THE IMPORTANCE OF OPTIMAL FERMENTATION IN DAIRY COW NUTRITION

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SUMMARY

The role of farm animals as producers of food for man is discussed. Maximum food production will be obtained only by an optimal combination of plant and animal husbandry. The ruminant is clearly the less competitive food producer among our farm animals, especially when it uses by-products from the food industry and forage from land not well suited. for plant husbandry.

The efficiency of an animal as a food producer depends largely on its DE intake and production potential. In the ruminant intakes-may be low by various reasons, of which especially suboptimal forestomach fermentation is discussed. This is illustrated with results of intake studies with high-yielding dairy cows in the Netherlands.

Optimal forestomach fermentation is not only important for intake but also for digestibility of the rations and their energy and N value. It is concluded that together ingestibility and digestibility inform on a feed's nutritive value for a ruminant to a very great extent.

Finally, methods for prediction of intake and digestibility are discussed.

INTRODUCTION

Man's need for food is steadily rising due to the increase in population. In many regions of the world production of food, from plant and animal origin, can hardly or in certain parts of the year notatall keep up with the demand. Import of food is often not possible or only to a small scale in view of the high transport and distribution costs. Thus there is a great need for improvement of the efficiency of production of food for mankind in the countries concerned. Greatest improvement in food production will not only be reached by improvement of existing plant and animal husbandry. Also changes from animal to plant husbandry or from non-ruminant to ruminant husbandry or vice versa might increase the country's total food production (van Es 1979).

A considerable part of plant husbandry is not edibleornot palatable enough for man, a monogastric with distinct food preferences. Therefore this type of food production leaves many by-products and residues which man does not like to eat. In many parts of the world, especially in the tropics and subtropics much of the natural vegetation is not suited as food for man because of its high content of plant cellwalls, mainly consisting of cellulose, hemicellulose, lignin, etc. Man dislikes such food and does not possess the necessary enzymes to digest it. Fortunately, most farm animals are less particular in their food choice than man. Moreover the herbivores among them are able, by means of their symbiosis with microbes, to utilize also the cellulose and hemicellulose of by-products and residues and of natural vegetation, often to a considerable extent (Cunha 1982; van Es 19751981).

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Land suited for plant husbandry usually produces per hectare more edible food for man when used for production of food crops like maize, wheat, rice, potatoes, soybeans, etc. than when used for animal husbandry. Thus in general highest food production for man would be obtained by such a combination of plant and animal husbandry in which plant husbandry uses the better land and animal husbandry uses both the remaining land and most of the by-products and residues of plant husbandry and-food industry. In this respect within animal husbandry preference would be given to ruminant husbandry since monogastric farm animals compete far more for food with man than ruminants. However, it should not be forgotten that poultry and especially pigs will eat much food which man does not or no longer like because of somewhat high cellwall content, bad smell or appearance. The use of offal from meat- and fish-industry for this purpose is well-known, in Norway even salmons are fed with it with success. Moreover, kitchen offal has been used for centuries for these monogastrics.

In practice changes, aiming at higher food production, from animal to plant husbandry or from non-ruminant to ruminant husbandry are far from easy to achieve. For the farmer it usually means that he needs other equipment and, what is more difficult, other knowledge. So rapid changes cannot be expected at all. Moderate to slow changes might be made when there is an economic profit for the fanner without a greatly increased risk and when a well-informed extension service assists him. Aiming at such clearly should be seen as a long-term policy. In the meantime, as a short-term policy, a first aim should be to improve the efficiency for food production of the existing plant and animal husbandries and a second aim should be maximal use in animal husbandry of by-products and residues from plant husbandry and food industry. Moreover, in animal husbandry, where profitable, feeds to be used might be treated technologically to improve their intake and nutritive value when fed to animals.

In the next sections it will be discussed how in animal husbandry such improvements of food production can be made. Special attention will be paid to the ruminant and to the limits of desired changes caused by the physiology of the animal.

THE ANIMAL AS A PRODUCER OF FOOD FOR MAN

Production level

The high maintenance needs of homeotherm animals -for energy 40% of all feed in a rapidly growing pig, 50% in a cow of 550 kg producing 12 kg of milk with 4% fat- is the reason why high production levels have to be aimed at. At a low production level high feed to product ratios are obtained. Thus, at first sight, animals with a genetic high production potential are to be preferred. However, this conclusion is in many cases not correct. Often the available feed is of low quality or so scarce, that nutrient intake permits only a production which is far below the genetic potentiai. Genetically less productive animals in such circumstances will do equally weil or maybe even better when, because of their long stay in that region, better adapted than more recently introduced genetically more productive ones.

Unequal ciistribution or availability of feed over the year is another negative factor for animal production. Under many circumstances preservation of feed over long periods and especially of young highiy digestible plant material is only possibie with great effort. Relying too much on the animal's possibi 1 i ty to use its reserves when feed intake is low is risky. Moreover, in periods of undernutrition the animal will reduce *or* stop production, whereas use of nutrients from the feed after temporary storage as body reserves is for maintenance and production at least 15% less efficient from a point of view of energy value (ARC 1980, p. 95) than direct use. When feed supply is low over the whole year or over longer parts of it it should be considered if the number of farm animals should not be reduced. During periods of undernutrition maintenance needs are only slightly lowered: the same quantity of feed used for a smaller number of animals would diminish undernutrition and might lead to higher production of the remaining animals. Intelligent use of the amounts of high-quality feeds if these are in limited supply, is of course a must for efficient animal production (Jackson 1981).

HIGH FEED INTAKE

Feed intake regulation in ruminants is far more complicated than in monogastrics (Baile and Della-Fera 1981). In most cases both in the tropics and subtropics except when heat loads are high and in the temperate zones voluntary intake of healthy animals depends primarily on energy needs of the animal and on fermentation in its forestomachs. High rates of live weight gain and of milk yield influence intake positively, provided conditions in the forestomachs permit so (ARC 1980; Counotte 1981). When production is slowed down by protein or mineral deficiencies, intake will be reduced too. Al kaii treatment of straw miaht improve intake and digestibility but not milk yield or rate of growth when the quantitv of absorbed amino acids is not sufficiently increased at the same time" (Ørskov 1981, 1982).

Due to the absence of oxygen microbes in the forestomachs can obtain only smail amounts of energy, as adenosinetriphosphate, from the feed, some 4-5 moles of ATP per mole of glucose resultinc from carbohydrate fermentation, half as much from proteins and hardly anything from fat and fatty acids (Tamminga 1981). Because of their greater accessability carbohydrates like sugars and most of the various starches and also soluble proteins are rapidly fermented. Often the rate is so rapid that absorption of the resulting volatile fatty acids (VFA) in the blood and neutralisation of these acids by the bicarbonate and other buffers of the saliva cannot prevent a fall in pH of the rumen fluid. It is not so that all starch ferments equally rapidly, potatoe and maize starch ferment less readily than wheat and barley starch. Nearly al l rumen microbes and especially those which can attack and utilize plant cellwall, the cellulolytic ones, show a slower growth and activity at lower pH. Most stop their activity at a pH of 5.5 (Counotte 1981; Ørskov 1981, 1982). A secondary effect of such initially high acid productions resuitina in lower pH is that in the course of time the ceiluiolytic microbes de&ease in number with the consequence that plant cellwall breakdown in stowed down. When that is the case, it takes a long time before long forage leaves the forestomachs because the reticulo-omasal orifice having a diameter of about 2 cm in cattle (Welch 1982) is a major obstruction for passage of large feed particles. As a result daily feed intake is reduced

Cellulolytic microbes usually attach themselves to the feed particles before startino their cellwall degradation. This takes some time, also they need some-easily fermentable materiai to do so. When the feed contains little of this, then the other microbes may consume all of it, which again slows down growth of cellulolytic microbes and therefore cellwall breakdown and intake.

There are a number of other causes why cellwall degradation and thus feed intake can be negatively affected (Demeyer 1981). Microbes need N for their growth, less than 1.5% N in the feed's dry matter results in reduced microbial activity. It is not so that below 1.5% N there is no microbial activity at all. Recycling of N from the blood and lower gut supply the forestomach microbes with some additional N but not enough for maximal rate of growth. Ammonia-N will do for most species, but for maximum growth some cellulolytic bacteria may use also soluble protein, peptides or free amino acids as an additional source of amino acids. Also, the levels of S and P in the feed should not be too low, as synthesis of a few of the amino acids from ammonia requires some S and P. The feed may contain sufficient total N, S and P but not enough of one or more of these in an available form. Tannins, present in several tropical and stibtropical feeds, can severely reduce the availability of protein- N for microbes. The opposite is also possible: the degradability of the N may be so high that when after a few hours cellwall fermentation starts most of the N is gone (diets with urea, low quality grass silage).

Czerkawski (1982) has shown that in the forestomachs the microbes can be supposed to live in three rather than in one compartment, i.e. free in the fluid, loosely connected with feed particles and well connected with feed particles. What is happening in each of these compartments can differ considerably, both with regard to the nutrient supply of the microbes and to the kind of microbial population. Preston (1982) gives clear examples for some tropical forages how complicated the symbiosis of the microbes among them and with the host is. Mertens and Ely (1982) tried to bring all essential effects together in a model.

From this it will be clear that for the ruminant both with regard to high intake and to high digestibility optimal rumen fermentation should be aimed at which also would improve the supply of B-vitamins. Anyway, N, S and P deficiencies should be avoided as well as pH's of the rumen fluid of 5.5 and below. Where possible, producing animals should have access to the feed at all times of the day when the quality of the feed is low and insufficient nutrient intake is the major cause of low production. Easily fermentable feeds should be fed mixed with forage or in more meals per day to prevent rapid pH changes due to too rapid intake. Attention should be paid to the pattern of feed ingestion during the day as long periods without voluntary feed intake may be a sign of suboptimal fermentation',

Nutrient intake will be still more negatively influenced when environmental temperatures and humidities are elevated. This is especially the case in producing animals whose own heat production -from maintenance and production- gives such a high heat load that their heat loss can hardly keep up with it. Intake reduction usually results in lower production with lowers this heat load. Moreover, in ruminants feeds with'a lower digestibility induce per unit of digested energy more heat. Such feeds with low digestibility are abundant in the tropics and subtropics because high environmental temperatures enhance the plant's ageing which results in slow and incomplete breakdown of forage in the forestomachs of ruminants (van Soest et al. 1978). The result is that from such feeds a ruminant will not ingest much and from each ingested quantity it will obtain only moderate amounts of nutrients and fairly large amounts of heat.

INCREASED'FEED INTAKE OF DAIRY COWS IN THE NETHERLANDS

In my country most dairy cows calve in January till March. They are kept indoors from October till May and are fed wilted grass silage nearly to appetite in addition 'to up to 14 kg concentrates according to milk yield. The concentrate mixtures hardly contain grain but are composed of some ten by-products from the own or foreign food industries. Home-grown concentrates are hardly used, nearly all concentrates come from cooperative and private feedmanufacturers. These do a few simple analyses on the batches of the various by-products, especially in those which show considerable variation, but all use the same feeding table (Centraal Veevoederbureau 1981) for composing their mixtures. This table is prepared by research, university and advisory service and regularly updated. It gives also some relations between the nutritive value and composition.

In May the cows go out to pasture, a 3-4 day rotation system is used mostly. Depending on animal production level available grass and weather conditions 1-5 kg of concentrates are fed daily.

With high yielding cows in their first half of lactation three types of studies were carried out in the last five years: 1) composition of concentrate mixture in relation to total intake of dry matter (stall period) 2) flat level feeding with ad lib forage vs. feeding to requirement (stall period) 3) voluntary grass intake as influenced by age of grass, quantity of grass offered and quantity of concentrates fed.

The first type of studies (de Visser, 1982) clearly showed that forestomach acidosis, off feed symptoms, etc. could be reduced markedly by lowering the content of easily fermentable components (mainly sugar and starch) in the concentrates without lowering their digestibility too much. Intakes of 15 kg concentrates per day of 600 kg cows fed wilted grass silage or cornsilage did not present difficulties. Ordinary concentrate mixtures can hardly be fed in quantities above 12 kg per day. Rumen fluid pH and lactic acid concentrations indicated a more optimal rumen fermentation.

Flat level feeding of ordinary concentrates (Rijpkema, 1981, 1982) hardly gave a lower production than feeding concentrates up to requirement, similar to results of Ostergaard (1979) and Doyle (1983). Probably, in the latter case the high concentrate amounts in early lactation influence rumen fermentation and digestibility negatively whereas in flat level feeding there is a loss of efficiency of feed utilisation due to more extensive fat mobilisation and lower peak yield. For optimal rumen functioning flat level feeding is clearly more appropriate.

Voluntary grass intake during 3-4 days grazing periods was the same at equal dry matter allowances of young and somewhat older grass. Young grass contains much easily fermentable material which despite the slow-intake might have made circumstances for fermentation less optimal than for the older grass. Still, intake of digestible organic matter and animal production were higher for the young grass (Meijs 1981). A higher grass allowance resulted in a greater dry matter intake, more grass left at the end of a grazing period and a more rapid regrowth. Probably, still enough grass was available on the 3rd or 4th day which was not so at the lower allowances. Feeding concentrates reduced grass intake to a greater extent at higher grass allowance, lower milk yield and higher concentrate level (Meijs, in press). Obviously, the greater the gap between energy needs and energy supply other than from herbage, the more grass will the cow try to eat. Higher concentrate. levels resulted in lower milkfat contents. Low rumen pH's (below 6) indeed were found. Obviously, despite the slow intake of the grass during grazing the combination of easily fermentable components in the grass and in the concentrates may lead to suboptimal fermentation. High milk yield may improve fermentation as it stimulates further grass intake.

MEANS TO IMPROVE INTAKE AND DIGESTIBILITY OF FEED BY RUMINANTS

Less digestible forages might be ground which decreases their digestibility, but increases their intake (van der Honing, 1975). Such procedures are expensive due to present fossile energy proces. Also the necessary equipment is costly. That in general is-also the problem with several other technological procedures like alkali-treatment etc. (Hartley 1981) which have a positive effect on digestibility and especially on intake. There are other problems with such procedures and treatments. Working with strong NaOH-solutions and with ammonia is not without danger for the labourers involved whereas animals fed NaOH-treated feed should have a regular supply of drinking water. Ammonia treatment, although not so effective as NaOH treatment, has the additional advantage of increasing the N content of the diet. However, for straw at least 1/3 of the NH_3-N is lost to the environment during the necessary aeration prior to feeding and it is questionable whether the remaining N has a protein value higher than that of NPN. In this connection the profit of using urea as a source of ammonia for livestock in this way should be compared to its use as fertiliser. Due to high costs of the alkali low concentrations are often used while treating forages. The resulting improvement of digestibility and intake is usually lower but long treatment periods may help. Low environmental temperatures work negatively, so does in the case of ammonia high water content as this absorbs most of it (Sundstøl et al. 1978, and personal information). Lime provides less health hazards but is less effective than NaOH or ammonia (Hartley 1981).

An interesting development is the use of feeds with not too easily degradable protein like fishmeal or a legume as a supplement to an alkali-treated low-quality forage (van Houtert 1981). This provides some easily available energy and often also some protein for the rumen microbes and; moreover, some digestible protein to the small intestine of the host animal, a welcome addition to the limited amounts of microbial protein.

PREDICTION OF THE NUTRITIVE VALUE OF FEEDS, ESPECIALLY OF THEIR INGESTIBILITY AND DIGESTIBILITY

Intake of digestible energy determines to a large extent an animal's production. It is true that the digestibility of energy and organic matter does depend somewhat on feeding level in the ruminant, but as long as forestomach fermentation is fairly normal the negative effect of feeding level is not very great (Ørskov 1982). Moreover, taking methane and urine energy losses into account, i.e. working with metabolisable energy (ME) instead of digestible energy (CE) makes the differences still smaller (ARC 1980). In monogastrics feeding level only seldom decreases digestibility (van Es 1982). For both type; of animal; differences in digestibility due to the feeds used in the diet are far greater than due to feeding level. Also in most cases the composition of the DE or ME of the ration only to a small extent influences the efficiency oftheutilisation of these two energies for maintenance and production. This is clearly shown by the success of feed evaluation systems based on TDN for lactating cows and those based on ME for poultry in practice. Some newer feed evaluation systems also are based on digestible or metabolisable energy, either completely (MAFF 1975) or to a large extent (French, Swiss, West-German and Dutch systems for ruminants, van Es et al. 1978). In the latter case the factor taken into account while converting ME in net energy is the ME content of the gross energy of the feed. So also in these net energy systems the main basis is the ME content of the feeds.

One factor not yet taken into account in the new energy systems is the influence of ration size and composition on fill of the gastrointestinal tract. In deriving the efficiency of the utilization of the ME into milk energy by regression both variables are first scaled by dividing by metabolic weight, i.e. the animal's actual weight in kg raised to the 3/4 power. In doing so any effect of the ration on fill size is lost, i.e. increased maintenance requirements due to greater fill are excluded. Our data suggest that fill has nearly the same maintenance requirement per kg as the whole animal. For a correct evaluation of the net energy value of feedstuffs such extra or lower (e.g. in case of fat) maintenance costs should be considered. Insufficient information on the effectofthe ration on fill is the reason that this correction has not yet been included.

In the ruminant also the nutritive value of the ingested N depends largely on fermentation and digestion. The combined absorbable amino acids differ little in biological value contrary to in the case of monogastrics. The quantity of absorbable amino acids depends on the degradability of the N of the feed, rate of microbial growth and digestibility of the protein entering the small intestine. Protein degradation in the forestomachs will be greater when the pH of the rumen fluid is high and the feed's retention time is long. Fortunately, as we have seen above, a high pH of the rumen fluid favours microbial growth and it depends on the- steady simultaneous progress of both protein and carbohydrate degradation if most of the degraded N is converted into microbial protein. The gain in absorbed protein due to more undegraded protein at lower pH of the forestomachs fluid is more than offset by the decrease of the rate of microbial growth. Thus, for most circumstances, favourable conditions for microbial fermentation in the forestomachs will also improve the ruminant's supply of absorbable amino acids, even although part of the microbial N is not amino acid N and another part has a low intestinal digestibility. Under such conditions about two third of the absorbable protein originates from microbial growth. Research on the factors determining microbial growth should therefore have preference over research on feed protein degradation. Both types of research, unfortunately, are difficult to perform correctly.

It can be concluded that information on the organic matter digestibility, DE or ME content of a feed is extremely valuable for evaluation of its nutritive value. However, feeds with a high nutritive value but low palatability have little value. in practical application. Having reliable methods to predict both a feed's ingestibility and digestibility (or DE or ME content) is therefore of 'utmost-importance for animal husbandry

PREDICTION OF INGESTIBILITY OF FEEDS

Two applications should be clearly distinguished: 1) indoor or feedlot feeding-and 2) grazing. In the first case large feedrests are usually not so welcome, so the animals are at the best fed up to a surplus of some 10%. This means that selective intake for cattle will be hardly possible,. although goats and sheeps still might do so. Grazing allows far more possibility for selective uptake, again it is for the smaller ruminants much easier than for the large ones.

Measuring voluntary intake of cattle in the first situation can indeed well be done by feeding the feed with a 540% surplus. Measuring intake in the second situation is far more complicated. The ideal solution to this problem probably will never be found. However, Zemmelink's approach (1980) appears a good compromise and offers a good insight. His procedure consists of feeding individually kept animals the feeds under test at several levels, allowing extensive selection. Feed and feed rests are weighed and analysed and some digestibility studies are done. For several feeds intake was considerably higher when ample possibility for selective uptake was given. Moreover, also the digestibility for the ingested material was higher. Obviously the animals selected those feed parts which had a better quality. This is also the case in the grazing situation as analyses of samples taken from the oesophagous have shown (Acosta and Kothmann 1978).

As the measurement of ingestibility of feeds, especially if grazed, is difficult and far from free of error, the prediction is even more so. The content of cellwall, estimated as neutral detergent fibre, is certainly an important factor determining the feed's intake (van Soest and Robertson 1980). However, as was mentioned earlier, the fact whether this cellwall is intact or ground and whether it is easily degradable by rumen microbes or not, influences intake considerably. It has to be confessed that at present only rather rough predictors of intake are available. Local experience with the own feeds, obtained with the above-mentioned techniques, together with analysis of cellwall content and, if possible also of extent and rate of breakdown when incubated with rumen fluid in vitro or in a dacron bag in the rumen, is all what can be offered at present.

PREDICTION OF DIGESTIBILITY

Variation in digestibility is largest within forages, still considerable within by-products and small in root crops and seeds (Wilson 1977; Demarquilly et al. 1980; Minson 1980; Sauvant 1980; Wilson et-al. 1981). Climate during growth of forages influences digestibility considerably, high environmental temperatures affect the digestibility-of the resulting forage negatively (van Soest et al. 1978). Information on digestibility of the many plant species in (sub)tropical regions is far from complete, relationships between digestibility and simple physical or chemical properties in these plants are seldom known.

Several papers on methods for predicting the digestibility of feeds for ruminants appeared in the last years (Aerts et al. 1977; Kirchgessner et al. 1977; Menke et al. 1979; Nehring 1979; Shenk et al. 1979; Demarquilly et al. 1980; Jarrige 1980; Marten and Barnes 1980; Minson 1980; van Soest et al. 1980; van Es and van der Meer 1981, Kirchgessner and Kellner 1981; van Es 1983). Their main conclusions do not differ much. In temperate forages digestibility can be predicted from content of crude fibre, but with a fairly large error. The precision of the prediction is better although still not high (but for practical purposes often acceptable in view of the errors made while sampling large usually rather heterogenous quantities of forage) when separate prediction equations are used for each type of forage. Basing the prediction on acid detergent fibre instead of on crude fibre gives hardly any improvement.

For tropical and subtropical forages, having high cellwall and lignin or silica contents, prediction of digestibility from crude fibre or acid detergent fibre content is still less reliable. For such forages, but also for temperate forages, by-products and compound feeds the in vitro digestibility test involving incubation with rumen fluid has proved to be successful. For highest precision to be obtained with this method in each testrun samples of similar origin as those to be tested of which the in vivo digestibility is known, should be included. This proviso is especially important for forages from (sub)tropical countries, for technologically treated forages, for by-products and for mixed compound feeds. The fact that donor animals -sheep, cattle- are needed for the production of rumen fluid makes that the method cannot easily be used on a large scale. Replacing the rumen fluid by wide-spectrum enzyme preparations seems possible in the near future as the preparations which are available at present have a fairly constant quality and show high cellulolytic activity. Both in the modification with rumen fluid and even more so with enzyme preparations the use of standard samples with known in vivo digestibility in each run is essential because in fact the in vitro procedure is only a crude imitation of in vivo digestion: the in vitro results obtained with the standard samples permit to make the necessary corrections.

Physical methods such as the near-infrared-reflectance spectrophotometry (Shenk et al. 1979; Cowe 1983) are promising because of their speed and non-destructiveness. Unfortunately, for prediction of digestibility they have not yet achieved sufficient precision although for other simpler purposes, e.g. the prediction of protein and fat content of some feeds, the method is already in use and gives satisfactory results.

For most practical purposes, e.g. informing the farmer on the digestibility of his forages, a very high precision is not needed. Predictions based on crude fibre or acid detergent fibre, but in many cases also on stage of maturity, cutting date, leaf number etc. (Jarrige 1980) can be used provided that regression equations are available relating fibre content or the other properties mentioned with in vivo digestibility of similar forage. If such in vivo data are not available, in vitro digestibility tests with rumen fluid will give a good indication on digestibility, al so for (sub)tropical forages, technologically treated forages, by-products and compound feeds. Highest precision is to be obtained from in vitro digestibility tests with rumen fluid or enzyme preparations when standard samples of known in vivo digestibility and of similar type are used in each run sothat appropriate corrections can be made.

In vivo digestibility figures of many (sub)tropical feeds are lacking. In view of the fact-that experiments to determine the digestibility of the organic matter of feeds with ruminants require not much work and give results of high precision and reproducibility, it can be recommended strongly that this important gap in our knowledge is filled in as soon as possible by in vivo digestibility trials in the countries where these feeds grow.

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