A REVIEW OF LINEAR RELATOINSHIPS BETWEEN ENERGY AND PROTEIN IN RUMINANT ANIMAL NUTRITION

Ocheja, J.O,[1] Agyo, B[2], Mohammed, F[3], Ogaji,E.O,[4] Jallo, U.I[1], Sechii, J., [5] Igbatigbi, L.O[6] and Ahmed, S.H.[7]

[1]Department of Animal Science, Federal University, Kashere, Nigeria
[2]Department of Agricultural Education ,Federal College of Education (Technical) Gombe, Nigeria
[3]Department of Animal Health and Production Technology , Federal College of Horticulture , Dadin Kowa,Nigeria
[4]Department of Agricultural Education, Federal College of Education, Jama are, Nigeria
[5]Department of Animal Production , Nassarawa State University, Lafia, Nigeria
[6]Department of Biological Sciences , Federal University, Lokoja, Nigeria.
[7]Department of Animal Science , University of Benin, Nigeria

ABSTRACT

The production of high quality protein such as meat, milk and eggs for human consumption and by-products such as hides and skin, wool, fur, hoofs, horns and manure requires large quantities of protein and energy , thus a good understanding of the linear relationships between protein and energy is important for improving efficiency and productivity in ruminant animal production.. Consequently energy and protein requirements , various linear relationships or interactions between protein and energy , mechanisms for energy supply for microbial protein synthesis as well as appropriate combinations of protein and energy feeds in ruminant animal nutrition as elucidated by various researchers were collated and discussed. Protein requirements depends on body weight and rate of gain, as a general rule, the protein requirement for maintenance is relatively low but the requirement for gain is relatively high the opposite is true for energy- requirement is high for maintenance the metabolizable energy requirement for calves for maintenance has been estimated as 115 kcal/kg$^{0.75}$. Energy required for gain of veal was described by the following equation ME=0.lLw 0.75x0.84 (LW^{0335}) (LW$^{1.2}$) where ME is the metabolizable energy requirement in kcal, LW is the live weight in Kg and LWG is she live weight gain in kg. The most important purpose to which feed nutrients are put is the production of energy, therefore feed intake is almost synonymous with energy intake. The concept of total digestible nutrient which is the sum of all digestible organic nutrients, carbohydrates, protein and fats (2.25) represents the approximate energy value of feeds these nutrients may be immediately used for energy or stored as glycogen, fat or gets incorporated into the body tissue. When ever there is shortage, energy stored in form of glycogen or fat will be mobilized and when these sources are exhausted, proteins will be hydrolyzed and delaminated and used for energy production. Thus every organic nutrient, except vitamins, is a source of energy . It was concluded that better knowledge of the energy and protein requirements, the linear relationships that exists between protein and energy as well as how to combine protein and energy feeds in ruminant animal nutrition was very important for efficient and productive ruminant animal production. Further research on the protein and energy requirements and the linear relationships that exists between protein and energy was recommended

Keywords: Linear, Energy, Nutrition, Microbial Protein, Ruminant Animals

1.0 INTRODUCTION

. The most important purpose to which feed nutrients are put is the production of energy, therefore feed intake is almost synonymous with energy intake. The concept of total digestible nutrient which is the sum of all digestible organic nutrients, carbohydrates, protein and fats (2.25) represents the approximate energy value of feeds these nutrients may be immediately used for energy or stored as glycogen, fat or gets incorporated into the body tissue. When ever there is shortage, energy stored in form of glycogen or fat will be mobilized and when these sources are exhausted, proteins will be hydrolyzed and delaminated and used for energy production. Thus every organic nutrient, except vitamins, is a source of energy (Hagemeistcr *et a!* 1980). MacDonald *et al* (2002) reported that fatty acids absorbed from the blood by the liver may be catabolysed for energy production or used for synthesis of triacyiglycerols. These then re-enter the blood supply in the form of lipo-protein where they may be used for lipid synthesis for energy production and fatty acid synthesis. The production of high quality protein in the form of meat, milk and eggs for human nutrition and other by-products such as hides and skin, fur, horns, fibre, Hooves etc, requires the production and supply of energy (Mac Donalds *et al*.,2002) these non food by-products are raw materials for industries that helps to develop the economy.(Abalaka *et al*, 2021).

The net protein synthesis (protein deposition, protein in milk, eggs, meat, protein for production of fibre etc.) is a process which requires much energy(Mac Donald *et al,* 2002) The way an animal is fed also reflects in the quality of its products and by-products (Ocheja *et al.,*2020) Protein requirements depends on body weight and rate of gain, as a general rule, the protein requirement for maintenance is relatively low but the requirement for gain is relatively high the opposite is true for energy, requirement is high for maintenance, the metabolizable energy requirement for calves for maintenance has been estimated as 115 $kcal/kg^{0.75}$ (ARC 1980). Energy required for gain of veal was described by Toullec 1989 by the following equation ME=0.lLw 0.75x0.84 (LW^{0335}) ($LW^{1.2}$) where ME is the metabolizble energy requirement in kcal, LW is the live weight in Kg and LWG is the live weight gain in kg. Consequently a concise and systematic study of the mechanisms of energy production and distribution for the production of high quality protein products such as meat and milk as well as other by-products is very important and the application of this knowledge will lead to a more efficient , and more productive ruminant animal production.

This paper gives a review of protein requirements , the linear relationship that exists between protein and energy in ruminant animal nutrition, the production and supply of energy for microbial protein synthesis as well as the appropriate combination of protein and energy feeds leading to a more productive ruminant animal production

2.0 MATERIALS AND METHODS

Literature on energy and protein requirements , the linear relationship that exists between protein and energy in ruminant animal nutrition, the production and supply of energy for microbial protein synthesis as well as the appropriate combination of protein and energy feeds were assembled from journals, conference proceedings, books and from the internet and there after discussed and reviewed.

3.0 RESULTS AND DISCUSSION

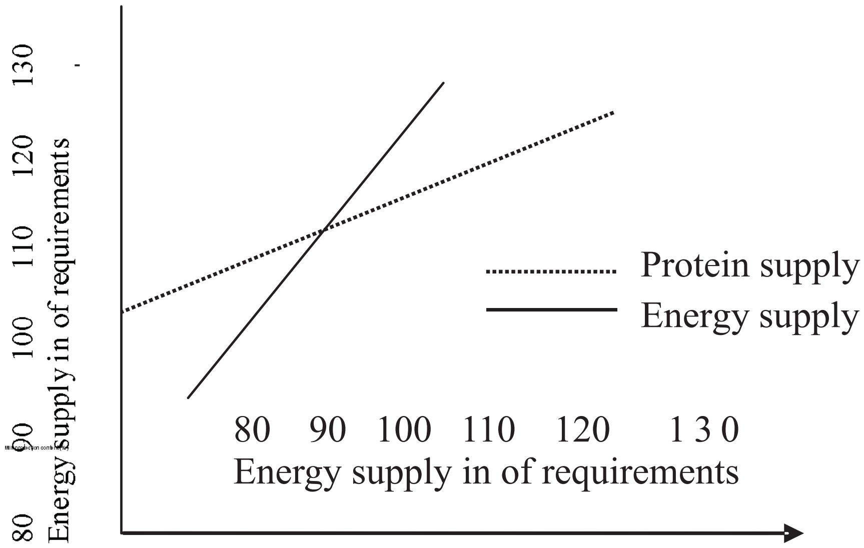
3.1 Feed Intake and Energy

The most important purpose to which feed nutrients are put is the production of energy, therefore feed intake is almost synonymous with energy intake. The concept of total digestible nutrient which is the sum of all digestible organic nutrients, carbohydrates, protein and fats (2.25) represents the approximate energy value of feeds these nutrients may be immediately used for energy or stored as glycogen, fat or gets incorporated into the body tissue. When ever there is shortage, energy stored in form of glycogen or fat will be mobilized and when these sources are exhausted, proteins will be hydrolyzed and delaminated and used for energy production. Thus every organic nutrient, except vitamins, is a source of energy (Hagemeistcr *et a!* 1980). MacDonald *et al* (2002) reported that fatty acids absorbed from the blood by the liver may be catabolysed for energy production or used for synthesis of triacyiglycerols. These then re-enter the blood supply in the form of lipo-protein where they may be used for lipid synthesis for energy production and fatty acid synthesis.

3.2 Energy Supply and Milk Protein Content.

The influence of energy surplus on microbial synthesis can he observed with energy deficiency this leads to a diminished microbial synthesis and a corresponding decrease in the supply of amino acids to the mammary gland. This condition is often met at peak lactation at high levels of performance. The importance of energy supply during peak lactation was demonstrated by Kaufman *et al* (1978) he showed that the Oleic acid content in the milk was additionally used as an indication of energy under feeding. The level of energy supply at the beginning of lactation also exerts a considerable influence on the partition of nutrients of milk and body reserve during the whole lactation period. According to Coppock *et al* (1968) 1000 litres of milk can be produced from body fat reserve but body protein can be made available for only l2Olitres of milk. The available fat can increase the energy supply to the mammary gland but not the supply of energy to the rumen. Hagemeister (1980) reported that at a given level of energy, milk yield increases with protein intake. Bacterial protein synthesis also depends on energy supply. Thus the interaction between dietary protein and dietary energy and the degradability of dietary protein will influence the small response in milk yield (and protein intake). Gordon (1977), Kaufman and Luping (1981) demonstrated these relationships and showed the importance of energy supply on protein yield and protein content of milk. An increase in the plain of nutrition is normally associated with an increase in milk protein content (Thomas 1980). The effects are partly related to increase in energy intake as can be seen in the figure below.

Figure 1: Influence of the supply of energy and protein on the milk protein content (adapted form Gordon 1977).



3.3 Energy Requirements for Protein Synthesis

The portion of the true energy (or of the protein) which is available for production is the amount remaining after the maintenance needs are satisfied. These maintenance needs for energy and for protein (or nitrogen) are proportional to (or dependent on) the metabolic size of the animal ($\mathrm{Wkg0}^{75}$). The true net nitrogen utilization corresponds to true net energy (Kaufman *et al* 1980). Protein synthesis requires the necessary amino acids as well as some 5 moles of ATP/mole peptide bond synthesized provided that it does not increase the rate of turn over of already existing tissues (Campbell 1977) One mole of ATP in the ruminant on average requires 95KJ ME. This means that the energetic efficiency of protein synthesis from ME approximates 2400/(1.1 x 2400 + 5 X 95) = 77%. In the young rapidly growing ruminant, protein deposition appears to be accompanied by an increased rate of turn over so that a considerable addition of ATP is needed for this purpose, decreasing the energetic efficiency.

3.4 Energy Supply for Microbial Protein Synthesis

The amount of energy available for microbial protein synthesis was defined in terms of the proportion of apparently digestible organic matter (DOM). That is apparently digested in the rumen (DOMR) (ARC, 1 984). There is a wide variation in the DOMR/DOM values published for goats but they do not differ consistently from those in the large survey for sheep and cattle (ARC 1980). The value adopted in ARC (1984) was 0.65 for all diets for both sheep and cattle. Microbial protein synthesis should be related to the amount of fermentable metabolizable energy (FME) in the feed (ARC 1993). Hobson and Summers (1967) observed that the nitrogen supply for the rumen flora above a rather low limit has no further influence on the extent of microbial protein synthesis. The situation is completely different in the case of energy supply. Generally we find a direct proportionality of the later to microbial synthesis. Such findings have been .obtained in early studies using *invitro* methods and these results were confirmed by Bauchop and Elsden (1960) and Walker and Nades (1970). Few bacterial strains showed relationship to energy supply deviating from those observed *invitro* by Hobson and Summers (1967). In general the relationship between fermentable energy and microbial growth are stated as g microbal N/kg of apparent digestible organic matter. Such data have been elaborated in many research by means of abdominal fistulas or duodenal re-entrant fistulas as well as by the use of labeling substances. Occasionally true digestible organic matter has been used but it does not seem to be most appropriate. The average of the values hitherto published was 30g N/kg of (DOMR) digestible organic matter in the fore stomach. As for the correction of this average for truly digestible organic matter in the fore stomach, a value of 24.7g N/kg was found by Mcmeniman *et al* (1976) the value corresponds fairly well to the average of 32g microbial N/kg of fermented digestible organic matter established in earlier work corresponding to 200g of bacterial protein as regards the protein supply to cattle it appears convenient to relate these values of microbial synthesis to energy measuring systems in practical use. If we use the starch unit 20g of bacterial protein /l00 starch units (65% of DOM of the ration is fermented) l00g of digestible organic matter corresponds to 81 starch units. Accordingly 1000 kcal ME yields about 38g of bacterial crude protein (Hagemeister and Kaufman 1974). Orskov *et al* (1976) observed that if however in low protein rations, where the ratio of digestible crude protein to starch unit is wider than 1:7 where the crude protein content is lower than 13% but sufficient energy is supplied the deficient protein can he covered by non protein nitrogen. If the diet is deficient in protein or if protein resists degradation, the concentration of rumen ammonia will be low (50mg/litre) and the growth of rumen microbes will be low Consequently, the break down of carbohydrate will be retarded (McDonald *et al* 2002). The microbes must have a readily available source of energy for protein synthesis. Consequently, feeds should be low in rumen degradable protein and high in readily fermentable carbohydrates (McDonald *et al* 2002).

According to Mc Donald *et al* (2002), the efficiency with which nitrogen is captured by the rumen micro organisms depends not only on the speed and extent of breakdown but also upon the synchronous provision of a readily available utilizable source of energy to fuel the synthesis of microbial protein. Failure to achieve this balance can result in too rapid and extensive a breakdown and the synthetic powers of the microbes may be over whelmed. Wastage may then occur since excess ammonia is absorbed and largely excreted as urea. Some ammonia is recycled via the rumen. The extent of recycling has been estimated at about 70% of nitrogen intake for diets of low protein (about 5g/kg) and as little as 11% for feeds of about 20g protein/kg. The extent of recycling in a particular situation may be calculated using the following equation.

$$Y=121.7-12.01x+0.3235x^2$$

Where: y = recycled urea nitrogen as a % of nitrogen Intake

X.= percent crude protein in dry matter

The part of the feed crude protein, which is immediately degradable, is unlikely to be as effective a source of nitrogen for the microorganisms as that which is the more slowly degraded nitrogen fraction is incorporated into microbial protein with an efficiency of 1 .0. Whereas the immediately degraded is less efficiently used. Estimates of the efficiency with which immediately degraded protein is incorporated vary but 0.8 is a commonly used figure. The yield of microbial protein which becomes available for digestion and absorption post ruminally by the host has been related to the energy of the diet stated in terms of digestible organic matter (DOM) digestible organic matter digested in the rumen (DOMADR), total digestible nutrient (TDN); net energy for lactation (NE_L)

metabolizable energy (ME), fermentable organic matter (FOM) fermentable metebolizable energy (FME) and rumén degradable carbohydrate. The last three eliminate fat and products of fermentation, neither of which are considered to provide energy which can be utilized by the rumen micro organisms. The energy of fermentation products is significant in the case of silages and some distillery and brewery by-products. Hays are not considered to have undergone fermentation, though they often contain measurable amounts of fermentation acids such as acetic and propoinic acids. The routine measurement of the contribution of fermentation products of metabolizable energy individual foods has not been a feasible proposition and assumed values are commonly used. The validity of: such values is questionable in view of the variation in the magnitude and diversity of the fermentation products in individual foods.

A simple linear relationship between available energy and microbial protein yield cannot reflect the true position it takes no account for the maintenance requirement of micro organisms which have been estimated to vary from 0.022 to 0.1 87g carbohydrates/g bacteria per hour. When fermentation is slow as with diets rich in structural carbohydrates, maintenance costs may be significant and estimates of microbial yield may 'be exaggerated. Further more, in the rumen environment, lowering the rumen PH from 6.7 to 5.7 has been shown to increase microbial protein production which may be significant when diets are rich in soluble carbohydrates and low in fibre with consequent production of lactic acid and ruminal acidosis. Finally variation in the form of nitrogen required by the different types of micro organism. Thus the organisms splitting non structural carbohydrates (NSC) are able to utilize peptide nitrogen and ammonia whereas those splitting structural carbohydrate are unable to use amino nitrogen and have to rely on ammonia as their source of nitrogen. It has been claimed that the yield of NSC splitting bacteria is increased by almost 20% when the proportion of peptides in the total NSC peptides increase from 14%, above 14% there is no further increase in yield, the relationship used in predicting microbial protein from fermentable energy has a high standard error of estimate and should be used with caution in addition such relationships may be used to calculate yields of microbial protein only when the energy supply is limiting. Sophisticated models attempt to relate microbial yield to the role of carbohydrate fermentation and rate of passage, theoretical growth rate, the energy cost of bacteria maintenance and the form of nitrogen available to the rumen microorganism. Many of the relationships involved in such calculations are based on laboratory characterization of the feed and the value of the model will depend on the validity of the relationships between the laboratory determination and the values used in the models.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Knowledge of the mechanisms of energy production and supply for microbial protein synthesis and hence their applications could lead to a more productive and more efficient ruminant animal production.

4.2 Recommendation

Further research especially at cellular levels on energy production for microbial protein synthesis is required and such research should be ones that are very practicable and the results can easily be applied by livestock farmers.

REFERENCES

Abalaka,E,O, Yahaya, B, Effienokwu, J.N, Adegbe, J.Y, Odiba, J, and Ali, P.A (2021) Weights of By-products of Carcass of West African Dwarf Goats fed *Panicum maximum* and Bambara Nut Offal and Cereal Spent Grains Based Supplement diet .*International. Journal of Agriculture. and Rural Deveiopment.* 24 (1): 5617 – 5621

Agricultural Research Council(1993). Energy and Protein Requirements of Ruminants . Wallington ,UK,CAB. Pp89 – 91.

Agricultural Research Council (1984) Energy and Protein requirements of Ruminants . Wallington,UK, CAB International Pp67 - 69

Agricultural Research Council (1980) . The Nutrient Requirements of Ruminant Livestock . Farm ham Royal Slough , England . Common Wealth Agricultural Bureau

Chesworth, J. (1992) Ruminant Nutrition: The tropical Agriculturalist Series CTA/ Macmillan .Series. Pp 46

Mc Donald, P., Edward, P.A,, Greenhalgh, J.F.D and Morgan C.A (2002). Animal Nutrition 2nd ed. Pearson Education Ltd, Singapore: Pp 308.

Ocheja,J.O, Apeh, U.J, Egbunu,G.F, Faruna,S.S, Abalaka, E.O, Amidu,M, and Faruna,J.M(2020). Effects of Concentrate Supplementation on Whole Sale Cuts and Sensory Properties of Meat from West African Dwarf Goats. *Nigerian Journal of Animal Science and Technology*. 3(4):72 – 77

Gordon, F.J (1977). The effect of protein content on the response of lactating cows to different levels of concentrate feeding *British J. Anim.prod*.25:181-191.

Hagemeister, H. Luping, W. and Kaufman, W (1980). Bacterial protein synthesis in the high yielding dairy cow: w. Haresign (editor) Recent advances in Animal Nutrition, Butter worth Publishers, London, pp 67- http//www/.extension.umn.edu/agriculture/dariy/beef/nutrition of the neonatal calf.pdf.

Thomas, P.C (1980) Influence of nutrition on the yield and milk protein content Dietary protein an energy supply in: Factors affecting the dyeld and content of milk constituents of commercial importance *Int Dairy fed. Bull. Doc* 125: 142-151

Lodge G.A and lister EE (1973). Effects of increasing energy value of a whole milk diets for Calves, II growth, feed utilization, and health *Can. J. Anim. Sci.*53:317-325

Toullec R. (1989). Veal calves, In: R Jarrige (Ed) Ruminant Nutrition: Recommended allowance and feed Tables, institute National, de la Recherche Afronomique. John Libbey and co. Ltd. London.