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Under-used products from crops and animals

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Under-use may take the form of (i) dumping or burning products which still have value as fuel or as a source of plant nutrients; (ii) returning them to the land when they could be used for animal feeding; (iii) feeding them to animals when they could be eaten by the human consumer.

A major under-use in the first category in the United Kingdom is that of cereal straw where it has been estimated that about 20% only of the 9 million tonnes produced is used for feeding. Apart from technical problems there are powerful economic reasons for this under-use.

In the second category, animal excreta include energy, nitrogen and minerals, some of which may be further used directly or indirectly for the feeding of other animals usually of a different species. So far the main effort has been in the use of poultry manure as a source of nitrogen for ruminants.

Since a high proportion of the diet of ruminants is obtained from grass and forage which contribute little directly to the human dietary, there is a stronger technical case for the use of cereals for very young ruminants and for cattle in late pregnancy and early lactation than is the case for non-ruminants where the diet consists mainly of cereals throughout the growing period.

Introduction

In attempting to prepare a paper on the subject of under-use one quickly becomes aware of the huge gap between under-use in a technical sense and in an economic sense. At the same time it does not seem to be helpful to discuss one or other aspect alone since this leads to impractical theoretical discussion.

There are three main categories of under-use of agricultural products. The first is the burning of the product or its dumping on land or in water so that it goes out of agricultural circulation. The second is the situation where a product goes back into the land when it could be fed to animals. The third is the feeding of products to animals when they could be fed to the human consumer.

The third category often involves political and ethical considerations as well as economic and technical problems and there will be little time to consider this form of under-use in this paper. The first two categories are interrelated and the subject is best considered under broad product heads.

Cereal straw

Cereal straw attracts the criticism of under-use more, perhaps, than any other product or by-product on the farm, and during the last few years a number of conferences have taken place concerning straw. The A.D.A.S. conference in Oxford in January 1976 dealt with many aspects of handling, storage and processing of straw (M.A.F.F./A.D.A.S. 1976). A number of factors are responsible for the current exceptional interest in straw, including doubts about the world supply of cellulose from trees, the possible need to use some more feed energy from

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straw in the diet of ruminants, and changes in methods of handling straw physically and chemically.

In spite of much discussion on the character and size of the straw problem during the last few years it is in fact difficult to define. The total quantity of straw produced was estimated on a regional basis for England and Wales for the harvest year 1972 by A.D.A.S. and their data were used by the N.F.U. working party on the use and disposal of straw (N.F.U. 1973). (See table 1.)

Table 1. Disposal of 9.5×10^6 t cereal straw in England and Wales, 1972

	disposal, %
feeding	15.0
bedding and crop storage	36.4
inter-farm sales	9.3
burned	36.6
ploughed in	1.6
non-agricultural use	1.1

(Data from the A.D.A.S. survey, 1972.)

No comparable national estimate of straw disposal has been made since 1972. In the intervening period the area of cereals grown in the United Kingdom has not varied greatly (U.K. highest (1972): 3793000 ha; lowest (1975): 3640000 ha). Nevertheless the amount of straw produced and, more important, the amount which has been surplus to farmers' requirements for feeding, bedding and normal off-farm sales has varied substantially from year to year.

In 1975 and 1976 the amount burnt in the field was less than in previous years. In 1975 this seems to have been partly due to a lower yield of straw. In 1976 it may have been due to hazards of burning during drought followed by the impossibility of doing so when wet weather intervened.

The problem of straw disposal also varies a very great deal with region. It is a generalized persistent problem in parts of the eastern and east Midland regions. In most other areas it is a local spasmodic problem of farm management.

Under-use of cereal straw is usually thought of in terms of straw which is burnt in the field or chopped, spread and ploughed in to increase the organic matter content of the soil. In 1972, in England and Wales it was estimated that about 38 % of cereal straw was burnt or ploughed in and only 15 % was actually fed to stock.

Many farmers believe that the only economic solution to surplus straw at present is burning it in the field. The N.F.U. Working Party 1973 examined the evidence on the economic and amenity effects of straw and stubble burning and could find no overriding objection to controlled burning if the straw burning code was strictly observed. The evidence suggested that burning straw had no substantial advantage or disadvantage so far as future cereal growing on the land was concerned and there is not much subsequent evidence to change that view. However, in 1973 it was estimated that 3.47×10^6 t were burnt and this represents about 53×10^9 MJ gross energy which could nominally be used for a great variety of purposes in addition to feeding or bedding livestock.

In spite of the many proposals for industrial use of cereal straw no process attracts a substantial proportion of the agricultural surplus in the U.K. In 1973 the proportion of the total straw production in England and Wales which was used outside agriculture was estimated at

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1.1 %. It seems unlikely that this percentage has increased and there was little to suggest a substantial increase in non-agricultural usage when the subject was discussed at Oxford earlier in the year (M.A.F.F./A.D.A.S. 1976). This situation could change dramatically at some time in future if the use of timber wood pulp outstrips the world supply of trees. At present, therefore, the main prospects of greater use of straw must of necessity be in agriculture either directly or indirectly.

Table 2. Area of cereals relative to cattle numbers in East Anglia compared with counties in the southwest, 1972 (M.A.F.F. 1972)

	wheat and barley	total cattle	area per head of cattle
	ha		ha
Norfolk and Suffolk	933523	257219	3.6
Cornwall and Devon	308953	1057142	0.3

It is difficult to assess the extent to which surplus straw in the eastern half of Britain may be taken up in the southwest or Wales where local straw supplies are often inadequate in relation to cattle numbers (table 2). There has been a substantial increase in movement of straw from east to west during the last 2 years. But the cost of transporting straw is high in relation to its value as feed. Currently, barley straw may be purchased in the eastern counties at about £16/t. It is of interest to consider the energy cost of moving straw relative to its energy content. Smith, Rutherford & Radley (1975) estimated the total primary energy cost of transporting straw (fuel and machinery) at about 2.8–2.9 MJ t^{-1} km^{-1}. Thus for a journey of 300 km from the eastern counties to the southwestern counties the total primary cost of transporting 1 t would be about 850 MJ for straw containing about 15480 MJ (straw taken as 86 % d.m. and 18 MJ kg^{-1} d.m.). In November 1976 it cost about £15 to transport 1 t of straw originally worth about £16 a distance of 300 km, while the energy required for the journey would be about 5.5 % of the gross energy value of the straw. The problem seems to be one of financial economy rather than an energy economy.

The N.F.U. working party recommended that 'where appropriate every encouragement should be given to farmers to use straw in making solid farmyard manure...'. In some areas, and indeed on some farms in any area, interest and effort is directed to the crop rather than to labour use in the livestock unit and in these circumstances dung and urine are, by one means or another, incorporated with some of the surplus straw. Some farmers use straw in their cubicles where limited amounts of straw are fed to cattle and where the buildings and system are designed to deal with excess straw moving to the back of the cubicle and to the passage for mechanical removal. Nevertheless, there are now many cattle units employing cubicles and designed to handle slurry neat or with small additions of sawdust, sand, etc. where it would be difficult or impossible to revert to using much straw.

Perhaps the greatest prospect for effective use of surplus straw is in ruminant feeding although there may be controversy over the way in which this is likely to take place. The basic problem of straw as a feed is that it is a poor source of protein and many of the essential minerals. While its gross energy content is not much less than that of many other feeds, a substantial proportion of this is indigestible even in the ruminant.

It has been known for many years that the digestibility of straw may be considerably increased by treatment with caustic soda and the recent development of a commercial system to

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exploit this fact by B.O.C.M. Silcock Ltd (1975) is of considerable interest. There will be controversy over the use of straw either with or without caustic soda treatment in concentrate mixtures because this will reduce their energy density and make them somewhat less effective in supplementing low cost roughage already on the farm. In spite of the hazard to those who work on farms, there will be those who will favour on-farm treatment, since this could greatly reduce transport costs. Nevertheless B.O.C.M. Silcock Ltd have provided ample evidence that the processing system improves digestibility *in vitro* and *in vivo*. If further evidence can be provided that this is reflected in proportionately improved animal production, this would seem to be a method of effectively improving domestic feed energy supplies. It is evident that this may entail supply of straw from restricted areas but in the short term would seem unlikely to take up more than 2 or 3 % of the national surplus.

Apart from processing of straw to make it more useful as a feed for ruminants there can be little doubt that much can be done to improve consumption and utilization by making greater use of the basic knowledge of ruminant nutrition acquired in particular over the last two or three decades.

In practice straw is often fed *ad lib.*, sometimes on the supposition that what it lacks in quality may be corrected by unlimited quantity. Work at the Rowett, Nottingham University, the National Institute for Research in Dairying and other centres has shown that, apart from the wide variation in nutritive value of wheat and barley straw as produced, both intake and digestibility may be affected by the physical form (chopping and grinding) in which straw is presented and also by the supplementary feed (particularly these affecting N supply) which are given with straw.

A number of feed firms sell concentrates designed to supplement straw for various classes of cattle. I doubt if many cattle owners integrate their home grown feeds to meet the special requirements of diets containing large proportions of straw. A better understanding of the work on straw feeding to ruminants which has been done and which is now being done may lead to more efficient and perhaps more extensive use of straw particularly for dry cattle and growing stock. The potential and limitation in the use of straw for young cattle is well illustrated in a recent review by Smith & Broster (1976).

Finally, I should like to draw attention to a point that is rarely included in technical discussions on straw. This concerns the use of straw as a strategic reserve by some cattle owners. This may be a reserve for temporary building or shelter but more often it is a reserve to keep stock alive when all else fails. It would be interesting to know how many dairy farmers in the south of England survived the drought and still retained a working stock of fodder for the current winter because they could switch to winter feeding régimes based on straw in July, August and September.

Grass

It is not within my remit to point out that grass production on the 7192000 ha of grassland in the U.K. is considerably below its potential, especially if greater use is made of nitrogenous fertilizers (table 3). It is, however, appropriate to consider if the grass which is produced is efficiently used; estimates of this are difficult to obtain. Greenhalgh (1975) estimated the stocking rate in Great Britain in terms of cow equivalents per hectare grazed pasture at 1.82 and suggested that this represented only 75 % of the grass grown which was not cut for conservation. There is evidence that in hay making and silage making, overall differences between grass dry

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matter grown and actually eaten is often in the range of 20–30 % of that grown. It is likely, therefore, that there is still scope for improvement in grass utilization.

So far as control of grazing is concerned it now seems that the precise technique of strip-folding, paddock grazing, set stocking, etc., may be of less importance than the overall rate of stocking and integration of grazing and cutting. With dairy cows the problem of intensification in the case of a spring calving herd is relatively simple, i.e. to provide enough high quality grass and to control its use during the period of peak production. In the case of autumn calving or 'year-round' calving, the problem of grazing efficiently is much more complex, particularly where the relative cost of concentrate feeds is likely to be high. It becomes necessary to plan on an annual basis and to attempt to achieve grass and grass products of high digestibility, not only for summer, but for autumn and winter also. This I think calls for a good deal of technical reappraisal particularly of (*a*) the place of clovers and lucerne in grass utilization systems, (*b*) the use of 'buffers' in grazing systems, and (*c*) the policy of conservation.

Table 3. Grass and lucerne, United Kingdom, 1976

	area/ha
temporary and permanent grass	7192000
rough grazing	6511000
lucerne	14000

(Data from M.A.F.F. 1976.)

(*a*) Many milk producers and some beef producers make no use of lucerne and clovers in their grazing systems. The total area of lucerne in the U.K. at 14000 ha is only 0.2 % of the total grassland at over 7 million ha, in spite of the fact that it used to be grown in every county south of the border. Clover is sometimes excluded from seed mixtures or its contribution to the sward is very low due to vigorous grass growth. Although growing lucerne is sometimes eaten by cattle with reluctance, clover is usually taken in preference to grass. Apart from the relative financial and energy economy of legumes and nitrogenous fertilizers in supplying N for sward production, there can be little doubt that lucerne and clover are important in determining the quality of the product so far as intake and digestibility are concerned. A reassessment of the place of clover and lucerne in cattle production on a long term basis is important because the rapid increase in the price of nitrogenous fertilizers is coincident with uncertainty about the supply and price of high protein feeds.

(*b*) One important cause of under-use of grass is the grazier's reluctance to increase his stocking rate since this is liable to lead to underfeeding later in the grazing season and in the subsequent winter or to a bigger bill for concentrates. It has been suggested from time to time that the advantages of high stocking rates without some of the disadvantages may be achieved by the use of 'buffer' feeds to supplement grass and allow higher stocking rates. It has been shown many times, particularly by Holmes and his colleagues (see Holmes & Jones 1964), that concentrates may often be unsuitable for this purpose since they may merely replace grass dry matter consumption and increase feed costs. Greenhalgh (1975) investigated the possibility of extending the use of grass swards strip grazed by beef cattle (300 kg live-weight). For this purpose a low cost feed is required which is not sufficiently attractive to be eaten in preference to the sward grazed but which is eaten to meet the shortcomings in quantity and quality of the regular sward. It has been the practice over the last three decades to encourage the use of nitrogenous fertilizers throughout the grazing season and to take up the grass which is surplus

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to requirements for grazing as silage or hay. On all-grass farms with low investment in buildings and machinery it may be very difficult to devise a more efficient system of grass use. But on mixed farms, particularly in the south, more economic utilization of grass in future may come from greater use of lucerne and clover in leys, tactical rather than strategic use of nitrogenous fertilizers, and a broader choice of crops for producing high quality roughage for the winter, e.g. maize, which is already expanding as a silage crop and fodder beet the area of which would increase if mechanization problems could be overcome.

(*c*) In spite of research and extensive effort over four or five decades, the nutrient losses in the making, storage and feeding of hay and silage are often very high. In all three aspects these losses may be reduced to a minimum by drying and in the event this method of conservation results in a grass (or lucerne) product with higher concentrate replacement potential.

The case for improving grass and lucerne utilization by artificial drying has frequently been attacked either on the score that the process is uneconomic or that it is excessively costly in fuel energy. I doubt if careful budgeting would show either of these factors to be overriding and the main reasons for lack of drying at farm level are that smaller grass driers are not available at a cost that most farmers, even those farming on a large scale, can afford. Added to this there is need for considerable technical skill in operating a grass drier efficiently. At the N.I.R.D. the overall cost of producing grass wafers in 1969 was estimated at £17.60/t while in 1976 it is estimated at £62.00/t (Connell 1976). At the same dates the price of dairy cubes increased from about £34/t to about £110/t.

The primary energy input for grass drying in high temperature driers has been assessed at about 16000 MJ/t (Joint Consultative Organization 1974). This is many times greater than the primary energy input required to produce the same amount of dry matter as silage or hay. However, this energy load may be greatly reduced by juice extraction before drying. The mean moisture content of original grass and lucerne at the N.I.R.D. was 83 % and of the wafers 12 % (Connell & Foot 1972). The pulping and pressing equipment used for juice extraction was reckoned to have a power consumption of from 22 to 29 MJ/(t fresh material) equivalent to a mean of 132 MJ/(t wafers). It resulted on average in a reduction in fuel consumption of about 40 %. Thus for an expenditure of about 132 MJ/t in pulping and pressing there was a saving of about 6400 MJ/t in fuel for drying. Clearly, this is not merely a matter of saving in fuel since the composition of the wafers will have changed with juice extraction, and the dry matter in the juice is known to be a good source of protein if methods and the time of using it are economic. The value of the products from juice is very dependent on the cost of alternative sources of protein.

Roots and forage crops

Under-use of roots, including kale, is mainly in the form of waste of animal feed rather than waste of plant nutrients because most roots and forage crops are now fed on the field and uneaten residues ploughed in to add to fertility for the next crop.

The sugar beet crop would perhaps rank as a major source of loss of feed nutrients (table 4). The 206000 ha of sugar beet grown in the United Kingdom in the current year would be expected to yield about 1 Mt of dry matter as tops assuming these include crown as well as leaf. With a metabolizable energy content of 9–10 MJ kg^{-1} d.m. and a digestible crude protein of about 90 g kg^{-1} d.m., this is a valuable source of feed for cattle and sheep. However, in 1975 the British Sugar Beet Corporation estimated that about 26 % of tops were fed to stock and 74 % ploughed in (A.D.A.S. 1976).

There are a number of reasons for this loss of good quality feed. The major reason is lack of consumers in the right place at the right time (table 5). In 1972 for every cow heifer and calf in Norfolk and Suffolk there was about ¾ acre of sugar beet. In the Holland division of Lincolnshire there were about 2 acres for each animal. At the same time no sugar beet was grown in Devon and Cornwall where there were more than 1 million cattle. The period of use of tops is limited by the fact that they deteriorate in the field as winter progresses.

Table 4. Disposal of sugar beet tops

sugar beet, U.K., 1976	206000 ha
yield of tops as dry matter	
1969–75 mean	5.5 t ha^{-1}
1975 B.S.C. survey:	
ploughed in	74 %
fed in situ	18 %
carted off for feeding	7 %
dried or ensiled	1 %

(A.D.A.S./B.S.C./Norfolk agricultural statistics.)

Table 5. Cattle and sugar beet, Eastern counties and Southwestern counties, 1972

	total cattle	sugar beet ha	area per head ha
Norfolk and Suffolk	257219	72200	0.27
Holland (Lincs.)	12197	9800	0.80
Devon and Cornwall	1057142	120	—

(Data from M.A.F.F., 1972.)

Although considerable quantities of sugar beet tops are ensiled on the Continent it is estimated that less than 1 % of production is ensiled in this country (B.S.C. Survey 1975, in A.D.A.S. 1976). With the advent of the topper harvesting several rows at once and chopping and loading without soil contamination, there would seem to be a prospect of increased silage making.

Of the fodder crops, kale is perhaps the one which merits most the label of under-use. This is partly because it is not now grown where it could be used and partly because when it is grown the field losses are sometimes substantial. The area of kale grown in England and Wales increased steadily after the war up to a maximum of 144000 ha in 1960. Since then it has steadily decreased to 52000 ha in the current year. A good crop of marrow-stem kale yields up to 14 t d.m. ha^{-1}, equivalent to about 150000 MJ of metabolizable energy and about 2 t of crude protein. It is accessible for consumption after the end of the growing season. Why is it losing popularity? It seems likely that the main reasons are associated with the folding of kale. These are numerous but one which is pertinent to this paper is the large field loss that may occur. These often reach 20 % of the crop and at the N.I.R.D. it has been shown that they may exceed 50 % (Line 1959). These field losses can of course be reduced by ensiling kale and indeed it is easy to make palatable silage from marrow-stem kale but seepage losses may be very heavy.

Maize, which is rapidly increasing as a silage crop in the south of England (1976: 29000 ha), seems to be relatively efficiently used. This is because the stem is automatically included in the diet and harvest losses are usually minimal. There is an inevitable loss in the silo but in large clamp silos at the N.I.R.D., Phipps (1976) has shown that this need not exceed 10 % of the dry matter harvested. There is sometimes deterioration due to heating at the exposed face when emptying clamp silos but this is dependent on the area of the face and rate of emptying.

Livestock wastes

There is no doubt that a great deal could be said about the under-use of most animal products as they are processed and pass through the market to the consumer where further waste may take place. Time, however, allows only brief comments on the under-use of products which do not normally pass through the market, that is, excreta from livestock.

It has been estimated that livestock in the United Kingdom produce about 120 Mt of excreta each year. This figure is not very useful since it includes dung and urine both from cattle, which may contain less than 7 % d.m., and from poultry, which may contain over 26 % d.m. (A.R.C. 1976). Also a substantial proportion is dropped on land, which may create important problems in farm management but not serious national problems of under-use or pollution. However, in the last three decades the rapid increase in the size of livestock units and the handling, storage and disposal of excreta without straw have in some cases increased the danger of under-use of excreta. It is a fact that the mixing of straw and excreta to produce traditional f.y.m. often had advantages to soil fertility which straw and excreta individually do not confer and the separation of the two has sometimes created two problems instead of one. However, this is a reflexion of the 30-fold increase in farm wages since before World War II.

In considering under-use of livestock excreta, perhaps the first point to assess is whether the same species of livestock producing the excreta, or a different species of livestock, can extract more feed nutrients from it. There are plenty of cases where this does in fact happen, e.g. coprophagy in some small animals, notably the rabbit, or consumption of cattle dung by pigs in strawed yards for the energy of undigested cereals and incidentally protein and water soluble vitamins. It might be argued that livestock diets should be so devised that maximum nutrients are taken out in one passage through the animal. However digestibilities rarely approach 100 %, and even allowing for the ash content of excreta (in the case of poultry this is often around 33 % in dry matter), there is always a considerable organic content and often a high N content. Up to now most of the work on recycling excreta has involved dried poultry manure. This product is often low in energy value and although it may have a high N content a variable proportion of this may be as uric acid which is of little value in poultry diets (Shannon, Blair & Lee 1973). Nevertheless it has been shown that dried poultry manure may be of value as a protein source in broiler diets (Lee & Blair 1973). It may have some value in diets for laying hens particularly where use can be made of its calcium and phosphorus content (McNab, Shannon & Blair 1974) and some value in diets for replacement pullets (Lee, Blair & Teague 1976).

There is also evidence that dried poultry manure may have a commercial value in ruminant diets. In the last 3 or 4 years, however, the amount used in this way has been decreasing. There are several reasons for this. Perhaps the most important is that, as a protein source, it is sensitive to both the price of alternative protein sources and also to the price of oil for drying. In addition,

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however, there have been worries about the possible transfer of pathogens, heavy metals and drug residues and some driers have been stopped because of odour problems.

Several abstract reports have appeared in *Animal Science* in the last 2 or 3 years describing attempts to assess the value of cattle excreta when recycling through ruminants. It is also difficult to draw conclusions from these results because they are to some extent contradictory and in any case the faeces used varied a great deal according to the diet fed to produce them. Most of the work was carried out using faeces partly dried on the concrete floors of feed lots or collected and dried artificially, ground and incorporated in rations.

In view of the reluctance of cattle to graze near dung on pasture it is perhaps surprising that intake of diets containing dried faeces has normally been satisfactory at inclusion rates of 10 % or 20 %. However, the digestibility of the dry matter in dried cattle faeces when included at 20 % in a normal basal ration for steers in Virginia (Lucas, Fontenot & Webb 1975) was found to be no more than 16.4 %.

Cattle manure produced indoors in the United Kingdom would on average have a much higher moisture content than that produced in feed lots in the U.S.A. The high fibre content and obvious handling problems seem to me to make it less promising for direct recycling than poultry manure. It is perhaps more likely that specific use may be made in future of the microbial protein and tissue cell protein remaining in cattle faeces. This might entail a systematic processing to produce a protein source for poultry, while a contra-flow of poultry manure forms part of the protein source for cattle. An example of a systematic exchange of nitrogen from faeces between species has been described recently by Ward & Seckler (1975).

There has been some interest in the recovery of N from excreta by microorganisms, algae, insect larvae and earthworms. In work on the last category, Fosgate & Babb (1972) used faeces from dairy cattle as a medium for growth of earthworms (*Lumbricus terrestris*) and claimed a daily production of 423 g crude protein in earthworms for each cow, which is equivalent in quantity to the crude protein in about 13 kg milk. Similar work using sheep and poultry excreta as a medium and the tigerworm (*Eisenia foetida*), has been reported from the University of Adelaide (Marler 1976).

Pearce (1975) has reported a series of investigations on the value of dried pig faeces fed to steers replacing up to 45 % of a hay diet and to sheep replacing up to 30 %. In the case of steers of 350–380 kg the derived digestibility of the dry matter of the dried faeces was 29 %. The diets of the pigs contained copper at 150 mg kg^{-1} and resulted in dried faeces containing about 550 mg Cu kg^{-1}; it was concluded that at an inclusion rate of 30 % over a period of several weeks adverse effects from the copper could be expected, although this did not appear to be the cause of the low digestibility.

The recent publication on farm livestock wastes by the A.R.C. (1976) was concerned in particular with work carried out on the subject in the U.K. and supported by special grants by the A.R.C. and M.A.F.F. The aim of this work was to control various types of environmental pollution as well as improving the use of excreta as a source of plant food. In considering improved utilization of livestock excreta there seemed to be little prospect of large scale uses of this material outside agriculture in the immediate future. The general conclusion is that, whatever is done to slurry to reduce pollution or improve handling, the dry matter which it contains, must go back on the land in one form or another by one route or another and sooner or later.

It is clear that processing, storage and distribution of animal wastes on the farm involve substantial losses of plant nutrients to the atmosphere, to land drains and watercourses and to deep ground water. Too often in recent years these losses have been assessed from the point of view of pollution rather than as a loss of fertilizing value. Before these problems can be adequately quantified a good deal more investigation is required. What are the losses to atmosphere of N in the various aerobic and anaerobic farm treatment systems? What are the losses of NPK in farm storage lagoons? What plant nutrients are lost in land drains or deep ground water following slurry application? Quantitative answers to these questions under a range of farm conditions are still fragmentary.

Conclusion

It will, I hope, be clear from these brief comments that large amounts of livestock feed nutrients are produced each year which are not in fact eaten by livestock. Most of this potential feed eventually goes back on to the land and provides a source of plant food for subsequent crops.

The exception is cereal straw, 3 or 4 Mt of which is burnt annually which returns only those plant nutrients which are in the ash. There is scope for using more straw as feed both by chemical treatment to improve its digestibility and by more accurate supplementary feeding for untreated straw.

It seems likely that less than 75 % of the grass grown is eaten by livestock and there is opportunity for some improvement in utilization although a greater output of livestock products might be obtained by growing higher yields of grass and lucerne.

Large quantities of high quality feed are lost to livestock feeding in the form of sugar beet tops each year but some of this loss is inevitable at present for logistic reasons.

There is a large pool of animal nutrients in the form of livestock excreta but the prospect of recovering these for animal feeding in the immediate future seems to be centred mainly on dried poultry manure and even here considerable technical problems remain.

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