013-6849
3. Clark, D.A., C.V.C. Phyn, M.J. Tong, S.J. Collis and D.E. Dalley, 2006. A systems comparison of once-versus twice-daily milking of pastured dairy cows. Journal of Dairy Science, 89(5): 1854-1862. doi:10.3168/jds.S0022-0302 (06)72254-8
4. Phyn, C.V.C., J.K. Kay, A.J. Rius, S.R. Davis, K. Stelwagen, J.E.H. Hillerton and J.R. Roche, 2010. Review: Impact of short-term alterations to milking frequency in early lactation. Proceeding of. 4th Australasian Dairy Science Symposium. Caxton Press, New Zealand, pp: 156-164.
5. Bertics, S.J., R.R. Grummer, C. Cadorniga-Valino and E.E. Stoddard, 1992. Effect of pre-partum dry matter intake on liver triglyceride concentration in early lactation. Journal of Dairy Science, 75: 1914-1922. doi: http://dx.doi.org/10.3168/jds.S0022-0302(92)77951-X
6. Roche, J.R., 2007. Milk production response to pre- and post-calving dry matter intake in grazing dairy cows. Livestock Science, 110: 12-24. doi: 10.1016/j.livsci.2006.08.016.
7. Butler, W.R. and R.D. Smith, 1989. Interrelationships between energy balance and postpartum reproductive function in dairy cattle. Journal of Dairy Science, 72: 767-783. doi: 10.3168/jds.S0022-0302 (89)79169-4.
8. Stockdale, C.R., 2005. Investigating the interaction between body condition at calving and pre-calving energy and protein nutrition on the early lactation performance of dairy cows. Australian Journal of Experimental Agriculture, 45: 1507-1518. doi: 10.1071/EA04104
9. Burke, C.R., J.R. Roche, C.W. Aspin, J.M. Lee and V.K. Taufa, 2006. A nutrient-signaling effect of grain feeding on post-partum an ovulatory interval in mature dairy cows. Proceeding of the New Zealand Society of Animal Production, 66: 334-338.
10. Burke, C.R., J.R. Roche, C.W. Aspin, J.M. Lee and V.K. Taufa, 2005. Effect of pre- and post-partum pasture feed intakes on post-partum anostrous interval in dairy cows. Proceeding of the New Zealand Society of Animal Production, 65: 221-224.

11. Holmes, C.W. and J.R. Roche, 2007. Pasture and supplement in dairy production systems. In: Rattray, P.V.; Brookes, I.M.; Nicol, A.M. ed. Pastures and Supplements in Sheep Production Systems. New Zealand Society of Animal Production. Occasional Publ., 14: 221-242.
12. Nicol, A.M. and I.M. Brooks, 2007. The metabolisable energy requirements of grazing livestock. In: Rattray, P.V.; Brookes, I.M.; Nicol, A.M. ed. Pastures and Supplements in Sheep Production Systems. New Zealand Society of Animal Production. Occasional Publ., 14: 151-172.
13. Roche, J.R., E.S. Kolver, J.M. Lee, P.W. Aspin, C.R. Burke, P. Taylor and A.R. Napper, 2005. Effects of feeding level for four weeks pre-calving on milk production is small and dependent on level of feeding in early lactation. Proceedings of the New Zealand Society of Animal Production, 65: 215-218.
14. Overton, T.R. and M.R. Waldron, 2004. Nutritional management of transition dairy cows: strategies to optimize metabolic health. Journal of Dairy Science, 87, Supplement, E105-119E. doi: http://dx.doi.org/10.3168/jds.S0022-0302(04)70066-1.
15. Broster, W.H. and V.J. Broster, 1984. Reviews of the progress of dairy science: Long term effects of plane of nutrition on the performance of the dairy cow. Journal of Dairy Research, 51: 149-196. doi:10.1017/S0022029900023414.
16. Moorby, J.M., R.J. Dewhurst and S. Marsden, 1996. The effect of increasing digestible undegradable protein supply to dairy cows in late gestation on the yield and composition of milk during the subsequent lactation. Animal Science (Penicuik Scotland), 63: 201-213.
17. Roche, J.R., 2003. Energy nutrition of the pasture based transition cow-a review. Acta Veterinaria Scandinavica, 97, supplement, 57-63.ISSN:0044-605X
18. Dirksen, G.U., H.G. Liebich and E. Mayer, 1985. Adaptive changes of the ruminal mucosa and their functional and clinical significance. The Bovine Practioner, 20: 116-120.
19. Stockdale, C.R., 2001. Body condition at calving and the performance of dairy cows in early lactation under Australian conditions: a review. Australian Journal of Experimental Agriculture, 41: 823-839. doi: 10.1071/EA01023
20. Stockdale, C.R., 2004. Effects of level of feeding of concentrates during lactation on the yield and composition of milk from grazing dairy cows with varying body condition score at calving. Australian Journal of Experimental Agriculture, 44(1): 1-9. doi: 10.1071/EA03021.
21. Nielsen, N.I., A. Hameleers, F.J. Young, T. Larsen and N.C. Friggens, 2010. Energy intake in late gestation affects blood metabolites in early lactation independently of milk production in dairy cows. Animal, 4(1): 52-60. doi: 10.1017/S1751731109990796
22. Stelwagen, K., C.V.C. Phyn, S.R. Davis, J. Guinard-Flament, D. Pomiès, J.R. Roche and J.K. Kay, 2013. Invited review: Reduced milking frequency: Milk production and management implications. Journal of Dairy Science, 96: 3401-3413. doi: 10.3168/jds.2012-6074.
23. Davis, S.R., V.C. Farr and K. Stelwagen, 1999. Regulation of yield loss and milk composition during once daily milking: a review. Livestock Production Science, 59: 77-94. doi: 0301-6226/99/$.
24. Phyn, C.V.C., J.K. Kay, A.J. Rius, S.R. Morgan, C.G. Roach, T.M. Grala and J.R. Roche, 2014. Temporary alterations to postpartum milking frequency affect whole-lactation milk production and the energy status of pasture-grazed dairy cows. Journal of Dairy Science, 97: 6850-6868. doi: 10.3168/jds.2013-7836.
25. Remond, B., D. Pomies, D. Dupont and Y. Chillilard, 2004. Once a day milking of multi-parous Holstein cows throughout the entire lactation: milk yield and composition and nutritional status. Animal Research, 53: 201-212.
26. Kay, J.K., C.V.C. Phyn, A.G. Ruis, S.R. Morgan, T.M. Grala and J.R. Roche, 2011. Effect of milking frequency and nutrition in early lactation on milk production and body condition in grazing dairy cows. Proceeding of the New Zealand Society of Animal Production, 71: 37-41.
27. Phyn, C.V.C., J.K. Kay, A.G. Rius, S.R. Morgan, C.S. Roach, T.M. Grala and J.R. Roche, 2011b. Effect of temporary alterations to milking frequency during the early post-partum period on milk production and body condition score in grazing dairy cows. Proceeding of New Zealand Society of Animal Production, 71: 45-49.
28. Loiselle, M.C., C. Ster, B.G. Talbot, X. Zhao, G.F. Wagner, Y.R. Boisclair and P. Lacasse, 2009. Impact of postpartum milking frequency on the immune system and the blood metabolite concentration of dairy cows. Journal of Dairy Science, 92: 1900-1912. doi: 10.3168/jds.2008-1399

29. Hady, P.J., J.J. Domeeq and J.B. Kaneene, 1994. Frequency and precision of body condition scoring in dairy cows. Journal of Dairy Science, 77: 1543-1547.
30. Broster, W.H. and V.J. Broster, 1998. Body score of dairy cows. Journal of Dairy Research, 65: 155-173.
31. Garnsworthy, P.C. and G.P. Jones, 1987. The influence of body condition at calving and dietary protein supply on voluntary food intake and performance in dairy cows. Animal Production, 44: 347-352.
32. Remppis, S., H. Steingass, L. Gruber and H. Schenkel, 2011. Effects of energy intake on performance, mobilization and retention of body tissue and metabolic parameters in dairy cows with special regard to effects of pre-partum nutrition on lactation. A review. Asia- Australian Journal of Animal Science, 24(4): 540-572.
33. Garnsworthy, P.C. and G.P. Jones, 1993. The effects of dietary fibre and starch concentrations on the response by dairy cows to body condition at calving. Animal Production, 57: 15-21.
34. Kunz, P.L., J.W. Blum, I.C. Hart, H. Bickel and J. Landis, 1985. Effects of different energy intakes before and after calving on food intake, performance and blood hormones and metabolites in dairy cows. Animal Production, 40: 219-231.
35. Ingvartsen, K.L. and J.B. Andersen, 2000. Integration of metabolism and intake regulation: A review focusing on periparturient animals. Journal of Dairy Science, 83: 1573-1597.
36. Friedman, J.M., 2000. Obesity in the new millennium. Nature, 404: 632-634.
37. Arora, T., R. Sharma and G. Frost, 2011. Research Review: Propionate. Anti-obesity and satiety enhancing factor. Appetite, 56: 511-515.
38. Keenan, K.P., M.A. Wallig and W.M. Haschek, 2013. Nature via Nurture: Effect of Diet on Health, Obesity and Safety Assessment. Toxicologic Pathology, 41: 190-209.
39. Friedman, J.M. and J.L. Halaas, 1998.Leptin and the regulation of body weight in mammals. Nature, 395: 763-770.
40. Treacher, R.J., I.M. Reid and C.J. Roberts, 1986. Effect of body condition at calving on the health and performance of dairy cows. Animal Production, 43: 1-6.
41. Reid, I.M., C.J. Roberts, R.J. Treacher and L.A. Williams, 1986. Effect of body condition at calving on tissue mobilization, development of fatty liver and blood chemistry of dairy cows. Animal Production, 43: 7-15.
42. Dalley, D.E., A.R. Sykes, P. Isherwood and A.B. Robson, 1996. Effect of ileal infusion of volatile fatty acid on feed intake and urinary magnesium excretion in sheep. Experimental Physiology, 81: 655-663. doi: 10.1113/expphysiol.1996.sp003966.
43. Carter, R.R. and W.L. Grovum, 1990. A review of the physiological significance of hypertonic body fluids on feed intake and ruminal function: salivation, motility and microbes. Journal of Animal Science, 68(9): 2811-2832. doi:/1990.6892811x
44. Garnsworthy, P.C. and J.H. Topps, 1982a. The effect of body condition of dairy cows at calving on their food intake and performance when given complete diets. Animal Production, 35: 113-119.