growth provided there is good summer grazing. If, however, it is necessary to serve heifers in midwinter to calve at 2 years of age in the following autumn, extra feeding in the form of concentrates may be necessary to ensure a high rate of fertility.

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Economies in Feeding for Milk Production

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A widely used method of rationing milking cows in Britain during recent decades was to give the cow about 20 lb. of hay daily for maintenance and $3\frac{1}{2}$ lb. of balanced concentrates for each gal. milk produced. In prewar days, this simple system was sound economically and nutritionally but it has now been rendered obsolete by the change in availability and in the relative values of home-grown food compared with purchased concentrates.

Factors affecting the efficiency of the rumen

In the same way that our conception of the cow's dietary needs was simplified by the hypothetical division of a ration into maintenance and production portions, so we may simplify our understanding of her digestive processes by picturing it in two sections, (a) the rumen and (b) the remainder of the digestive system. The latter section is similar to that of single-stomached animals and is chiefly of value to the cow for dealing with diets composed of concentrated foods. The former section (the rumen), however, is primarily concerned with the digestion of fibrous or bulky foods, now usually home-grown, and it is this portion that deserves special attention under present-day economic conditions. Three general lines of approach are suggested to improve the efficiency of the rumen fraction of the cow's digestive organs:

(1) To breed cows that are more efficient in digesting roughage foods, (2) to train cattle during their growth period to become more efficient in dealing with roughage, and (3) to provide rations that ensure maximum efficiency of digestion and assimilation.

Breeding

Cows can be bred for almost any clearly defined quality, e.g. milk records provide a measure of milk-yielding powers and consequently it is reasonably easy

to breed cows for higher milk yields or for higher butterfat content. There is, however, no simple means of expressing a cow's ability to digest roughage and consequently breeding for this quality is singularly difficult. The present technique of bull breeding in this country is dominated by the idea that the first essential of a bull-breeding herd is a high average milk yield. This idea may be sound, but unfortunately most breeders realize that the easiest way to obtain high milk yields is to use a ration composed largely of concentrated foods. Thus, bull-breeding herds tend to produce animals that are efficient converters of concentrates (rather than bulky foods) into milk. An appropriate comment on this procedure is that the pig is much more efficient than the cow as a converter of concentrates into milk solids. Although there is a clear need to improve by breeding the efficiency with which cows can convert roughage into milk, there may be difficulties in attaining this aim until a system can be found for measuring and expressing such qualities.

Training

Crichton & Aitken (1954) have dealt with the rearing of dairy heifers and I need only add my conviction that the rationing of growing heifers influences their ultimate ability to convert roughages into milk. Frequently, a high-plane diet for growing cattle tends to be largely concentrates, whereas a low-plane diet is roughage. Experiments at Shinfield several years ago tended to show that heifers raised on a low plane eventually milked better than their contemporaries raised on a high plane. Regarding the use of roughage for very young cattle, we have, during the summer of 1953, raised a batch of five calves from birth to 6 months on 48 gal. of milk plus grazing and no other food. The calves are now well developed and thoroughly healthy.

Provision of suitable rations

My colleague, Dr C. C. Balch, has found that under what may be called normal conditions, the digesta in the rumen of a cow consist of a lower layer of liquid and an upper layer which has the consistency of damp long hay (Balch & Kelly, 1950). Under abnormal conditions, the digesta are more or less homogeneous and have the consistency of oatmeal porridge. This latter condition occurred during experiments at Shinfield (Balch, Balch, Bartlett & Rowland, 1953) with rations that depressed milk-fat percentage. The rations were either high in concentrates and low in long hay, or contained hay in a finely powdered condition. Under such conditions, the microbial activity in the rumen does not follow the normal course, and the products of digestion are different, e.g. less acetate is produced.

The optimum level of concentrates in the rations of dairy cows may be judged from the work of Jensen, Klein, Rauchenstein, Woodward & Smith (1942) who studied the milk-yield responses of cows when their rations contained additional grain; when the planes of nutrition were 90, 100 and 130% of the ration standards, 1 lb. extra grain in the ration resulted in $1\frac{1}{2}$, 1 and $\frac{1}{2}$ lb. extra milk respectively. Thus, at prewar price levels when a pound of milk was worth about twice as much as a pound of grain, it was profitable to allow very large amounts of concentrates

in the rations; at present, however, some authorities contend that it is desirable and profitable to provide no concentrates at all in the rations. Modern methods of rationing suitable for the no-concentrate regime are described in a practical way by Holmes (1953).

That there may be some disadvantage in depriving milking cows of all concentrated foods is suggested by the work of Huffman, Duncan & Chance (1952), who appear to have demonstrated that concentrates contain some unidentified factor or factors essential for milk production. It seems desirable, therefore, to include in rations at any rate a small amount of concentrates.

Digestion and assimilation are probably aided by intensively active growth of micro-organisms in the rumen. To encourage this condition, some workers have tried to improve the microbial flora by transferring boluses of rumen contents from one animal to another. Under some conditions, this may be beneficial but the evidence so far produced does not appear very convincing. Better effects are obtained by giving the cow a diet that ensures in the rumen a better medium for microbial growth. Thus, the nature of the carbohydrates in the diet assumes considerable importance and the work of Waite & Boyd (1953*a*, *b*) is of special interest regarding the carbohydrate content of grasses. A third item which is probably of major importance in the rationing of ruminants is the avoidance of sudden dietary changes which may check the growth of rumen flora. Examples of such ill effects may be observed from the work of Hungate, Dougherty, Bryant & Cello (1952), who reported the death of sheep when the ration was suddenly changed from roughage to cracked maize. Again, grass tetany in cows has been found to occur with greater frequency when the change to spring grazing is sudden rather than gradual.

Regarding the conservation of grass for winter milk production, there is a modern tendency to belittle the value of hay and to bolster silage. This tendency may be justified in the damper parts of Great Britain, but I suggest that in the drier areas of the south Midlands and eastern counties grass tends to dry up during many summers whereas root crops such as beet can always be relied upon to yield a crop, also in these areas good hay can be made with reasonable certainty. My enthusiasm for hay is stimulated by the fact that hay appears to be of special value to ensure normal digestion in the rumen of the cow.

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