

Continuing Education Article

Energy Utilization is not a Constant Function of Metabolic Body Size in Ruminant Animals

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ABSTRACT

A considerable variation in total energy expenditure exists among animals. Metabolism of visceral organs constitutes a major proportion of total energy expenditure: the visceral mass, as proportions of weight or metabolic body size varies with breed or type, diet, maturity and physiological state. These findings suggest that most of the variation in animal energy expenditure may be attributable to variation in metabolism of visceral organs of animals. Of the energy losses associated with maintenance functions, a large proportion appears to result from metabolism in the liver and gastrointestinal tract.

Key Words: Energy; Breed; Metabolism; Metabolic body weight; Diet; Physiological state

Maintenance requirements have frequently been expressed as energy required per kg of body weight⁷⁵ (metabolic body size). The concept of metabolic body weight (BW) originated from the work of Brody (1945) as cited by Koong *et al.* (1985) in which basal metabolic rate (fasting heat production) was related to BW in the form of a power function in an interspecies evaluation of mature animals. However, evidence exists (Koong *et al.*, 1985) that, within a species, many variables such as breed, sex, season, diet, age, thermal environment, level of production and previous nutritional history influence estimates of fasting heat production or maintenance. Maintenance has been defined as the feed energy required for zero body energy change (energy stasis) or feed energy required for zero BW change (weight stasis). Although these definitions are often used for similar purpose, the use of energy stasis or weight stasis may result in different results and interpretations, especially in growing animals (Ferrell & Jenkins, 1985). Approximately 65 to 75% of the energy required for beef production is used by the cow herd and about 70% of the energy required by the cow herd can be attributed to energy costs for cow maintenance (Gregory, 1972). Ferrell and Jenkins (1984) found that maintenance requirements per unit of weight or metabolic body size in cows of different types differed little as a result of weight per se, but their genetic potential for milk production was related positively to maintenance energy requirements, and these differences are expressed in the nonlactating female. Ferrell and Jenkins (1985) suggested that variation in total energy requirements among cow types may exist. Some inconsistency

exists in energy requirements for gestation and lactation among types of beef cows, but variation in energy requirements for these functions appear to be small relative to variation in energy requirements for maintenance. Also, regardless of cow type, 70 to 75% of the total annual energy requirements were required for maintenance functions. Condiff *et al.* (1983) suggested that metabolizable energy needs for maintenance vary among cow types, and also that variation in maintenance exists beyond that associated with size or milk production potential. Estimates of maintenance of nonpregnant, pregnant and nonlactating cows appear to be similar. However, substantial differences in maintenance requirements may be incurred during lactation. Additionally, maintenance may differ because of body condition or previous nutritional level. One can readily determine that maintenance of the producing female constitutes a major proportion of the energy required for cattle production.

Sources of variation. Energy requirements for maintenance may differ among animals differing in genetic potential for production and/or physiological stage. According to several authors cited by Ferrell and Jenkins (1985), maintenance is not constant only with BW or metabolic body size. It can vary with age, sex, season, temperature and present or previous nutritional level of the animal. Because maintenance energy cost constitutes a major proportion of energy consumed for cattle production. Therefore, an enhanced understanding of sources of variation in maintenance energy expenditures needs to be developed to fetch optimum productivity from livestock. Some of the important

factors responsible to cause variation in maintenance energy expenditures are discussed below.

Body Composition. Readily observable body composition differences among breed, sex or age of cattle have led many investigators to suggest that variation in body composition is the primary source of variation in fasting or maintenance energy expenditure. Several studies surveyed by Ferrell and Jenkins (1985) have shown maintenance energy expenditures to be correlated highly with body lean or protein mass and correlated poorly with body fat mass. However, data also are available (Ferrell & Jenkins, 1985) to strongly suggest that body composition per se may not be the predominant factor in determining fasting or maintenance energy expenditure.

Protein and fat accretion. Several authors cited by Ferrell and Jenkins (1985) have indicated that energetic efficiency of body protein deposition is less efficient than fat deposition. Estimates of the efficiency of fat deposition (60 to 80%) have been consistently within the range of theoretical estimates. Estimates of efficiency of protein deposition (40 to 50% for non-ruminants and 10 to 40% for ruminants) have been lower than theoretical estimates of synthetic efficiency and, in ruminant species, have been variable. The estimates of protein accretion efficiency are lower than theoretical estimates which are at least partly the result of energy costs associated with protein turnover. However, heat production commonly attributed to whole body protein accretion (by mathematical techniques to partition energy among maintenance, protein and fat accretion) may actually be a result of general increase in heat production that is correlated with components of protein accretion (Millward *et al.*, 1976).

Body tissues. In general, reports have attempted to relate fasting heat production, maintenance or energetic efficiency to whole body composition or protein and fat accretion in the whole body. Considerable evidence has accumulated to suggest that overemphasis of economically important characteristics (e.g. whole body composition) has perhaps distracted from more biologically important considerations. Carcass protein (skeletal muscle) is recognized as a predominant contributor to whole body protein, and skeletal muscle is the major site of protein accretion (Ferrell & Jenkins, 1985). The data reported by Tess *et al.* (1984) demonstrated that fasting heat production was associated more highly with weight of protein in the viscera than weight in the carcass of pigs. Smith (1970) as cited by Ferrell and Jenkins (1985) based on an

extensive review of the literature, suggested that energy expenditure of visceral organs was a major proportion of basal energy expenditure. He estimated about 30% of the basal energy expenditure resulted from metabolism in the gastrointestinal tract, liver and heart and that an additional 22% was contributed by the skin, brain and kidney. Smith and Baldwin (1974) also reported that weights of the liver, heart, mammary gland, lungs, rumen, abomasum, spleen, intestines and adrenal glands were higher in lactating than in non-lactating cows. These workers suggested that changes in tissue weights may be related to differences in maintenance energy expenditure for lactating vs non-lactating cows. Ferrell *et al.* (1983) postulated that differences in maintenance expenditures were related to animal weight differences rather to the previous nutritional treatment per se. They found that liver and intestinal weights were related highly to fasting heat production or daily feed intake. These results support the suggestion that variation in visceral organs weights may contribute substantially to variation in total energy expenditures.

Blood flow and oxygen consumption. Webster *et al.* (1975) noted that portal blood flow increased curvilinearly with increased ME intake per kg of body size. Lomax and Baird (1982) observed higher rates (50 to 60%) of portal and hepatic blood flows in lactating as compared with non-lactating cows. They suggested that higher rates of portal blood flow of lactating cows are a result of greater energy intake, rather than being attributable to lactation per se. Ferrell and Jenkins (1985) reviewed the literature and reported that oxygen consumption in the liver was 15 to 18% of the total oxygen consumed by lambs (44 kg) in thermoneutral environment, and in newborn lambs, oxygen consumption of the gastrointestinal tract and liver was 11 and 15% of total oxygen consumption, respectively.

Protein synthesis. Ferrell and Jenkins (1985) in their review noted that total protein synthesis in the liver and gastrointestinal tract tissues was greater than in skeletal muscle for cattle. Kidney and pancreas (16 to 17%) had a greater proportion of total protein synthesis than that from striated muscle (24 to 28%). Again, these data are indicative of the high metabolic costs of liver and gastrointestinal tissues and implicate protein synthesis as being directly or indirectly related to these costs. This is not to say that protein synthesis is the only cause of energy expenditures in these tissues. Other authors, in the same review article, suggested that energy expenditure and oxygen consumption of skeletal muscle is higher in newborn lambs than in ewes and higher in lactating ewes than in non-lactating ewes.

REFERENCES

- Condiff, L.V., C.L. Ferrell and T.G. Jenkins, 1983. Output/input differences among F₁ cows of diverse biological type. *J. Anim. Sci.*, 57(Suppl. 1): 148.
- Ferrell, C.L. and T.G. Jenkins, 1984. Energy utilization by mature, non-pregnant nonlactating cows of different types. *J. Anim. Sci.*, 58: 234-43.
- Ferrell, C.L. and T.G. Jenkins, 1985. Cow type and the nutritional environment: Nutritional aspects. *J. Anim. Sci.*, 61:725-40.
- Ferrell, C.L., J.A. Nienaber and L. J. Koong, 1983. Effects of previous nutrition on maintenance requirements and efficiency of feed utilization of growing lambs. *J. Anim. Sci.*, 57(Suppl. 1): 431.
- Gregory, K.E., 1972. Beef cattle type for maximum efficiency, putting it all together. *J. Anim. Sci.*, 34: 881-88.
- Kleiber, M., 1961. *The Fire of Life*. John Wiley and Sons, Inc., New York.
- Koong, L.J., C.L. Ferrell and J.A. Nienaber, 1985. Assessment of interrelationships among levels of intake and production, organ size and fasting heat production in growing animals. *J. Nutr.*, 115: 1383-97.
- Lomax, M.A. and G.D. Baird, 1982. Blood flow and nutrient exchange across the liver and gut of the dairy cow. Effects of lactation and fasting. *British J. Nutr.*, 49: 481-96.
- Millward, D.P., P. J. Garlick and P. J. Reeds, 1976. The energy cost of growth. *Proc. Nutr. Soc.*, 35: 339-47.
- Smith, N.E. and R.L. Baldwin, 1974. Effect of breed, pregnancy and lactation on weights of organs and tissues of dairy cattle. *J. Dairy Sci.*, 57: 1055-60.
- Tess, M. W., G. E. Dickerson, J. A. Nienaber and C. L. Ferrell, 1984. The effects of body composition on fasting heat production in pigs. *J. Anim. Sci.*, 58: 99-110.
- Webster, A.J.F., P.O. Osuji, F. White and J.F. Ingram, 1975. The influence of food intake on portal blood flow and heat production in the digestive tract of sheep. *British J. Nutr.*, 34: 125-39.

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