Trop Anim Health Prod (2012) 44:975–981
DOI 10.1007/s11250-011-9998-7

Effect of varying dietary energy levels during the last trimester of pregnancy on subsequent first lactation performance in Sahiwal heifers

Muhammad Fiaz · Muhammad Abdullah · Muhammad Nasir · Khalid Javed · Masroor Ellahi Babar · Talat Naseer Pasha · Makhdoom Abdul Jabbar

Accepted: 20 February 2011 / Published online: 17 November 2011

Abstract The aim of the study was to determine optimum dietary energy level during the last trimester of pregnancy for Sahiwal heifers in subtropical Pakistan. Sixteen Sahiwal heifers, 5–6 months pregnant, were assigned to four dietary treatments with four heifers on each treatment. Isonitrogenous (CP=14.1%) diets having varying energy, namely, ME 88%, ME 100% (Control), ME 112% and ME 124% of NRC recommended level for pregnant heifers, were fed until calving. All were fed a similar diet after calving. Precalving weight gain was highest ($P<0.05$) in heifers fed ME 112 and 124% (486±13 and 497±5 g/day, respectively) followed by ME 100% (444±7 g/day), and the lowest weight gain was recorded for ME 88% (397±8 g/day). A similar trend was observed for feed efficiency. Body condition score at calving in groups ME 124% and ME 112% was higher than ME 88% and ME 100%. Nutrient digestibility, birth weight of calves and milk composition except fat content were not influenced by energy levels. The highest daily milk yield was observed in heifers fed ME 100% followed by ME 112, 124, and 88%. We conclude that the NRC recommendation is applicable to the subtropical region.

Keywords Dietary energy · Milk yield · Milk composition · Weight gain · Body condition score · Sahiwal heifers

Abbreviations

ADL	Acid detergent lignin
ADF	Acid detergent fiber
BCS	Body condition score
CP	Crude protein
DM	Dry matter
FCM	Fat corrected milk
ME	Metabolizable energy
N	Nitrogen
NDF	Neutral detergent fiber
NRC	Nutrient requirements of cattle

Introduction

Sahiwal is a fabulous dairy cattle breed and renowned throughout tropical and subtropical countries due to its excellent heat and tick resistance (Bajwa et al. 2004) but its production level is much lower. Main causes are random breeding, poor nutrition, improper housing and inefficient reproductive management (Javed et al. 2002). Malnutrition is one of most important factors limiting ruminant production in developing countries (Osakwe et al. 2004; Olafadehan and Adewumi 2009). Animals in nonproductive stage (before calving) are severely neglected because of higher expenses without any visible return (Bhatti et al. 2007). The nutritional requirements of heifers become more significant during

M. Fiaz · M. Abdullah · K. Javed
Department of Livestock Production,
University of Veterinary and Animal Sciences,
Lahore, Punjab, Pakistan

M. E. Babar
Institute of Biochemistry and Biotechnology,
University of Veterinary and Animal Sciences,
Lahore, Punjab, Pakistan

M. Nasir (✉) · T. N. Pasha · M. A. Jabbar
Department of Food and Nutrition,
University of Veterinary and Animal Sciences,
Lahore, Punjab, Pakistan
e-mail: nasir@uvas.edu.pk

pregnancy because mammary tissue is undergoing allometric growth. The udder increases markedly in size during the fifth to sixth months of pregnancy. Prepartum maternal diet directly influences postpartum milk production and composition, and increased dietary energy enhances mammogenesis (Swanson et al. 2008). Appropriate nutritional management of replacement heifers during gestation period is indispensible for optimum mammary growth and subsequent first lactation performance in tropical herds, thereby, affecting livestock development in this agroecological zone (Maquivar et al. 2010). Although dietary energy is one of the most critical factor for production performance, very little is known about the requirements of dietary energy for pregnant heifers in tropical and subtropical areas of the world. The main objective of the present study was to determine optimum energy requirements of Sahiwal heifers during the last trimester of pregnancy and to investigate precalving of different dietary energy levels on subsequent first lactation performance.

Materials and methods

Location and climate of study area

This experiment was conducted at Livestock Experiment Station Jahangirabad, Khanewal, in the subtropical lowlands of Pakistan. Jahangirabad (30° 18′ N, 71° 56′ E) is the home of Sahiwal breed having extreme climate; very hot in summer up to 48.4°C and cold in winter down to 1°C with 93-mm average rainfall.

Animals, dietary treatments, design and feeding

Pregnant Sahiwal heifers (n=16) at the stage of fifth to sixth months' gestation were selected and assigned to four dietary treatments (A, B, C and D) under completely randomized design experiment in which each treatment had four replicates. Isonitrogenous (CP=14.1%) diets having varying energy, viz; A=88%, B=100% (Control), C=112% and D=124% of NRC recommended level for pregnant heifers were fed to the respective groups until calving. After calving, all heifers were fed a similar diet having CP and energy level as recommended by NRC for lactating animals. Four additional animals of the same age, weight and condition were kept as positive control and fed only ad lib green fodder under routine farm management conditions.

Data recording

Feed intake of each animal was recorded daily, whereas body weights of all pregnant heifers were determined fortnightly. Monthly body condition scoring (BCS) of animals was done by taking average individual assessment of three individuals and independently scoring the animals. The scoring method involved a manual assessment of the thickness of fat cover and prominence of bone at the tail head and loin area on a scale of 1–5: a score of 1 was extremely thin and a score of 5 was extremely fat (DEFRA 2001). Milk production was recorded daily and milk samples were collected weekly for milk composition analysis.

Digestibility trial and lab analysis

During the digestibility trial, fecal "grab" samples were taken after 2-h interval during a 24-h period. For each collection, a 50-g sample was weighed and composited to form one sample per animal. Samples were stored at −20°C till analysis. Acid insoluble ash was used as a digestibility marker (Van Keulen and Young 1977). Feed and fecal samples were analyzed for DM, N, ash contents, NDF, ADF and ADL (AOAC 2005; Van Soest et al. 1991). Milk composition analysis was carried out through Lactoscan-S Milk Analyzer (50 W, Milkotronic Ltd., Bulgaria) in WTO-Quality operation labs at UVAS, Lahore for following milk constituents: milk fat, solids not fat, milk protein, lactose and total solids.

Statistical analysis

The data were analyzed through one-way ANOVA techniques under Completely Randomized Design using SAS 9.1.3 portable software. The differences among treatment means were tested through DMRt. The mathematical model assumed was:

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij}$$

where,

- Y_{ij} each observation on ith treatment due to jth animal
- μ overall mean
- τ_i effect of ith treatment ($\sum \tau i=0$ and i=1, 2, 3, 4)
- ε_{ij} random error associated with i^{th} treatment and j^{th} animal with the restriction that variance σ^2 and mean zero.

Results

Dry matter intake

The effect of precalving dietary energy levels on nutrient intake is showed in Table 1. Dry matter intake and CP intake during last 90 days of gestation was not different (p>0.05) among treatment groups. However, values of NDF and ADF intake during prepartum period of 90 days were significantly

Table 1 Effect of different levels of energy on precalving nutrient intake in pregnant Sahiwal heifers (Mean ± SE)

Nutrients	Treatments			
	(ME 88%)	(ME 100%)	(ME 112%)	(ME 124%)
DM (kg/day)	7.50±0.02[a]	7.56±0.05[a]	7.55±0.02[a]	7.54±0.02[a]
CP (g/day)	1,058±03[a]	1,067±07[a]	1,064±03[a]	1,063±03[a]
NDF (g/day)	3,580±11[a]	2,452±17[b]	1,955±06[c]	1,719±05[d]
ADF (g/day)	2,394±07[a]	1,544±11[b]	1,200±04[c]	1,063±03[d]

[a,b,c,d]Mean values within rows with different superscripts are significantly different ($P<0.05$)

highest in ME 88% followed by those in ME 100% and ME 112%, whereas the lowest values were recorded in ME 124%.

Average daily gain

The influence of precalving different dietary energy density on ADG of pregnant heifers is presented in Table 2. Heifers fed extra dietary energy (ME 112 and 124%) beyond NRC recommendations during the last trimester of pregnancy gained higher than of those fed other dietary levels, whereas ADG was also higher in ME 100% than that in ME 88%. Precalving ADG in heifers fed traditional diet (ad lib green fodder) kept under positive control group was only 300±09 g/day.

Feed efficiency

Feed efficiency of diets with varying dietary energy levels is mentioned in Table 2. Diets having higher energy levels than recommended by NRC (ME 112 and 124%) were similar in terms of feed efficiency. Feed efficiency of diets having ME 112 and 124% was higher than those having ME 100% and ME 88%, whereas control diet (ME 100%) was also more efficient than low energy diet having ME 88%.

Body condition score

Body condition score at the time of calving in first calf heifers fed different levels of dietary energy during the last trimester of gestation is also presented in Table 2. The BCS at calving in ME 124% was similar with that of ME 112% but higher than of that in ME 100% and ME 88%. The difference between BCS of heifers in ME 100% and ME 88% was nonsignificant, whereas BCS between ME 100% and ME 112% was also not different ($P>0.05$). The BCS at calving in heifers of positive control group fed traditional diet (ad lib green fodder) during the last trimester of gestation was only 3.12±0.12.

Nutrient digestibility

The effect of different dietary energy levels on digestibility of nutrients during last 90 days of gestation is mentioned in Table 3. The digestibility percentage of DM, CP, NDF and ADF was not influenced ($P>0.05$) by different dietary energy levels and overall average percentages of digestibility were 69.7, 71.2, 58.5 and 52%, respectively.

Birth weight of calf

Birth weight of calves born by first calf heifers fed different dietary energy levels during the last 90 days prepartum is given also in Table 2. Birth weight of newly born calves from first calf heifers was not different ($P>0.05$) among treatment groups. The overall average birth weight in calves was 21 kg.

Milk yield

The effect of precalving dietary energy levels on daily milk yield in first calf heifers is presented in Table 4. Daily milk yield in dietary energy level (ME 100%) as per recommended by NRC was higher than other energy levels, whereas

Table 2 Effect of dietary energy levels on precalving average daily gain, feed efficiency, body condition score and birth weight of calves in Sahiwal 1st calf heifers (Mean ± SE)

Parameters	Treatments			
	(ME 88%)	(ME 100%)	(ME 112%)	(ME 124%)
Average daily gain (g/day)	444±07[b]	397±08[c]	486±13[a]	497±05[a]
Feed efficiency	0.048±0.001[c]	0.054±0.001[b]	0.059±0.002[a]	0.06±0.001[a]
Body condition score (1–5)	3.5±0.04[c]	3.6±0.07[bc]	3.75±0.02[ab]	3.87±0.07[a]
Birth weight of calves (kg)	20.75±1.25[a]	20.25±0.25[a]	21.25±0.47[a]	22.25±0.25[a]

[a,b,c] Mean values within rows with different superscripts are significantly different ($P<0.05$)

Table 3 Effect of different levels of energy on precalving digestibility of nutrients in Sahiwal heifers (Mean ± SE)

Nutrients	Treatments			
	(ME 88%)	(ME 100%)	(ME 112%)	(ME 124%)
DM %	69.5±0.64[a]	69.1±0.43[a]	69.6±0.55[a]	69.7±0.65[a]
CP %	71.2±0.27[a]	70.8±0.45[a]	71.2±0.42[a]	71.4±0.59[a]
NDF %	58.1±0.31[a]	57.4±0.25[a]	58.1±0.70[a]	57.8±0.42[a]
ADF %	51.8±0.47[a]	51.7±0.23[a]	51.7±0.47[a]	51.7±0.27[a]

[a]Mean values within rows with the same superscripts are not significantly different (P>0.05).

yield in ME 88% was found lower than other levels. However, milk yield was similar between ME 112% and ME 124%. The average daily milk yield in first calf heifers kept in positive control group fed precalving ad lib green fodder was only 2.56±0.28 kg/day. The same pattern was observed in the case of fat-corrected milk (FCM) as shown by Table 4.

Milk composition

The influence of different dietary energy levels on milk fat is mentioned in Table 4. Results depicted that provision of precalving extra dietary energy than recommended by NRC (ME 112 and 124%) significantly increased fat percentage than that of other diets having low energy level (ME 88%) and ME 100% as per recommended by NRC. The value of fat percentage in milk of heifers fed ME 100% was also found to be higher than that of ME 88%. The same pattern is seen in the case of total solids but percentages of other milk constituents, protein, lactose and solids not fat, were similar ($P>0.05$) across dietary treatments as mentioned in Table 4 and their averages were 4.89, 3.85 and 9.44%, respectively.

Discussion

Dry matter intake

Similar precalving DM intake in the present study might be attributed to factors that animals under experiment were of similar age, size, weight and stage and consumed similar quantities of their respective diets because measured quantity of diets were offered daily according to body weight of animals. Similar CP intake might be attributed to experimental diets being isonitrogenous in nature. However, NDF and ADF intake were significantly maximum in ME 88% and minimum in ME 124%, whereas these were also greater in ME 100% than those in ME 112%. The pattern of NDF and ADF intake (maximum in ME 88% and minimum in ME 124%) in the present study might be attributed to similar patterns of dietary densities of these nutrients.

Results of previous studies (Dewhurst et al. 2002; Ryan et al. 2003) substantiated findings of the present study that precalving feeding management did influence prepartum total dry matter intake. However, results of McNamara et al.' (2003) study were contrary in terms that dry matter intake was higher in animals fed concentrate supplement during the last 4 weeks of gestation. The possible reasons for this contradiction might be due to different dietary treatments and higher NDF content in silage and silage straw diets that may affect dry matter intake.

Average daily gain

Improvement in precalving weight gain of heifers fed on higher dietary energy levels than recommended by NRC in the present study might be attributed to availability of surplus energy, fulfilling not only additional pregnancy

Table 4 Effect of precalving varying dietary energy levels on milk yield and its constituents in Sahiwal first calf heifers (Mean ± SE)

Parameters	Treatments			
	(ME 88%)	(ME 100%)	(ME 112%)	(ME 124%)
Milk yield (kg/day)	5.87±0.06[a]	4.20±0.07[c]	4.68±0.10[b]	4.72±0.14[b]
FCM (kg/day)	6.26±0.06[a]	4.22±0.06[c]	5.23±0.12[b]	5.34±0.15[b]
Milk fat (%)	4.02±0.07[c]	4.45±0.03[b]	4.79±0.05[a]	4.88±0.01[a]
Protein (%)	3.84±0.08[a]	3.81±0.03[a]	3.88±0.08[a]	3.88±0.04[a]
Lactose (%)	4.90±0.04[a]	4.91±0.06[a]	4.90±0.12[a]	4.87±0.08[a]
Solids not fat (%)	9.43±0.06[a]	9.42±0.11[a]	9.48±0.11[a]	9.46±0.07[a]
Total solids (%)	13.46±0.03[c]	13.8±0.11[b]	14.27±0.17[a]	14.34±0.07[a]

[a,b,c]Mean values within rows with different superscripts are significantly different ($P<0.05$)

requirements but also enabled heifers for their own growth. Provision of extra dietary energy during the last trimester of pregnancy becomes more significant as pregnant heifer needs extra energy for maintenance and development of fetus in her uterus (Moran 2005).

The results of the present study were strengthened by the findings of Olafadehan and Adewumi (2009) and Radunz et al. (2010) that prepartum-rich energy diet improved condition and average daily gain. However, Rabelo et al. (2003) reported differently that weight gain was not affected by precalving dietary energy treatments. The possible reason for this discrepancy might be shorter period (1 month) of precalving feeding management in that study.

Feed efficiency

The higher feed efficiency in ME 112 and 124% might be attributed to availability of surplus dietary energy enabling heifers to convert feed into live body mass more efficiently. Results of the current study were in line with the findings of Hoffman et al. (2007). Similarly, results of another study by Jenet et al. (2004) also affirmed that extra ME than recommended by NRC enhanced feed conversion efficiency in three physiological states: puberty, growth and pregnancy.

Body condition score

Improvement in body condition of heifers through ME 124% of NRC in the present study might be attributed to the factor that higher level of energy during the last trimester leads to development of extra body reserves needed in early lactation period to fulfill high demand of lactogenesis. The improvement in body condition is also corroborated by the findings of Ryan et al. (2003) and Cavestany et al. (2009) that precalving-rich energy concentrate had increased prepartum BCS even in cows. Similarly, Rabelo et al. (2003) also affirmed that precalving high energy diet improved BCS.

Nutrient digestibility

No influence of precalving dietary energy levels on digestibility of nutrients in the present study might be attributed to the best adaptability of Sahiwal pregnant heifers to utilize diets under local environment conditions and make it digestible for maintenance, growth of conceptus and growth of dam. In a previous study, Vanzant et al. (1991) also reported that organic matter digestibility was not influenced under pregnancy. However, findings of Dewhurst et al. (2000) were contrary in terms of decreased apparent rumen digestibility of nutrients during the last 6 weeks of gestation. The possible reason for this divergence might be different precalving dietary treatments.

Birth weight of calves

The similar birth weights of newly born calves in the present study might be attributed to the factor that needs of conceptus (growth of fetus, fetal membranes, uterus and mammary glands) are accorded high priority by the homeorhetic controls it transmits to the dam (Stanley 2005). No effect of prepartum dietary energy treatment on birth weight of born calves was also substantiated by findings of previous published work (Doepel et al. 2002; McNamara et al. 2003; Rabelo et al. 2003; Sanson and Coombs 2003; Olafadehan and Adewumi 2009). However, findings of Radunz et al. (2010) were contrary in nature where birth weight of calves was higher in cows fed rich energy diets prepartum. The possible reason for this divergence might be due to different precalving dietary treatment in beef cows.

Milk yield

The optimum milk production was achieved in ME 100% of NRC recommendation, whereas yield was decreased in higher dietary energy levels (ME 112 and 124%). The lesser milk yield in diets having higher energy levels than recommended by NRC might be attributed to more availability of mammary fat pad that may limit further parenchymal tissue development and, consequently, decrease milk yield during subsequent lactation (Le Cozler et al. 2008). In a previous study, Rabelo et al. (2003) reported that first calf heifers fed prepartum low energy density diet tended to have higher 3.5% FCM production than those fed higher energy density diet. However, Holtenius et al. (2003) reported discrepant results that milk yield in cows fed precalving varying dietary energy levels was similar among dietary treatments. The possible reasons for this discrepancy might be due to different breeds: Swedish black and white cows.

Milk composition

The milk fat percentage was increased by increasing precalving dietary energy level. The increase in fat content might be attributed to factor that extra dietary energy beyond NRC recommendation could have a positive effect on uptaking of milk fat precursors by mammary cells. However, other milk constituents, protein, lactose and SNF percent, were not influenced. No influence of precalving dietary energy on these milk constituents might be attributed to important homeorhetic controls of nutrients

partitioning that are necessary to supply mammary needs for smooth milk synthesis.

The increase in fat content by precalving-rich energy dietary treatment was substantiated by previous studies (McNamara et al. 2003; Duske et al. 2009). Similarly, few workers (Dewhurst et al. 2002; Doepel et al. 2002; Rabelo et al. 2003) also affirmed that protein and lactose production were not affected by prepartum dietary treatments.

Conclusion

Provision of extra dietary energy during the last trimester of gestation beyond NRC (2001) recommendations for small breed pregnant heifers improved prepartum performance in terms of average daily gain, body condition and feed efficiency. However, nutrient digestibility, birth weight of calves and milk composition except fat content were not influenced with energy levels. The highest daily milk yield was observed in heifers fed ME 100% followed by ME 112, 124, and 88%. We conclude that the NRC recommendation is applicable to the subtropical regions.

Acknowledgements Authors gratefully acknowledge the cooperation of Mr. Muhammad Ameen, Production Manager Supertech Feeds Multan, Mr. Akhtar Hussain, Incharge Jadeed Farms Khanewal and Mr. Muhammad Anjum, Production Manager Multan Feeds for preparation of experimental diets.

References

AOAC, 2005. Association of Official Analytical Chemists. Official Methods of Analysis, Washington, DC.

Bajwa, I.R., Khan, M. S., Khan, M. A. and Gondal, K. Z., 2004. Environmental factors affecting milk yield and lactation length in Sahiwal cattle, Pakistan Veterinary Journal, 24, 23–27

Bhatti, S. A., Sarwar, M., Khan, M. S. and Hussain, S. M. I., 2007. Reducing the age at first calving through nutritional manipulations in dairy buffaloes and cows: A review, Pakistan Veterinary Journal, 27, 42–47

Cavestany, D., KulcsÃ¡r, M., Crespi, D., Chilliard, Y., Manna, A. L., Balogh, O., Keresztes, M., Delavaud, C., Huszenicza, G. and Meikle, A., 2009. Effect of Prepartum Energetic Supplementation on Productive and Reproductive Characteristics and Metabolic and Hormonal Profiles in Dairy Cows under Grazing Conditions, Reproduction in Domestic Animals, 44, 663–671

DEFRA, 2001. Condition scoring of dairy cows. Department for Environment, Food and Rural Affairs, London. DEFRA Publication, pp: 1–8

Dewhurst, R. J., Moorby J. M., Dhanoa M. S., Evans R. T. and Fisher W. J., 2000. Effects of altering energy and protein supply to dairy cows during the dry period on intake, body condition and milk production, Journal of Dairy Science, 83, 1782–1794

Dewhurst, R. J., Moorby J. M., Dhanoa M. S. and Fishert W. J., 2002. Effects of level of concentrate feeding during the second gestation of Holstein-Friesian dairy cows. 1. Feed intake and milk production, Journal of Dairy Science, 85, 169–77

Doepel, L., Lapierre, H. and Kennelly, J. J., 2002. Peripartum Performance and Metabolism of Dairy Cows in Response to Prepartum Energy and Protein Intake, Journal of Dairy Science, 85, 2315–2334

Duske, K., Hammon H. M., Langhof A. K., Bellmann O., Losand B., Nürnberg K., Nürnberg G., Sauerwein H., Seyfert H. M. and Metges C. C., 2009. Metabolism and lactation performance in dairy cows fed a diet containing rumen-protected fat during the last twelve weeks of gestation, Journal of Dairy Science, 92, 1670–1684

Hoffman, P. C., Simson C. R. and Wattiaux M., 2007. Limit feeding of gravid Holstein heifers: effect on growth, manure nutrient excretion and subsequent early lactation performance, Journal of Dairy Science, 90, 946–954

Holtenius, K., Agena S., Delavaud C. and Chilliard Y., 2003. Effects of feeding intensity during the dry period: Metabolic and Hormonal responses, Journal of Dairy Science, 86, 883–891

Javed, K., Abdullah M. and Khan M. A, 2002. Estimation of breeding value and genetic trends in Sahiwal cattle in Pakistan, Journal of Animal and Plant Sciences, 12, 1–6

Jenet, A., Yimegnuha A., Fernandez-Rivera S., Tegegne A., Osuji P. O., McCrabb G. and Kreuzer M., 2004. Long term response to feeding level in lactation performance of Boran (*Bos indicus*) and Boran Holstein cows, Animal Science, 78, 331–343

Le Cozler, Y., Lollivier, V. , Lacasse, P. and Disenhaus, C., 2008. Rearing strategy and optimizing first-calving targets in dairy heifers: a review, Animal, 2, 1393–1404

Maquivar, M. G., Galina, C. S., Galindo, J. R., Estrada, S., Molina, R. and Mendoza, G. D., 2010. Effect of protein supplementation on reproductive and productive performance in *Bos indicus*×*Bos taurus* heifers raised in the humid tropics of Costa Rica, Tropical Animal Health Production, 42, 555–560

McNamara, S., Mara F. P. O., Rath M. and Murphy J. J., 2003. Effects of different transition diets on dry matter intake, milk production and milk composition in dairy cows, Journal of Dairy Science, 86, 2397–2408

Moran, J., 2005. Tropical dairy farming: feeding management for small holder dairy farmers in the humid tropics, (CSIRO Publishing, Melbourne)

NRC, 2001. Nutrient Requirements of Dairy Cattle, National Academy Press, Washington, DC.

Olafadehan, O. A. and Adewumi, M. K., (2009). Productive and reproductive performance of strategically supplemented free grazing prepartum Bunaji cows in the agro pastoral farming system, 41, 1275–1281

Osakwe, I. I., Steingass, H and Drochner, W., 2004. Effect of dried *Elaeis guineense* supplementation on nitrogen and energy partitioning of WAD sheep fed a basal hay diet, Animal Feed Sience and Technology, 117, 75–83

Rabelo, E., Rezende R. L., Bertics S. J. and Grummer R. R., 2003. Effects of transition diets varying in dietary energy density on lactation performance and ruminal parameters of dairy cows, Journal of Dairy Science, 86, 916–925

Radunz, A. E., Fluharty, F. L., Day, M. L., Zerby, H. N. and Loerch, S. C., 2010. Prepartum dietary energy source fed to beef cows: I.

Effects on pre and postpartum cow performance, Journal of Animal Science, (doi:10.2527/jas.2009-2744)

Ryan, G., Murphy J. J., Crosse S. and Rath M., 2003. The effect of pre-calving diet on post calving cow performance, Livestock Production Science, 79, 61–71

Sanson, W. and Coombs D. F., 2003. Performance of bred heifers fed various supplements during gestation, The Professional Animal Scientist, 19, 267–272

Stanley, C. C., 2005. Regulation of glucose metabolism in dairy cattle, (Unpublished PhD thesis, Louisiana State University)

Swanson, T. J., Hammer, C. J., Luther, J. S., Carlson, D. B., Taylor, J. B., Redmer, D. A., Neville, T. L., Reed, J. J., Reynolds, L. P., Caton, J. S. and Vonnahme, K. A., 2008. Effects of gestational plane of nutrition and selenium supplementation on mammary development and colostrum quality in pregnant ewe lambs, Journal of Animal Science, 86, 2415–2423

Van Keulen, J. and Young B.A., 1977. Evaluation of acid insoluble ash as a natural marker in ruminant digestibility studies, Journal of Animal Science, 44, 282

Van Soest, P. J., Robertson H. B. and Lewis B. A., 1991. Method of dietary fiber and non-starch polysaccharides in relation to animal material, Journal of Dairy Science, 74, 3583

Vanzant, E. S., Cochran R. C. and Johnson D. E., 1991. Pregnancy and lactation in beef heifers grazing tall grass prairie in the winter: Influence on intake, forage utilization and grazing behavior, Journal of Animal Science, 69, 3027