FEED BY-PRODUCTS IN PIG NUTRITION

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SUMMARY

More and more pig husbandry moves to faster growth, to use of cheaper feeds, to housing in larger groups, to less care for the individual animal, etc. This led to a great number of questions on nutrition, most of a more basic character.

The higher feeding level and the higher content of fiber in the diet probably caused somewhat lower digestibilities than found sofar for the same feeds. It, moreover, influenced gut fill and hindgut fermentation, thus also dressing percentage, maintenance needs and the conversion of DE in NE. The available information is reviewed. It suggests that in fast growing pigs only some 10% or less of the NE results from hindgut fermentation and that the lower dressing percentage due to by-product diets is nearly only due to higher gut fill. Moreover such diets cause a higher maintenance requirement and a lower efficiency of the conversion of ME into NE. All these aspects should be considered when new systems of energy evaluation of feeds for pigs are to be introduced.

INTRODUCTION

In the past 5 years a considerable increase in the number of studies on energy metabolism of pigs can be noticed. This was clearly stimulated by several well-known changes in pig husbandry. Because of consumers' preferences the farmer has to produce leaner meat, a development which fortunately goes along rather well with his necessity to reduce production costs in view of steadily rising feed, labour and housing costs. Lean pigs require less feed for each kg gain and to some extent can be fed ad libitum which reduces labour costs. Furthermore, the farmer prefers piglets and young pigs which grow rapidly and sows which produce many weaned piglets per year to reduce feed and other costs of maintenance and rearing. He likes to feed those animals cheap feeds and so shows more interest in" by-products and wishes to know their nutritive value. Use of such feeds may be of advantage for the world's food supply (van Es 1981; Cunha 1982) as well as for preventing environmental pollution by these- by-products. High fossil energy prices are the reason why there is a renewed interest in housing systems without additional heating and therefore knowledge on the lower limit of the zone of thermoneutrality of pigs under practical conditions is asked for. Pigs, moreover are kept together in greater numbers per enterprise with increased risk of subclinical and clinical disease. Still, little is known on the energy utilisation of pigs which are subclinically ill. Information on the effect of antibiotics and other additives on energy metabolism, be it positive, negative or absent, is also lacking.

Clearly there are a great number of questions to be answered and the answers should apply to present and future pig husbandry where rapidly growing lean pigs, fed with cheap feeds, kept in great number per enterprise and looked after with as little labour as possible will be used. The investigations needed to present answers to these questions are far

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from easy as also many factors of a more fundamental character are involved. For example, production of lean tissue has more secrets than production of fat. Cheap feeds usually have higher plant cell wall contents which can only be utilised by the pig via fermentation. High production levels might negatively affect digestion, increase maintenance and so lower ME utilisation. Animal behaviour in intensive systems may differ from that in extensive systems and this may affect energy metabolism. Moreover, climatic conditions are involved also (Farrell 1979).

In next sections some aspects of energy metabolism will be considered and special attention will be given to the above mentioned questions of modern pig husbandry. In general it is assumed that the pigs receive neither too low nor excessive quantities of protein, vitamins and minerals, and that they are kept within the zone of thermoneutrality.

DIGESTION

High feed intake may make the digestion process less efficient as it increases rate of passage. It probably will not affect the digestibility of nutrients digested in the small intestine because of its long length although clear evidence of this is still lacking. However, for the feed constituents which are digested by fermentation; mainly in the hindgut, it may be different because fermentation needs time. As feeds with higher contents of cell wall are well known, also from studies in humans, to stimulate rate of passage (Fioramonti and Bueno 1980), it will be clear that the combination of high feeding level and higher cell wall content of the ration might result in a lower degree of digestion by fermentation in the hindgut.

Both at Braunschweig (Böhme et al. 1982), Copenhagen (Just et al. 1982) and Lelystad (van der Honing et al. 1982) result; of digestion trials suggest that the digestibilities of feeds determined recently are often below those found in (most) feeding tables and produced 10 or more years ago. The reason for this is not quite clear. A lower feeding level used in digestion trials in the past might be an explanation, especially for fibrous feeds. Another reason might be that in the past in digestion trials batches of excellent quality of feeds were mostly used. At present, batches of average market quality are prefered. Besides this by-products might have obtained a lower nutritive value in the course of time as food technology succeeds in extracting the better constituents more completely.

Another reason might be changes in the techniques used in the digestion trial. The higher feeding level used at present has already been mentioned. In most digestion trials in the past pigs were used equipped with harness to keep faeces collection bags in position. Applying harnesses and often also weighing the animal might have been done immediately before the start of a digestion trial with as a result considerable defaecation. During the trial the animal was usually given little possibility to move which is well known to slow down rate of defaecation. Especially for trials with a short collection period (< 5 days) such a procedure would result in high digestibilities. Also, not-too young pigs were used whose digestion by fermentation at moderate or low intake level might once more have resulted in high digestibilities (Wenk 1981).

A renewed effort of determing digestibilities of present feedstuffs with pigs of 20-100 kg at high feeding level can be recommended. In such studies the energy content of feed and faeces should be measured rather than predicted from proximate analysis. The energy determination (bomb-calorimetry) is highly reliable and prevents the introduction of systematic errors from incomplete fat analysis of proximate analysis.

FERMENTATION

As fermentation in the hindgut results in volatile fatty acids, lactic acid, CH_4, maybe some H_2, heat and CO_2, it cannot be expected that one gram of hemicelluloses and celluloses which is fermented and apparently digested, will have the same energy value for the pigs as one gram of starch digested in the small intestine (ARC 1981, p.41-44). Due to the formation during fermentation of combustible gases and fermentation heat an energy loss of 10-20% is to be expected, moreover volatile fatty acids give for instance per kJ 10-20% less ATP than starch. A rough estimate is that fermented carbohydrate energy has about 60% of the energy value of starch energy digested in the small intestine. Evidence for a low utilisation was presented by Just et al. (1983) and by Müller and Kirchgessner (1982).

As to the extent of fermentation Müller and Kirchgessner (1982) clearly show that lignified cellwall resists fermentation considerably more than e.g. pure cellulose. Many by-products contain cellwalls which are lignified. It should be noticed, also in view of what was said in the digestion section, that in their study feeding level was low and older animals were used. In the work of Just et al. feeding level was hiaher, but still below the level used in practice and in the studies of van der Honing et al. (1982) and Böhme et al. (1982).

Like in nearly all their work Just and co-workers wish to attain the same growth rate for all treatment groups, a very useful condition for their comparative slaughter technique because as a result maintenance costs will be approximately equal. Thus, growth rate of the pigs with the lowest quality of feed dictates the degree of feed restriction to be used for the better rations. Practice will not use rations of such a low quality, but use low quality feeds fortified with high quality ones, among the latter often some fat. That is the reason why in the studies of van der Honing et al. (1982) and of Böhme et al. (1982) lower percentages of low quality-s are included and in the former also fat with the aim to achieve a high energy intake. Under such conditions there is less possibility for fermentation than in those of Just et al.'s work.

Müller and Kirchgessner (1982) showed that the amount of methane energy produced from fermented carbohydrates was not far from what is found in ruminants, some 10% of the fermented energv. So CH_4 production level might be used as a rough estimate of the extent of fermentation in the pig, because only little H_2 can be expected from a CH_4 producing fermentation (Bryant 1979). In most work with pigs at moderate to hiah feeding levels CH_4 energy losses are below 1.0%of DE and these losses-are only slightly greater in the case of rations with higher levels of by-products fed at a high level (van der Honing et al. 1982), most probably a consequence of their increased rate of passage. Thus, assuming the energy of CH_4 to be 10% of the fermented energy, not more than 10% of the DE will be absorbed from the gut via fermentation. Imoto et al. (1978) and Kass et al. (1980) arrived from rates of VFA production of contents of the intestines at 5% or less. Estimates from work with T-shaped or reentrant cannulae in the terminal ileum are also often below 10% but a few high figures, near 30%, are mentioned (Kennelly et al 1981; Alimon and Farrell 1980; Just et al 1982). It is not easy to estimate the reliability of the data from studies with cannulated pigs in view of very finely grinding of the diet, low feeding levels and short collection periods.

Assuming that under practical conditions 15% of the DE is due to fermentation, this would mean that in view of the 40% lower net energy value of such DE, by far the major part of the net energy, 90% or more, would result from energy digested in the small intestine with the pig's own digestive enzymes. Thus, clearly . the value as an energy feed for-rapidly growing pigs is for many by-products for the major part due to their content of nutrients which can be digested in the small intestine and not to their cellwallcarbohydrates. At lower feeding level and with rations with higher contents of not too heavily lignified fiber, e.q. in non-lactating mature sows and mature breeding boars, the amount of nutrients absorbed from by-products via fermentation might be somewhat hiaher.

EFFECTS OF BY-PRODUCTS ON GUT WEIGHT AND ON DRESSING PERCENTAGE

Feeds which stimulate fermentation in the hindqut usually influence the pig's body weight and dressingpercentage. Three-different effects can be distinguished in this respect. Because most of these feeds have a higher fiber content they have a lower nutritive value, so that more dry matter has to be fed for the same DE intake, which increases the weight of the content of the gastrointestinal tract. Moreover, fibrous feeds tend to raise the water content of the digesta in the hindgut which also increases gut weight. A second effect may be an increase of the empty weight of the gastrointestinal tract, especially of the large intestine. Finally, other parts of the animal may increase in size among others because of growth of tissues supporting the heavier gastrointestinal tract.

Together, these effects result in a decrease of the dressing percentage of the pig. For as far as this is due to the first effect this is not serious since it is compensated by the higher total body weight. For the second and the major part of the third effect the negative influence on dressing percentage is areal loss as the higher body weight caused by these has hardly any market value, so most of it qoes to offal. The nutrients needed for their synthesis could have been used instead for the synthesis of saleable tissues of the carcass.

The heavier body weight due to such feeds will increase the animal's maintenance requirements which for growinq pigs consist of 40-50% of their total requirements. It applies to all the-days of the growth period. One kg gut contents may require less maintenance energy than one kg tissue, but certainly some energy. The body weight increases due to empty weight of the tract and supporting tissues will require per kg about the same amount of energy for maintenance as other tissue.

It is clear that those negative side effects on dressing percentage and on maintenance costs due to using feeds which stimulate fermentation have to be given due attention. Just (1975, 1982) repeatedly stressed their importance. For a good understandina reliable data on the effect of kind of diet on weight of gut contents, empty gut weight and dressing percentage and on increased maintenance costs are needed. Unfortunately, this information is far from abundant and for the first aspects partially conflicting. Just and his group find at a slaughter weight of 90 kg an increase in gut fill of about 0.5 kg for each percent increase of crude fiber in the dry matter of the ration. They state that the increase will be still greater when the last feed is given on the day of slaughtering instead of one day earlier (their own procedure). Moreover, they found hardly any influence of an increase of fiber content of the diet on the empty weight of the animal: the lower dressing percentage was mainly due to higher gut fill. Böhme et al. (1982 and personal information) found about the same increase of 0.5 kg per % fiber, however 15 min. after last feeding. Similarly fed pigs slaughtered some hours later had much smaller differences in stomach content, resulting in an increase of total gut content of only about 0.3 kg for each percent of fiber. Their pigs had after the last feed no access to water. The effect on the empty weight of the tract seemed negligible. Also Pond et al. (1980) found hardly any increase for the weight of the empty tract for diets with 0 or 20% alfalfa meal fed ad lib. Kass et al. (1980) did find an increase in empty tract weight, but only of 1.2 kg when they fed rations with 60% alfalfa meal, also ad lib, i.e. about 0.06 kg for each percent of fiber. In these two studies no data on gut contents or dressing percentages are given.

Bohman et al. (1955), also working with ad lib fed diets containing 0-50% alfalfa, found between the extremes (% of crude fibre in dry matter differed 13 units) a difference of about 1.5 kg in empty tract weight, i.e. nearly 0.1 kg for each percent of fiber. However, dressing percentage decreased from 75 to 68, i.e. about 0.5% unit for each percent of fiber. Information on gut content is not given. Coey and Robinson (1954) used restricted feeding of rations with various amounts of ground oat-chaff and straw. Such amounts were fed that daily gains were nearly equal. They only present killing-out percentages, probably showing the same effects as dressing percentages, which decreased by about 0.5% unit for each percent of fiber.

From this we might conclude that empty tract weight probably is hardly influenced when fibercontents are not excessive. Thus for practical pig feeding we can assume that the lower dressing percentages of pigs fed by-product diets are due to higher gut fill. Clearly we have to be better informed on the size of this fill and especially its relationship to fiber.

Next we need better knowledge on increased maintenance due to higher gut fill which probably for each kg of fill is less than for a kg of tissue, say 0.5 times as much. In rations we would not use high percentages of feeds with much fiber, but for correct feed evaluation we have to evaluate the separate feeds. If we assume an effect of 0.5% unit for each percent of fiber on dressing percentage mainly consisting of gut fill, then a feed with 10% more fiber would result in 10 x 0.5 = 5% higher live weight and thus increase total feed costs of which 40% is used for maintenance by about 0.5 x 5 x 0.4 = 1%, which is not very alarming. However, for such a diet the DE might consist of, say, 5% more energy of fermentative origin having, as discussed above, a 40% lower NE. Thus this would decrease the diet's feeding value by 2%. Together the 1% higher maintenance costs and the 2% lower feeding value cannot be neglected. On the size of these figures clearly more information is needed urgently.

DE OR ME

In most of the more recent studies for mixed diets energy losses with methane and urine were small. This confirms earlier views that DE contents inform on the energy values of feeds equally well as ME contents (Farrell, 1979). Energy losses with urine are mainly due to urea and since practical rations have a fairly low and constant protein content urinary energy losses as a percentage of gross energy intake do not fluctuate much. The number of actually determined ME values of feeds is much smaller than of determined DE values. Moreover, in many cases the ME value was partially calculated, only gross, feacal and urinary energies were measured and methane losses estimated or neglected. Both aspects should be considered before making a choice between the two values.

While converting DE values of separate feedingstuffs into ME values by calculation there is another problem. Usually such DE values come from digestibility trials in which N retention is moderate or even small, e.g. because older pigs low feeding levels or high protein contents have been used. Thus, urinary energy losses are high. In practice higher N retentions in growing pigs are obtained, moreover high protein contents of the rations are not used. On average after 50% of the N of the digestible crude protein will be retained. So it seems appropriate to correct for the high urinary energy losses found in the digestibility trials when data on the ME content of the feeds are to be obtained for use in practical circumstances. The approach of Just (1982) of adding or substracting 4.9 kJ per g of catabolized protein in the digestion trial in excess of 50% of the digestible crude protein to the ME found seems very useful. It is clear that the figure of 50% should be changes somewhat when on average N retentions in practice are at a higher or lower level.

MAINTENANCE NEEDS AND ME UTILISATION FOR PROTEIN AND FAT ACCRETION IN THE GROWING PIE

Thorbek et al. (1982) comparing data of growing pigs when fasting and when kept-energy equilibrian once more clearly showed that pigs reduce their energy metabolism during fasting (see also ARC (1981) p.13). It is generally assumed that fasting animals do so by lowering their activity and their rate of protein turnover (ARC 1981: p.18; Reeds et al. 1980). Nevertheless, still in theory correct ME needs at energy equilibrium, i.e. for maintenance, could be derived from fasting data if k_m values were used to convert fasting heat production into ME needed for maintenance (ME_m), which include a correction for the effect of lower metabolism during fasting. This approach is followed a.o. by the ARC working group on energy metabolism of ruminants (ARC 1980). Graham (1982) presents evidence that changes in an animal's energy metabolism have a slow and persistant character. Obviously it takes time for metabolism to change to a new level and therefore measuring suitable k_m values for converting fasting heat production in ME requires much time and care. The direct determination of ME_m, i.e. in experiments near energy equilibrium, clearly is the better choice.

However following Graham's line of thought for the growing animal also the maintenance feeding level might induce a more economical energy metabolism as in view of its endocrinological state it can be considered underfed at this feeding level. Webster et al. (1982) did not find evidence for such an effect. Probably the change from a high to a low level of energy deposition is far less drastic for intermediary metabolism than a change from energy deposition to energy mobilisation.

Thorbek et al. (1982) derived that in their non-fastino animals ME_m was not related metabolic weight, but to a linear function of metabolic weight: $a + bW^{\frac{3}{4}}$, giving a decreasing value of ME_m per unit of metabolic weight with higher bodyweight. They consider the decrease to be due to the diminishing percentage of organs and tissues with high energy metabolism (e.g. liver, heart, kidney) in the animal body as a whole with advancing age. One may wonder if this was not partially also due to changes in activity of the pigs with age. Verstegen et al. (1982) clearly showed that physical activity is responsible-for a far from negligible part of heat production. At the 8th Energy Symposium Halter et-al. (1980) and Vogt et al. (1980) gave similar evidence. Verstegen et al's work dealt with group-kept individually-fed pigs. Although it is clear that group-kept animals are more active than animals kept single on metabolism cages, even in such a cage physical activity cannot be neglected. Usually, activity decreases with age, although this is not so clear in Verstegen et al's study. The space allowed in the metabolism cage may influence the

the pig's activity,, in some institutes space is provided in relation to the animal's weight, in other institutes (a.o. that of Thorbek) the space is not changed so that the young pig has more possibility for activity than the older pig. It is a pity that a good interpretation of the ME_m values of Thorbek et al. 1982) is not very well possible because of lack of information on physical activity.

Roux et al. (1982) clearly demonstrated that also the often used regression model $ME = a\ RE_p + b\ RE_f + c\ W^p$ in which RE_p and RE_f are energy retained as protein and as fat, respectively, or modifications for energy studies with growing animals does not provide very reliable data on maintenance needs nor on efficiencies of protein and fat deposition, especially in full-fed animals. The main reason for it is the correlations between the independent variables and the model's oversimplification as mentioned earlier by Pullar and Webster (1977) and van Es (1980). Working with at least two feeding levels and measuring physical activity would help and can be certainly recommended for all such studies with growing animals. Another improvement would be made if a simple method were available to measure the animal's rate of protein turnover as this probably is also partly responsible for the high value of a in the above model.

The lack of a correct model of energy metabolism during growth is the reason why comparisons of the energy values of rations cannot easily be made. The only safe solution at present is to avoid most of the pitfalls of partitioning between maintenance, protein and fat deposition in the following way. Rations of different make-up are fed to the same or comparable animals and body weight and daily gains are kept equal among treatments. Thus, there is little need for a very precise partitioning of the ME as body weights and daily protein and fat depositions differ only slightly. In that case differences in energy retention at similar ME intake reflect the ration's energy value and the simple model $RE/W^{\frac{3}{4}} = a\ ME/W^{\frac{3}{4}} + b$ can be used to correct for small differences in body weight and ME intake without introducing errors. This approach is chosen by van der Honing et al. (1982), Böhme et al. (1982) and Just et al. (1982) although there are some differences. In the former two studies the balance technique is used and especially in the first high levels of protein deposition is aimed at for all treatments by using boars. In the latter study the comparative slaughter technique is used which has the advantage that the influence of the ration on dressing percentage, empty gut weight and gut fill can be measured. In this study daily gains are moderate because, as said earlier, rate of daily gain is dictated by the ration of the lowest quality.

When using the actual live weights in the three studies the residual standard deviation of the model $RE/W^{\frac{3}{4}} = a\ ME/W^{\frac{3}{4}} + b\ ME/GE + c$ is not or hardly lowered by the introduction of the second independent variable ME/GE, the metabolizability of the ration. For a given value of $ME/W^{\frac{3}{4}}$ about the same value of $RE/W^{\frac{3}{4}}$ is found. This is probably the result of two factors which compensate each other's effects: 1) a lower ME_m per metabolic weight of pigs with higher gutfill (less active tissue), and 2) a lower efficiency of utilisation of DE of fermentative origin in the same pigs. However, due to their effect on fill diets with more fiber increase gut fi 11 and therefore live weight and thus maintenance costs- Such diets clearly have to be punished for causing these higher costs. Experiments are in progress at my institute in which rapidly growing pigs are fed different types of diets for periods of three weeks to study the diet's effect on actual live weight to see how much the diets should be punished.

Just and colleagues (1982, 1983), using the comparative slaughter trial technique, approached the problem in a different way. While-on the same normal diet the pigs of 20 kg are divided over the various treatment groups, so at the start of the trial there are no diet-induced gut fill differences. The animal's of one group are slaughtered and the energy content of the piglets is determined after removal of the content of the gut by washing with water. Immediately afterwards the groups receive different diets in such amounts that they grow equally fast. In the middle of the growing period their total live weight is measured a few times. The animals remain on the same diet and are slaughtered when reaching a weight of 90 kg. Carcass weight is determined precisely, moreover the energy content of the pigs is determined, again after removal of the content of the gut.

During the trial it is determined precisely how much feed has been ingested, moreover in usually three digestion and N-balance trials energy losses with faeces and urine are measured. From these data the ME intake is calculated, while neglecting methane losses. The net energy produced is calculated by subtracting the energy in the animal at the start from that at the end. To this maintenance net energy is added equal to: 0.326 x (average metabolic weight) x (number of days of trial) MJ. The constant 0.326 was derived from trials in which average rations were used giving a slaughter loss of 25%. The average weight is calculated in a special" way: (weight at start + middle weight + carcass weight at slaughter x $\frac{100}{75}$) x $\frac{1}{3}$, the result is brought to 3/4 power to obtain average metabolic weight. Thus the first weight applies to one with average slaughter loss, and the third is forced to do so. Just (personal communication) would prefer also to remove weight variation due to gut fill variation resulting from diet composition from the middle weight data but has no good means to do so correctly. The influence of not removing it is not large as the middle weight is only 1/3 of the sum of the three weights.

The important feature of calculating average weight is that in this way most of the variation in maintenance costs due to gut fill above or below the amount found for a normal ration giving 25% slaughter loss, is excluded. Thus for low quality diets giving a higher gut fill, a higher live weight and probably higher maintenance costs only so much maintenance-NE is considered as a normal ration would require. As a results all higher maintenance costs are not taken into account in the NE calculation, thus a lower efficiency of the utilisation of the ingested ME for (standardized) maintenance and production is found.

The content of NE calculated in this way, of the dietary dry matter was found to be highly correlated to the ME content of the dry matter: ME (MJ/kg DM) = 0.8 ME (MJ/kg DM) -2.0. Clearly both the greater gut fill and the higher percentage of DE of fermentative origin were the cause of the lower NE content of diets with a lower energy density.

It is hoped that the corrections for fill of the energy balance results mentioned above will lead to similar results as those of the slaughter technique. None of the two techniques is simple or free of error. The comparative slaughter trial requires an accurate determination of the ME intake over the whole, rather long growth period, furthermore analysis of tne slaughtered pigs should be done very carefully. The energy balance trial lasts shorter and has the disadvantages that all errors accumulate in the energy retention and that living conditions are less close to those in practice, moreover slaughter loss and gut fill are usually not determined. Therefore it would be somewhat risky to derive a possible new system of energetic evaluation of feedstuffs from the results of only one of the two.

The value of *a* in the regression equation was lower in the study of van der Honing et al. with rapidly growing boars than in that of Böhme et al. with castrates and females, most likely caused by the high rate of protein deposition.

CONCLUSIONS

There is urgent need for new digestibility data on feeds, especially by-products, when fed at high levels to growing pigs of 30 - 90 kg.

Furthermore, better information is needed on the effect of diet on gut fill, hindgut fermentation, maintenance costs, ME utilisation and dressing percentage. In evaluating the energy values of feeds all these aspects should be taken into account.

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