Reprinted from: MEAT ANIMALS (1976)
Edited by D. Lister, D.N. Rhodes, V.R. Fowler and M.F. Fuller
Book available from Plenum Publishing Corporation
227 West 17th Street, New York, New York 10011

MEAT PRODUCTION FROM RUMINANTS

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INTRODUCTION

Ruminants produce meat in several systems of animal husbandry. In this paper attention will be paid to veal calves and beef cattle and occasionally to dairy cattle and lambs. For each of these animals the economy of meat production depends on many factors: costs of producing the newborn animals, costs of investments, housing, feeding and care for the animals until slaughter. Important too are the choice of breed, type, feeding regime and age at slaughter which affects carcass quality and the quantity of meat produced. The complexity of these branches of animal husbandry is the greater when meat production is not the single purpose, but both milk and meat are being produced. This became clear in my country when in a long-term comparison of American Holstein-Friesians with Dutch Friesians the formers' higher milk yield was offset economically by their lower carcass quality.

Even when there is only one main purpose the complexity of the enterprise may be great, e.g. in the case of lamb production where the choice of the breeds of the sire and dam can considerably influence the number of offspring and the quantity and the quality of the meat produced. Multiple births, moreover, may lower the growth potential of some of the lambs (1).

The complexity is increased further by the difficulty of predicting by simple means available on the farm the genetic meat potential of the individual animal and the feeding regimes it needs for optimal feed conversion and the meat quality the consumer prefers. Even with advanced techniques available at research institutes such predictions are thought far from easy. Partly this is due to the lack of sufficient information on the basic aspects of growth and development. For another part the integration of available knowledge on the growing animal - its genetics, endocrinology and biochemistry, and on nutrition and meat technology is not ideal. Finally, consumer preferences are variable and it is often not clear what are the qualities desired in meat. Even if these preferences were made clearer, they would, in the rather traditional system of meat marketing, be transmitted only slowly to the farmer. Special preferences of consumers for meat from young animals sometimes also limit the full development of their growth potential.

In this paper an attempt will first be made to describe the essentials of the process of development of the animal body as far as it is important for meat production. Next, attention will be paid to nutrition, for feed costs play an important part in the economy of meat production. Finally, some remarks will be made on technology.

GROWTH AND DEVELOPMENT OF THE ANIMAL BODY

Protein and fat synthesis, live weight gain and preferred degree of carcass fat content.

Initially in the growing animal muscle synthesis is quantitatively most important; at a later stage synthesis of fat in the tissues may become predominant, especially at high feeding levels (2). Muscle synthesis results in considerable live weight gain as a great part of muscles consists of water. Fat is mostly laid down in the fat cells and there is a partial replacement of water by fat. In terms of energy deposition per kg weight gain, the difference between these two kinds of synthesis is remarkable. The synthesis in muscle of 0.21 g of protein containing 1.2 kcal (5 KJ) is usually accompanied by the retention of about 0.78 g water, resulting in a total weight gain of 1 g. A fat deposition of 1.4 g results in some 0.4 g water being replaced by fat in the growing animal, resulting again in a weight gain of 1 g and increasing body energy content by 13.3 kcal (56 kJ), 11 times as much as in the case of muscle. The data on weight gain are from a study (3,4) with veal calves in which live weight gain was regressed on protein and fat deposition, and from chemical analysis (5) of bulls weighing 150-580 kg; they do not apply to very young or full-grown animals.

It will be clear from this that in general it is not profitable to allow the animal to deposit more fat than is needed for obtaining the desired meat quality. To do so it would be important to have a good knowledge of the total quantities of protein and energy which have to be produced, so that rations can be fed which suit the requirements of the animal. Here problems arise. Non-carcass parts of the body have little value, but in ruminating animals may amount to 40 to 50% of their weight. The N content of these non-carcass parts is not very much below that of the whole body (5): their energy content also cannot be neglected; it increases with the fatness of the animal. Obviously this involves considerable amounts of protein and energy but information on the composition of non-carcass parts is scarce.

Information on the composition of the carcass is less scarce although most of it comes from dissection studies and specific gravity measurements rather than from direct determinations of fat, protein and energy content. The ideal carcass should have a high muscle content and a high ratio of muscle to bone. However, with regard to its fat content - from the point of view of animal nutrition a very important item - preferences in the various countries differ. In the continent of Europe leaner meat is preferred than in the United Kingdom and the USA; besides this there is a general tendency in the world toward leaner carcasses. Low fat contents make the meat less tender, especially unappreciated in older animals as tenderness of the muscles decreases with age. Thus, opinions differ, and are changing, on the desired composition of the carcass and information on preferred fat, protein and energy contents is far from abundant.

Measures to reduce maintenance costs

To improve the animal's gross feed efficiency the growth period should usually be as short as possible (less maintenance feed). With rising feeding level daily gain will be enhanced, so this might serve the purpose. However, since fat synthesis is far more susceptible to an increase in feeding level than protein synthesis, and in view of the optimal fat content of the carcass mentioned above, the improvement cannot be found by increase of feeding level. The improvement obviously should be found by using animals with a high genetic potential for muscle synthesis. I doubt whether extremely high energy levels or protein levels which are above protein requirements (provided that the energy supply is sufficient) enhance muscle synthesis. The first tends to produce over-fat animals; the impression of a beneficial effect on muscle synthesis may be due to the fact that increased fat deposition in the muscles has been taken for protein synthesis.
The second measure may only be effective if during parts of the day shortages of limiting amino acids at the cell level may be prevented.

Protein synthesis can also be increased by using anabolic agents. With veal calves Berende et al.(6) and van Weerden et al. (7) showed that considerable improvement of live weight gain and N deposition could be obtained by anabolic agents. However, the time of slaughter should not be too remote from the time of treatment, otherwise net gain is small. My own measurements (8) on their calves showed that there was no fall in the efficiency of utilisation of the energy of the feed. Treatment too early resulted in a temporary weight increase followed by a decrease of similar magnitude. Moreover, from their figures it appears that the increase was greater when the treatment was applied to older calves, i.e. when they are in a stage in which protein synthesis makes up a decreasing part of total synthesis. Also in view of the greater effect of diethylstilboestrol on the growth of steers than of bulls (6) it may be postulated that the effect of anabolic compounds is a temporary speeding up of protein synthesis which is especially effective when the body's own production of anabolic hormones is low. Because of the possible presence of undesired residues of anabolic substances or their degradation products in the meat it seems better to use dehorned bulls rather than steers for beef production; this also leads to rapid growth and low maintenance costs. However, in view of the world food shortage the advantages and the disadvantages of the use of anabolic agents in animal husbandry should be very carefully weighed. Human health organizations tend to reject this use, often more for psychological reasons than because of scientific evidence. FAO and WHO intend to organize a conference on this topic; agreement on such subjects, of course, should be reached at the international level.

Methods of selection at an early age

Within-breed variation of genetic potential for muscle synthesis is considerable even within single-purpose beef breeds as shown by Geay et al (9). The variation is also great in the case of dual purpose breeds for which selection for meat production is of secondary importance. For such animals it would be very useful if at an early age they could be divided in groups with higher and lower muscle growth potentials. This would facilitate appropriate feeding measures, e.g. allowing continuous ad lib. feeding to the former group and restricted feeding - especially near slaughter time - of the other group, resulting in animals which are not too fat. For single purpose beef breeds also the possibility of distinguishing promising animals at an early age would greatly help selection.

The cause of the higher daily rate of lean deposition is not quite clear. Lister et al. (10) use McCance and Widdowson's (1) metabolic clock theory and believe that the lean mass in animals with a higher mature weight has to be synthesized in about the same time period as the smaller lean mass of animals with a smaller mature size. Bergström (11) is of the opinion that the time in years needed to reach maturity in cattle is equal to the mature weight raised to the 0.3 power. This also makes it necessary for the animal which has a higher mature weight to have a higher absolute and relative daily synthesis of lean mass although not to such a degree as according to the other theory. Bergström, however, also mentions between-breed and within-breed differences in muscle to bone ratios.

It seems not illogical to assume that mature bone size determines mature age rather than mature lean mass. Regardless of which of these theories is correct it would be useful to predict the animal's genetic potential for muscle synthesis at an early age. One wonders if it would be sufficient for this purpose to follow the weight increase and feed intake of the animals over a given age or weight interval while on a ration not too low in protein (to exclude compensatory growth). Poor feed conversion figures would point to a higher proportion of fat being synthesized. The preference for group feeding, probably, would interfere with this method of testing. Enzyme (12,2) or hormone assays of biopsy samples of fatty tissues or blood might give information on fat synthesis. Protein turnover studies might give more direct information on the genetic potential for protein synthesis but these techniques are very difficult to perform with large animals (13) even at a research institute. Similar studies on muscle biopsies could be considered. The observation of Jentsch et al (14) that high propionic acid levels in the rumen of beef cattle are correlated with higher levels of protein synthesis is interesting. This could be an indication of the importance of gluconeogenesis in ruminating cattle for protein synthesis so that assay of the enzymes involved might be useful. However, the high rate of gluconeogenesis might also be due to the high level of fat synthesis. This possible effect of propionic acid on protein synthesis might be related to a similar positive effect of fatty acids with a medium chain length in veal calves and pigs, a theme of research in France.

Lister et al. (10) suggested that the increasing leanness of pigs, with only a small variation in mature weight, might be due to selection for low fat synthesis rather than for high protein synthesis. In cattle with a high mature weight the high level of protein synthesis would automatically mean a low level of fat synthesis unless protein synthesis would stimulate feed intake or would lower maintenance needs. High intake and low physical activity, however, are usually found in animals which tend to fatness.

ENERGY REQUIREMENTS

Due to the uniform and highly digestible rations of veal calves energy requirements for these animals can be simply expressed in metabolisable energy (M_E) measured with nonruminating calves (3,4). The animals need abount 110 kcal M_E (460 kJ) per unit of metabolic weight ($kg^{\frac{3}{4}}$) for maintenance and nearly 70% of the M_E

present above the amount needed for maintenance is converted into energy in fat and protein. The amount of energy lost as methane in these animals is very small and can be neglected; urinary energy losses increase with age from 2 to 5% of the gross energy. Thus, it is clear that digestibility is the main determinant of the M_E-content of the feed. Lower digestibilities are usually met when the expensive milk proteins are replaced by plant proteins; the presence of partly or completely undigested plant proteins in the gut appears to reduce growth rate still more. Exchange of milk lactose by cheaper starch products is possible only to a limited extent, especially in young calves (15).

Protein turnover rate is thought to play an important part with regard to the feed energy required for protein deposition in young calves. Biochemically, linking the amino acids to make a protein molecule requires little energy. Measurements with growing animals suggest a considerably higher energy requirement (16). Hoffmann et al. (17) (quoted by Kielanowski (18)), and Kielanowski (18), are of the opinion that all kinds of protein synthesis require large amounts of energy. From my own balance data (16) on milk and egg protein production I derived a lower energy requirement per gram of protein synthesized. This might be due to the fact that the body tissues of the mature animals involved had a low rate of protein turnover. In the rapidly growing animal this rate is thought to be higher (19), resulting in a greater energy requirement per g net production of protein. The discrepancy between these views is due to the limited amount of experimental information, to difficulties of interpretation because of the lack of precision of estimates of the maintenance needs of growing animals, and to the minor contribution of protein to total energy deposition.

A model was made of the relation between live weight, feed intake and feed composition and growth rate which for Dutch Friesian bull-calves approximately fits the experimental data (3,4).

Energy utilisation in ruminating beef cattle is considerably more complicated due to the fermentation in the forestomachs, the higher slaughterweight and the variety of feeding stuffs which may be used. Recent investigations by Jentsch et al. (14) have shown that information on the M_E content of feeding stuffs used in rations for beef production can easily be derived from data on their digestibility when fed to sheep near the maintenance feeding level. On average, the feeding level of beef cattle seldom exceeds twice maintenance; at this level there is a small depression of digestibility which, however, is nearly compensated by lower energy losses in methane and urine.

The effect of ration composition, especially the ratio of M_E

to gross energy, on the utilisation of M_E for maintenance and for production is of considerable importance. Thus, for a correct energetic evaluation of the ration, the ratio of maintenance to production metabolism should be known (20). This means that the same ration or feedstuff may have different net energy values for high compared to low daily gains. Obviously, net energy varies with the animal production level (21). However, according to a proposal to account for it presented by Alderman (22), and slightly modified by me, the differences are not very great: at daily liveweight gains of 0.75 (moderate) and 1.25 kg (high) the computed net energy contents for barley, hay with 20, and hay with 40% crude fibre in dry matter are 2109 and 2037, 1521 and 1408, 867 and 753 cal/g dry matter, respectively or, relative to the barley values, 100 and 100, 72 and 69, 41 and 37. In view of this, instead of working with the whole range of net energy contents (= feeding values), calculated by computer for each production level, it seems sufficient, while accepting a slight inaccuracy, to work with only two feeding values, one for high and one for moderate production levels. It should be clear that in that case the requirements should be expressed in the appropriate feeding values.

PROTEIN REQUIREMENTS

Experiments (3,23) have shown that in veal calves the protein content of the diet may be reduced with increasing liveweight. Homb (24) found a similar effect in pigs. It is explained by the fact that with advancing body weight, protein deposition becomes less important relative to total metabolism. In practice use is made of this principle either by a steady increase of a component in the diet which is low in protein or by changing to a diet with less protein after some weeks. Another method is to use the same ration throughout the whole growth period but with a protein content which is somewhat low relative to the animal's needs in the first weeks and rather high during the final period.

In this case obviously use is made of compensatory growth.

Protein or N standards for (ruminating) beef cattle used in practice appear to be rather high. Both Jentsch et al. (14) and Schulz et al. (5) derived lower N requirements in their countries. De Boer (25) came to a similar conclusion from results of feeding trials performed over several years with Friesian and Meuse-Rhine-Yssel bulls fed primarily on beet pulp and 1 kg hay daily. He considered 7 g protein (N x 6.25) per unit of metabolic weight to be about the minimum amount required by these bulls in the weight range of 250-500 kg for a satisfactory daily gain.

The discrepancy between these research results and the recommended standards can be only partly explained by the necessary safety margins included in the latter figures. It is true that the former are from experiments with dual purpose breeds so that for breeds with higher potentials for muscle synthesis the minimum requirements may be higher. For ruminant animals the composition of the N-free components of the ration is, of course, important for the availability of N.

TECHNOLOGY

In view of the world food situation and the high prices of those feedstuffs which are suitable for monogastrics, forages and concentrates with higher levels of cellulose seem most suited for ruminant feeding, including beef production. However, the intake of bulky feeds with high lignin contents, given as single feeds, is often too low to raise the production level enough to make beef production economically attractive. Obviously, feeds of higher nutritive value should be given along with such forages. Feeds like fresh and artificially dried grass, corn silage and beet- and citrus-pulp suit the purpose very well.

Berner (26) recently wrote excellent papers on the production of beef by bulls kept at pasture in the northern part of Germany. Due attention was given to the quality of the grass as related to its digestibility and intake when the pasture was used permanently or in a rotation system in the various months of the year. In the rotation system digestibilities of organic matter ingested change only slightly from April to October (from 80 to 75%, similar to values found by me (27) for Dutch grass fed ad lib. to lactating cows). Intake was estimated to be 1.8-2.0 kg dry matter per 100 kg body weight. In the permanent pasture considerable reductions were assumed to occur with regard to digestibility in the course of time, as this system involves older grass being eaten. This was thought to be accompanied also by some decrease of intake. The net energy intakes in April to August in the rotation system are sufficient to allow daily gains of about one kg; thereafter, and also on permanent pasture, they are lower. Additional feeding of appropriate quantities of a low protein concentrate (1-3.5 kg per head daily) in this and other such unfavourable situations is very beneficial as it restores the rate of growth to normal, allowing a weight gain during the pasture season of some 200 kg. Similar studies at the "Hoorn" institute by Weide are in progress with lambs to see if it is necessary, in Dutch circumstances and using the rotation system, to feed additional concentrates. An attempt is also being made, by total collection of faeces, to obtain some information on the replacement of grass by concentrates.

The use of pelleted artificially dried grass for beef production is favoured by the high intakes but hampered by their high prices when they have a high M_E- content. Grass or hay pellets with lower M_E-contents should be used together with some concentrates to assure a sufficient rate of weight gain. As is the case with the rations based on beet- or citrus-pulp some long forage should be fed or given as bedding to prevent digestive disturbances.

Corn silage has come increasingly into use in Europe thanks to the development of better corn varieties and of harvesting machines which chop to a length of about 6 mm; this favours the ensiling process. Very mature corn contains whole grain which cattle do not chew to a sufficient degree, resulting in lower digestibilities. Similar results have been found (28,29) when comparing whole grain with cornmeal in dairy cows. Sheep do chew the hard grains so that the digestibility data found with them for mature corn silage may be higher than for cattle. The development of equipment for tractors suited for taking from the silo some 500-100 kg quantities as a whole facilitates feeding and allows storage for a few days without heating.

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