NUTRITION AND REPRODUCTION*

THE maintenance of regular and healthy reproduction coupled with a sound breeding policy is clearly essential to the development of successful animal husbandry. Until recent years the major causes of reproductive troubles were commonly sought in the field of disease, but conclusive evidence is now available that in very many cases the basic causative factor primarily arises from faulty nutrition. The effects of such factors, moreover, are not necessarily exercised directly upon the sex organs, but may affect their activities only indirectly through the establishment of abnormalities in other parts of the body whose healthy co-operation is essential to the optimum working of the reproductive processes.

That general bodily condition may react upon reproductive efficiency has long been known to observant breeders. Extremes of leanness and fatness must be avoided. The half-starved animal, whether male or female, is likely to be slow in arriving at puberty and of low breeding efficiency thereafter. The female in such condition may for a time produce healthy offspring, but only through incurring a strain upon her body that may soon cause the production of dead or weakly offspring and permanent damage to herself. The underfed male will show his weakness in reduced number and vigour of the sperms. At the other extreme, the detrimental effects of over-fatness are revealed in the widespread experience that in both sexes the maintenance of animals in " show " condition for more than short periods is generally accompanied by low fertility.

Under-nutrition may arise from a general deficiency of energy supply or from deficiency of one or more of the specific essential factors, such as vitamins or minerals, or from the combined effects of more than one deficiency, and the nature of the reaction upon reproductive activity will vary with the character of the nutritional defect. In the female an effect that seems to be common to all types of nutritive deficiencies is a disturbance of the œstrous cycle, leading to irregularity or in severe cases to actual cessation.

ENERGY REQUIREMENTS

The minimum energy requirement for reproduction in the female is obviously that represented by the energy stored in the form of new tissues in the growing fœtus and its membranes, in the enlargement of the uterus and the development of the mammary glands. To estimate the actual energy requirement, however, this minimum must be increased, since even under the most favourable conditions it is hardly possible for the whole of the available energy that is applied to the reproductive process to be stored up in the new tissues. In other words,

* By Charles Crowther, M.A., Ph.D., of Harper Adams Agricultural College, reprinted from *The Journal of the Ministry of Agriculture*, Vol. XLV, No. 8, 1938.

we must provide not merely for the material produced but also for the work of reproduction. Each of these items, which together form the total energy requirement, will vary at different stages of the gestation period.

That the rate of storage of energy in the fœtus and other uterine products rises steadily as gestation progresses has been well demonstrated in studies with young sows at the Illinois Agricultural Experiment Station. In these studies it was found that with a sow producing a litter of eight pigs the daily storage of energy rose from less than 2 Calories in the first week to 272 Calories in the sixteenth week of gestation. Similar increases were also recorded in the storage of protein and mineral elements. For the whole period the average daily storage of energy was 104 Calories, and assuming that the additional storage of energy in the growth of the mammary glands would not exceed 10 per cent. of this figure, an estimate of an average daily requirement of 115 Calories of net energy to cover the specific needs of reproduction was arrived at. When this is compared with the net-energy requirement for maintenance of gilts of the weight used in these studies (200 lb.), which was put at 2,000 Calories, it will be seen that the extra energy requirement of the in-pig gilt as compared with the " empty " gilt amounts to no more than 5 or 6 per cent., and even at its highest point in the closing week of gestation when it may have risen to 300 Calories, this represents but a 15 per cent. addition to the basic maintenance requirement. If these energy figures be converted into terms of the corresponding weights of digestible nutrients, the ratios will remain much the same and we may conclude that as far as extra energy supply is concerned the additional requirements for pregnancy of the sow are trivial in the early stages of gestation and at no stage are likely to exceed 20 per cent. of the basic maintenance requirement. With longer period of gestation of the cow, the extra energy requirement in proportion to the size of the animal is probably even smaller.

These computations leave out of account, however, the bodily condition of the mother herself, and if this is low at the onset of pregnancy it will clearly be advisable to feed on a more liberal scale until the desirable state of bodily fitness has been attained. This is all the more important since some draft upon the reserves of the body is almost certain to be made, even with abundant food supply, to sustain the milk flow subsequent to parturition, when it reaches its maximum level.

A further point to keep in mind in connexion with these estimates of food (energy) requirements is that they assume that the ration is adequate with regard to all other essential factors. Should there be a deficiency of protein or phosphorus, for example, then probably a greater amount of food will be required to secure the same level of storage of energy. The nature of the ration requires separate consideration therefore, apart from the question of energy supply.

PROTEIN REQUIREMENT

Bearing in mind that the dry substance of the fœtus and other products of gestation is rich in protein, it follows that the trend of protein storage with advance of gestation will be similar to that of energy, small in the early stages and rising to a relatively high level at the end. Thus, in the Illinois studies referred to above the daily rate of storage of crude protein rose from 0·5 grm. in the first week to 33 grm. in the sixteenth week. This is a far smaller relative increase than that found in respect of energy storage, which is to be expected since, as the fœtus develops, an increasing proportion of the retained energy is stored in the form of fat.

Over the whole period the average rate of protein storage was 14 grm. per day,* which may be raised to 16 grm. to allow for protein stored in the increase of mammary gland. As to how much digestible protein should be included in the food supply to provide for this storage, this will depend upon the " biological value " (or " quality ") of the food protein. If this be assessed for common types of rations at 50 per cent., the average daily requirement of digestible protein in the food to secure an average storage of 16 grm. would be 32 grm. Similarly, to provide for the 35 grm. daily storage in the last week of gestation about 70 grm. of disgestible food protein will be needed. According to American estimates the pig of 200 lb. live weight requires for maintenance about 100 grm. of protein per day. German estimates give the much lower figure of 60 grm. but even taking the higher figure it will be seen that the additional requirement for food protein imposed by pregnancy is no less than 32 per cent. on the average of the whole period and 70 per cent. in the closing stage of gestation. Although, therefore, the total food requirement during pregnancy as indicated above may be but little increased, the protein requirement is substantially increased and therefore the composition of the ration must be adjusted, by reducing the cereal fraction and increasing the protein-concentrate fraction, to ensure the necessary increase of protein supply. The same principles apply to other classes of livestock, but where the rate of development is slower the relative increase of protein supply required will be less. Thus, Maynard estimates that the maintenance requirement for protein for the cow may be increased during gestation by an average of 17 per cent. over the whole period, or 40 per cent. in the closing stage.

These are probably under-estimates of what is *desirable*, since here again, as also for energy storage, regard should be had to the desirability of enabling the parent to store up a reserve of protein in her body, apart from the bare needs for reproduction, in order to provide some insurance against the drain to which she may be exposed later when the heavy demands of lactation have to be met.

VITAMIN REQUIREMENTS

Despite a considerable amount of research, the precise significance of vitamin supply for reproductive efficiency is still not clearly defined. Only for vitamins A and E does there seem to be a clear case for postulating that the maternal diet must include extra amounts to cover any specific requirement for reproduction. For the welfare of the mother herself the whole range of vitamins may be of importance, and certainly the A and D vitamins, whilst a liberal supply of these vitamins to the mother makes possible the accumulation of reserves in the fœtus, which will be valuable in the early stages of

* This figure agrees well with that of 12·5 grm. obtained by Evans in experiments at Cambridge.

post-natal life. That there is a specific requirement for vitamin D for reproduction would seem probable, but conclusive evidence as to this has not yet been obtained, especially as regards farm animals.

That an adequate supply of vitamin A is essential for efficient reproductive activity has been established for both sexes. In the male a deficiency of this vitamin quickly induces a marked lowering of fertility. In the female the first sign of vitamin-A deficiency is commonly the development of irregularity of œstrus, which ultimately may cease entirely if the vitamin deficiency is very severe. If fertilization takes place, the gestation may be prolonged and terminate in difficult parturition ; the placenta will often be abnormal and the incidence of fœtal death and resorption, or of abortion, will be increased. These effects arising primarily from placental injury are said to differentiate cases of vitamin-A deficiency from fœtal death due to deficiency of vitamin E which is occasioned more directly by defects in the fœtal tissue istelf. The diagnosable symptoms of vitamin-A deficiency vary somewhat according to the species of animal and the severity of the deficiency.

Little is known as to the minimum requirements of vitamin A for reproduction, but there is evidence that they are at any rate greater than those for maintenance. The simplest practical safeguard against deficiency of this vitamin lies in the supply of leafy greenstuffs, either fresh or artificially dried. Where this is not available, or with animals, such as the pig, that can only digest relatively small quantities of roughage, the inclusion of yellow maize in the ration will be helpful. There is evidence, however, that pig-feeding rations, even when relatively large proportions of yellow maize are included, are often barely adequate in supply of vitamin A unless either a store of the vitamin has been built up in the animal during the pre-natal and early post-natal periods, or some additional good source of the vitamin, such as greenstuff or cod-liver oil, is added to the ration. As to the former alternative, experiments at Cambridge and elsewhere have demonstrated that only a very small fraction of the vitamin A of the maternal food-supply can be stored up in the offspring, so that with a rapidly growing animal like the pig the most liberal pre-natal supply of the vitamin to the mother will not for long safeguard the offspring against deficiency in the post-natal food supply.

The basic need for vitamin E for reproductive efficiency has been demonstrated, but there is little evidence as yet that breeding troubles due to deficiency of this factor are met with more than very rarely in farm practice. Nor, indeed, is it to be expected that this class of trouble would be often met with in view of the supply of the vitamin in greenstuffs and the germ of cereal grains. Should the exigencies of flour milling, however, lead to a greater removal of the germ from the " offals " than is as yet customary, the possibilities of Vitamin-E shortage in breeding stock kept indoors with little or no greenstuff or unmilled grain would need to be examined.

MINERAL REQUIREMENTS

The general importance of an adequate supply of mineral elements for the building up of the developing fœtus is obvious. Calcium and phosphorus are essential for bone formation, alkalies for the proper functioning of the body fluids, iron for the production of the necessary hœmoglobin in the blood, iodine for the efficient working of the thyroid gland, and other mineral elements for other specific purposes. There is little possibility with these mineral requirements of off-setting a deficiency of one element by a surplus of another of similar character, say of potassium by sodium.

For the purposes of energy supply, carbohydrates, fats and proteins are to a large extent mutually replaceable, but in regard to mineral supply the functions in the body of each particular element are largely specific and can therefore only be met by the supply of that element in the food.

Judged in terms of quantity, the most spectacular mineral requirement for growth, and therefore for reproduction, is that for calcium and phosphorus, since these form so large a part of the structure of the bones. The magnitude of this requirement explains also why deficiencies of calcium and phosphorus are more frequently the cause of trouble in practical animal husbandry than any other form of mineral shortage.

The direct incidence of deficiency of calcium or phosphorus on reproductive efficiency has been conclusively demonstrated by experimental work in many parts of the world. As an example, the classic work of Theiler and his associates with cows on the phosphorus-deficient grazing areas of South Africa may be quoted. When the grazing was supplemented by bone meal or other phosphorus concentrates the calf crop was about 60 per cent. greater than when no such supplement was given. Similar effects upon fertility also accompany calcium deficiency, which causes an increase in the number of progeny born dead or weakly.

Over the world in general, calcium deficiency is probably less widespread than phosphorus deficiency, but there are many areas, including a large part of Britain, in which the position is reversed. In housed animals fed mainly on grain and other concentrated foods it is also more often the supply of calcium than of phosphorus that needs special attention.

The effects of shortage of these elements on reproduction are the more insidious through the gradual character of their development, since for a time, which may be prolonged, the deficiencies of the food may be made good by depletion of the supplies of calcium and phosphorus in the maternal skeleton. Even with a continuous deficiency, therefore, little effect may be apparent at the first, or even at the second pregnancy, and when eventually it does appear the general tendency will be to look for the cause in some recent change of diet or treatment rather than in the long-continued (but unsuspected) dietary mistake. The unwisdom of allowing a drain upon the mineral reserves of the maternal body during the gestation period becomes actual folly when it is remembered that this period is followed by the period of milk production, in which for a time some further depletion of the maternal mineral stores is almost inevitable even with a liberal supply of minerals in the food.

It is difficult to arrive at reliable data for the calcium and phosphorus requirements of the pregnant animal since these must cover not only the amounts actually stored in the contents of the uterus but also the maintenance needs of the mother, who should indeed receive more than this in order to enable her to build up reserves in her bones with which to meet the subsequent strain of lactation. As to the actual storage in the growing fœtus, the data obtained in the American studies with pigs referred to above indicated that about 95 per cent. of the calcium and 90 per cent. of the phosphorus were stored up in the second half of pregnancy, and no less than 60 per cent. and 50 per cent. respectively were stored up in the last three weeks. It would seem, therefore, to be more particularly in the later weeks of pregnancy that attention should be given to the adequacy of the supply of these two mineral elements.* The same applied to the storage of iron, except that in this case the rate of increase of storage increased more gradually from start to finish, although about 80 per cent. of the total was stored in the second half of the period and nearly 40 per cent. in the last three weeks.

In other American studies the conclusion was reached that the ration of pregnant sows should contain not less than 0·4 per cent. of calcium, or say 0·3 per cent. rising to 0·5 per cent., with rather less phosphorus. For gilts the proportion would need to be a little higher to cover the gilt's own growth requirements.

As regards ruminant animals, with their longer period of gestation, the daily requirement of minerals is less in proportion to body size. Thus, in the ewe it is estimated that 0·2 to 0·35 per cent. each of calcium and phosphorus in the daily ration will be adequate. In the cow a still lower proportion, say 0·15 to 0·25 per cent. is probably adequate for maintenance and reproduction, but here the estimation of the requirements for the needs of production is complicated in the first pregnancy by the simultaneous need for the purposes of growth of the heifer, whilst in later pregnancies a still greater complication arises if, as is usual, milk production is continued through the greater part of the new gestation period. In practice, therefore, it is hardly possible or indeed necessary to discriminate between the requirements for the various needs which together make up the total requirements. A rough standard which, judged by American data, will probably not be far wide of the mark for average conditions, can be arrived at by taking a minimum requirement of 0·10 per cent. each of calcium and phosphorus in the dry matter of the food for the "empty" dry cow, increasing this by 0·07 per cent. for the dry, in-calf cow, and by a further 0·07 per cent. for each gallon of milk. On this basis, the cow of average size, in-calf and giving 2 gallons of milk daily would need in her daily ration about 0·3 per cent. each of calcium and phosphorus.

The requirement for other mineral elements need only be dealt with briefly, since it is probably only rarely in ordinary breeding practice that actual deficiency with regard to them arises. It is true, for example, that the need of the pregnant animal for iron is probably twice or thrice as great as the maintenance requirement, but unless the animal is kept under highly artificial conditions, such as are for many reasons undesirable for breeding stock, it is

* On the other hand, results obtained by Evans at Cambridge indicated that, even with a liberal supply of calcium in the food, the enhanced requirements of the fœtus in the later stages of pregnancy were largely drawn from the maternal reserve, so that the wiser plan may be to give calcium liberally in the first half of the gestation period in order to ensure that this reserve is fully developed when it is needed, rather than to rely upon direct assimilation from the food at the time when the need is greatest.

unlikely that even this enhanced iron requirement will not be met by the ordinary food supply. The risk is certainly greater with a prolific quick-growing species like the pig than with slower-growing species, and for the in-pig sow, without any making any nice calculations as to iron supply, it may be worth while to enrich the dietary slightly with iron on the off-chance that some little of it may be stored in the young pigs, which thereby may be better equipped to avoid the post-natal risks of anæmia.

The only other mineral element that perhaps needs special mention is iodine, but as to whether deficiency of this element is likely to be at all common in practice it is difficult to obtain clear guidance. Since iodine is an essential factor in the activities of the thyroid gland, which include an intimate influence upon the processes of reproduction, it is obviously very important that there should be no risk of shortage of iodine in the breeding animal. The evidence from practical feeding experiment with iodine supplements to ordinary rations is very conflicting, and certainly does not as yet warrant any general recourse to iodine supplements for breeding stock. A deficiency of iodine so pronounced as to affect reproduction seriously will almost certainly establish a goitrous condition in the parent animal, and where such condition can be diagnosed an increase in iodine supply is clearly required. In the light of existing information we are inclined to agree with Maynard that " there is no conclusive evidence that the feeding of additional iodine to breeding animals is helpful except in the specific situations where goitre is occurring, or that it has any benefits other than goitre prevention.

. . . . Since the danger of over-dosage with iodine is a real one, it seems wise to restrict its use to the prevention of goitre and related troubles in areas where they otherwise occur, until positive benefits for other purposes have been clearly proved ".

Finally, a word may be said as to the possible need for a supply of salt to the breeding animal. No information is available on this point, but since there is evidence that deficiencies of salt supply may arise in respect of quick-growing animals like the pig and chicken it may perhaps be as well to keep in mind a similar possibility in regard to pre-natal growth, although in this case the maternal body will probably provide an adequate regulator of supply to the uterus even on a salt-deficient diet. It is plain commonsense, however, that a deficiency which can be foreseen should be avoided.