*24 July, Third Session*

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## Efficiency of Food Utilization in Pigs

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It has been estimated that the food eaten by the pig accounts for 75–85% of the cost involved in the production of pork and bacon. The importance of efficient utilization of food is best appreciated by realizing that in the United Kingdom, with a pig population of over 5 million a reduction of 10% in the total amount of pig food, such as could be obtained by improving efficiency of food utilization, would amount to a saving of some £10 million a year. At prices prevailing at the moment an improvement in efficiency of food conversion of 0·1 lb./lb. live-weight gain would save about 5s. per pig. The difference in conversion rate between 3½ lb. and 4½ lb. amounting in terms of money to about £2 10s. 0d. per pig would, in many instances, mean a difference between a commercially very successful pig establishment and one losing money.

During the last 15 years the price structure was arranged to ensure some margin of profit even to the less efficient pig keeper. The figures quoted above indicate clearly how profitable such an arrangement was to the efficient producer. The situation, however, is rapidly changing, and it will not be long before a certain degree of efficiency will be a prerequisite for profitable pig keeping.

There is no reliable statistical information about average efficiency of pigs as converters of food in this country. However, to venture a guess, it would be rather above than below 4 lb. of meal for 1 lb. live-weight gain. My only purpose in attempting such a guess is to indicate that there is plenty of room for improvement. What can be done in a relatively short time is well illustrated by some Danish data reported recently (Hansen Larsen, Clausen & Jespersen, 1952) which show that during the last 40 years the average conversion rate in the Danish Landrace pigs was reduced from 3·77 to 3·15 Scandinavian feed units/lb. live-weight gain.

This brings me to the main theme of my contribution, namely that one should be extremely careful in reporting and interpreting values concerning efficiency of food utilization. Many different factors must be taken into consideration, as otherwise the results may be quite meaningless, if not actually misleading.

Before considering some of the factors in detail, it is at this stage appropriate to mention several principles governing the growth of pigs and their food consumption. Table 1, reproduced from Mitchell & Kelley (1938), embodies some of these principles and shows clearly that the energetic efficiency of growth decreases with the weight of the animal, owing to the fact that maintenance requirements increase in relation to the weight gain. As the pig grows older, its average rate of

Table 1. *Daily food requirements and heat production of growing and fattening pigs*

(According to Mitchell & Kelley, 1938)

| Body-weight (lb.) | Mean daily gain (lb.) | Total net energy required (Cal.) | Metabolizable energy required (Cal.) | Dry matter required (lb.) | Feed economy of gains* (lb.) | Total heat produced (Cal.) |
|---|---|---|---|---|---|---|
| 2·5 | 0·15 | 268 | 359 | 0·24 | 1·8 | 209 |
| 5 | 0·23 | 444 | 593 | 0·39 | 1·9 | 375 |
| 10 | 0·37 | 719 | 954 | 0·63 | 1·9 | 651 |
| 25 | 0·65 | 1285 | 1688 | 1·11 | 1·9 | 1233 |
| 50 | 0·97 | 1887 | 2462 | 1·62 | 1·9 | 1783 |
| 75 | 1·25 | 2422 | 3207 | 2·11 | 1·9 | 2207 |
| 100 | 1·50 | 3098 | 4141 | 2·73 | 2·1 | 2641 |
| 125 | 1·73 | 3929 | 5282 | 3·48 | 2·3 | 3206 |
| 150 | 1·95 | 5035 | 6813 | 4·57 | 2·6 | 3908 |
| 175 | 2·03 | 5756 | 7812 | 5·14 | 2·9 | 4361 |
| 200 | 1·95 | 6354 | 8639 | 5·68 | 3·3 | 4739 |
| 225 | 1·75 | 6955 | 9475 | 6·24 | 4·0 | 5100 |
| 250 | 1·55 | 8115 | 11113 | 7·31 | 5·4 | 5688 |

* Expressed in lb. food (containing 12% moisture) required per lb. gain.

growth increases until it reaches the peak, at about 175–200 lb. live weight, and then declines until eventually growth ceases altogether. The amount of the total energy required by the pig does not follow the same pattern. It gradually increases as the pig gets older and bigger, and, in terms of food required, the gain in live weight becomes progressively more expensive, and in consequence the efficiency of food utilization drops as the weight and age of the animal increase. The young pig is much more efficient in utilizing its food for growth than an older one. As soon as an animal begins to deposit fat at an increased rate, the amount of energy it requires per unit of gain also increases. Fig. 1 shows clearly the changes in the fat content of pigs of different ages. Around 100–120 lb. live weight there is an obvious turning point. It is of the greatest importance that practical pig feeders should realize that the growth of a pig involves different components at different stages of development, and these in turn require different raw materials, both qualitatively and quantitatively. Unfortunately, our fundamental knowledge is not far enough advanced to enable us to make precise recommendations on this aspect. The effect of age on the utilization of single components of the diet is only one of the unknown factors. Do younger pigs, for example, utilize the protein fraction of the ration better than older ones? Does a deficiency of a single vitamin affect the efficiency of food utilization? There is some evidence that, for example, deficiency of thiamine does (Heinemann, Ensminger, Cunha & McCulloch, 1946). There can be no doubt that at present the enlightened pig feeder allows in his preparation of rations a considerable margin of safety in the amounts of each component used in order to ensure against the risk of a deficiency. The aim of scientific investigators must be to develop means for a safe reduction of these margins.

There is a definite relationship between the nutritional quality of the ration and the efficiency with which the pig can utilize it. This relationship has recently

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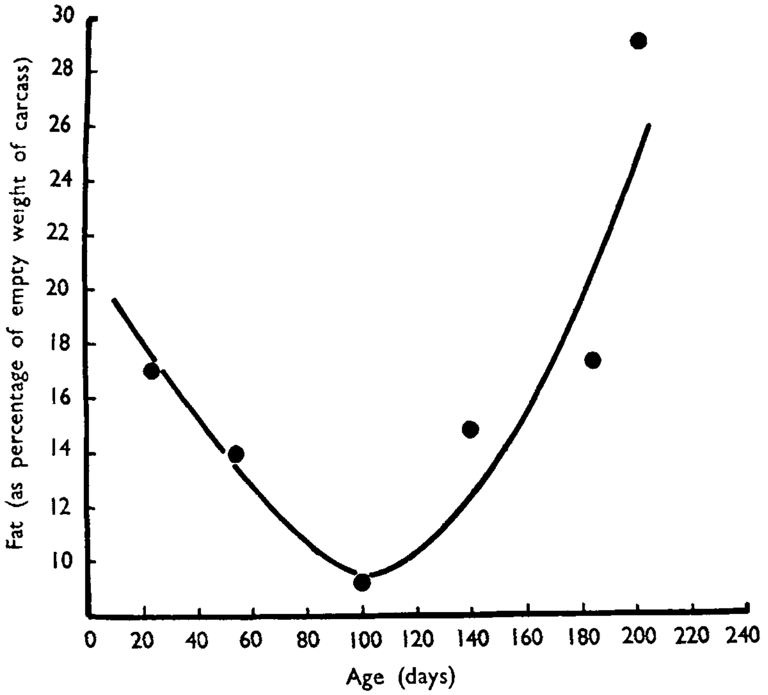


Fig. 1. Changes in fat content of pig carcasses at different ages. (From Wood, 1926.)

been demonstrated in a spectacular way by Hanson (1954) who showed that the better balanced the diet the less of it is required to produce 1 lb. live-weight gain. In his experiment the better the diet the more of it was consumed by the pigs, and the higher was the efficiency of food utilization. And, what is perhaps of the greatest significance, the pigs receiving the best-quality diet, which was by far the most expensive one, showed the highest profit.

The results of Hanson's (1954) test help to emphasize my next point, namely, how futile and often misleading is the method for expressing the efficiency of food utilization used in this and other countries. It is to express the amount of food required to produce 1lb. live-weight gain. This method ignores completely the quality of the ration, and thus its usefulness is really limited to either standardized rations or to comparisons between different rations in strictly controlled experiments.

There are several other methods for expressing the efficiency of food utilization: the starch-equivalent method of Kellner and, based on it, the Scandinavian method employing the feed units, and the American method employing the total digestible nutrients (T.D.N.). All these attempt to take into account a measure of the quality of the rations fed, and in this respect are certainly superior to the method used in this country. Unfortunately, each of these methods has some shortcomings, and there can be no doubt that we score where simplicity is concerned. It is of the utmost importance to realize that, unless the same method is used, it is absolutely futile to compare results without establishing a common denominator.

A common denominator is essential not only for the quality of the rations but also in relation to the time factor involved in calculating the efficiency values. In order to illustrate this point I have taken at random a few of our records, from which can be seen that when comparing the efficiency of different pigs it is of the utmost importance to make certain that similar initial weights, and particularly similar final weights, form the basis of the calculation. For Table 2 I have taken records for twelve pigs, covering the whole fattening period from weaning to bacon weight, and have calculated the efficiency of food utilization for different initial weights. In Table 3 the final weights form the variable factor. Whereas the initial weights, within the 35–80 lb. range, affected the calculated conversion rates only slightly, the variation in the final weights, within the 180–240 lb. range, affected the efficiency by 0·5 lb./lb. live-weight gain.

Table 2. *Effect of initial weight of pig on the calculated efficiency of food utilization. Mean for twelve pigs. Final weight: 210 lb.*

| Weight taken as initial weight (lb.) | Food conversion rate (lb. food/lb. live-weight gain) |
|---|---|
| 35–44 | 3·49 |
| 45–54 | 3·52 |
| 55–64 | 3·54 |
| 65–74 | 3·59 |
| 75–84 | 3·61 |

Table 3. *Effect of final weight of pig on the calculated efficiency of food utilization. Mean for twelve pigs. Mean initial weight: 37·3 lb.*

| Weight taken as final weight (lb.) | Food conversion rate (lb. food/lb. live-weight gain) |
|---|---|
| 180 | 3·15 |
| 190 | 3·22 |
| 200 | 3·30 |
| 210 | 3·38 |
| 222 | 3·46 |
| 230 | 3·51 |
| 240 | 3·58 |

In the incomplete knowledge of nutritional requirements of the pig new developments may acquire a sudden importance. As an illustration one can quote the recent advent of antibiotics as growth promoters. Used in minute amounts as ingredients in pigs' rations, under many conditions, antibiotics appear to stimulate growth and improve the efficiency of food utilization. As far as the latter is concerned, the available evidence points to an average improvement of 3–5%. Unfortunately, at present the mechanism through which antibiotics exert this effect is not understood and it is often difficult to explain the considerable variation in response recorded in practice. It has been suggested that antibiotics stimulate the rate of gain in a healthy pig by some mechanism operating almost entirely by way of increased appetite. An improvement in feed efficiency in no way detracts from the belief that the growth response is dependent upon an increase in feed consumption, as with the faster rate of growth a lesser proportion of the feed would be needed for maintenance.

A definite relationship appears to exist between the rate at which the pig grows and the efficiency with which it utilizes food. As a rule, other factors being equal, the faster a pig reaches bacon weight, the better is its food utilization.

This brings me to another important factor affecting the efficiency of food utilization, which can be well illustrated by some relatively old data from an experiment by Ellis & Zeller (1935). They compared gains and feed consumption of pigs on four levels of feeding. The treatments and the results are given in Table 4. The self-fed group made the highest average daily gain, but required the largest amount of feed per lb. live-weight gain. Obviously, restriction in the food allowance resulted in decreased quantity of feed required to produce a unit of gain. On the other hand, it lengthened the fattening period, the extent of the prolongation depending on the level of restriction. The self-fed pigs, compared with those restricted in food intake to 4% daily of their body-weight, took 13 days less to fatten at the cost of an extra 180 lb. of meal. This is an obvious instance where restriction would, under our conditions, result in an economic advantage. One should, however, beware of generalizations. The saving of feed is bound to be affected by a number of factors, as for example the quality of the diet fed or the thriftiness of the pigs. There can also be no doubt that in some circumstances the advantages from the saving of feed may be completely offset by increased labour charges, shortage of labour, and other undesirable factors associated with the lengthened feeding period.

Table 4. *Comparison of gains in weight and feed consumption of pigs on four levels of feeding : (a) self fed, or given a daily weight of food equivalent to (b) 4, (c) 3 or (d) 2% of the live weight*

(According to Ellis & Zeller, 1935)

| Treatment | Initial weight (lb.) | Time to reach approx. 200 lb. live weight (days) | Daily gain (lb.) | Food conversion rate (lb./lb. live-weight gain) |
|---|---|---|---|---|
| a | 66·3 | 100 | 1·45 | 5·00 |
| b | 63·0 | 113 | 1·26 | 3·80 |
| c | 61·3 | 151 | 0·95 | 3·54 |
| d | 63·3 | 224 | 0·62 | 3·50 |

In general, unrestricted feeding should be avoided not only because it lowers the efficiency of food utilization, but also because of its adverse effect on the carcass quality of the resulting pigs. With the present-day grading system in this country, the chances of obtaining the premium grades with *ad lib.* fed pigs are smaller than with reasonably restricted pigs. One should also bear in mind the figures produced by Leitch & Godden (1941), which clearly point to the fact that with unrestricted feeding the efficiency of utilization of all the major components of the ration is adversely affected.

In circumstances when the adoption of *ad lib.* feeding routine may appear advisable, consideration should be given to indirect restriction by reducing, during the last quarter of the fattening period, the starch-equivalent value of the ration. This could be apparently accomplished by including in the relatively highly digestible rations feeds high in crude fibre, or such materials that would markedly increase the bulk of the ration without contributing anything nutritionally. Experimental evidence is yet very scanty on which one could base recommendations for such methods to be employed in practice. Hardly anything is known about the effect of such routines on the efficiency of food utilization. The recent reports of Crampton, Ashton & Lloyd (1954) point to many problems that may be involved.

The effect of climate, particularly air temperature and humidity, on the efficiency of food conversion has been studied recently by Heitman & Hughes (1949), and their results are reproduced in Fig. 2. The effect of the temperature level was marked. One should, however, bear in mind that these experiments were carried out in a psychrometric chamber, on a few animals only. On the other hand, it is known

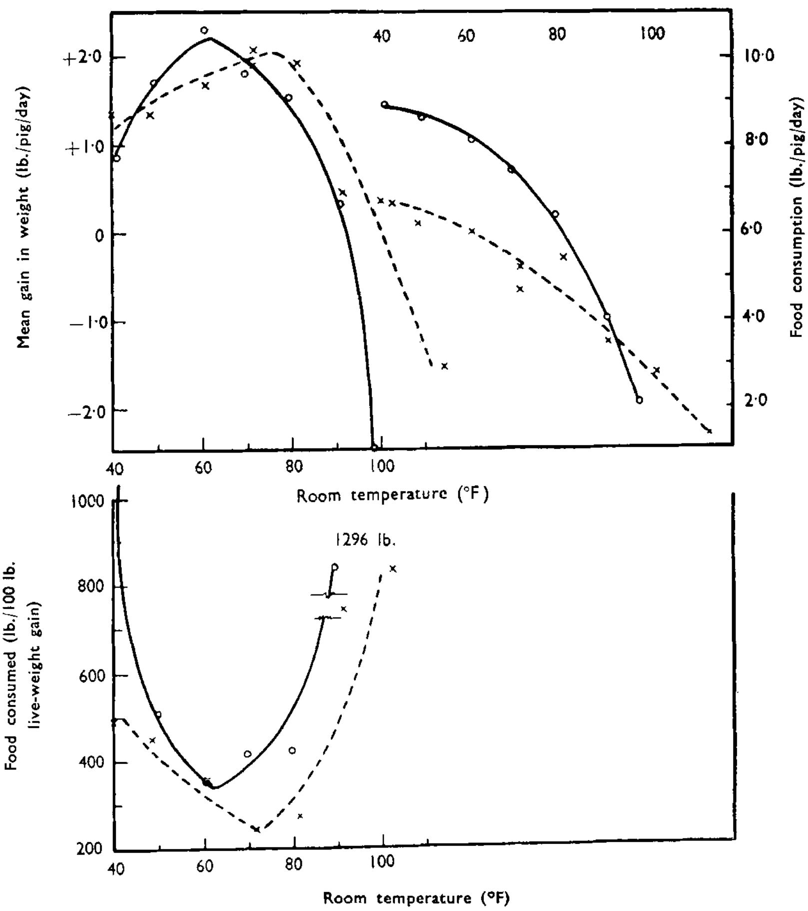


Fig. 2. Effect of air temperature on rate of gain in weight, food consumption and utilization of food by pigs. (From Heitman & Hughes, 1949.) —, pigs weighing 166–260 lb.; – – –, pigs weighing 70–144 lb.

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that the efficiency of food utilization is affected by the season of the year. Dunlop & West (1942), for example, recorded experimental evidence pointing to the fact that more food is required per unit of gain in winter than in summer.

The Danes have realized that the effect of environment may be decisive in efforts to evaluate the capacity of their breeding stock, and in their new progeny-testing stations made provisions for standardizing the climatological factors.

Space does not permit elaboration here on the extremely useful tool which progeny testing provides to the breeders of pigs. As far as food conversion is concerned, progeny testing is the only means of providing reliable information. It is essential, however, that the limitations of the method are understood before its results are interpreted. In Fig. 3 results are reproduced for a test group, where four litter-

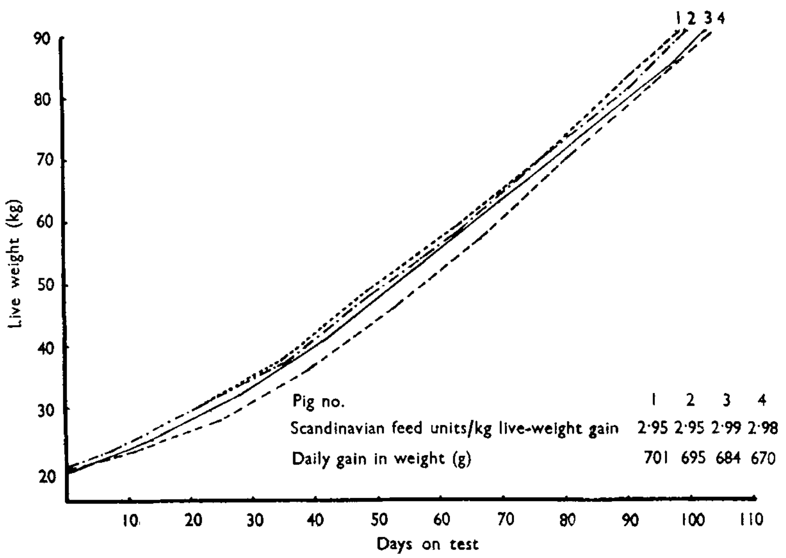


Fig. 3. Example of a test group in a progeny test on pigs where four litter-mates showed very uniform food conversion and liveweight gain. (By courtesy of Professor H. Clausen of Denmark.)

mates show a very uniform feed conversion and live-weight gain: obviously a very satisfactory picture. In Fig. 4 variations in feed conversion within a test group are presented, of the same magnitude whether due to genetic factors (curves not braking), or to illness. The Danes would discard the latter record from the test group. Unfortunately, often such a clear-cut distinction cannot be made, bringing out the point that a single test record should not have a higher value than possibly that of indicating a trend. Several test records must be available before an animal should be called 'progeny tested'.

In the United States evidence from co-ordinated trials is now accumulating on the effect of different breeding methods on the efficiency of food utilization. Table 5, taken from Gregory & Dickerson (1952), illustrates clearly the tendency to disadvantages connected with close inbreeding and apparent advantage of top-crossing. Such results must be watched closely, as in time they may provide useful clues for

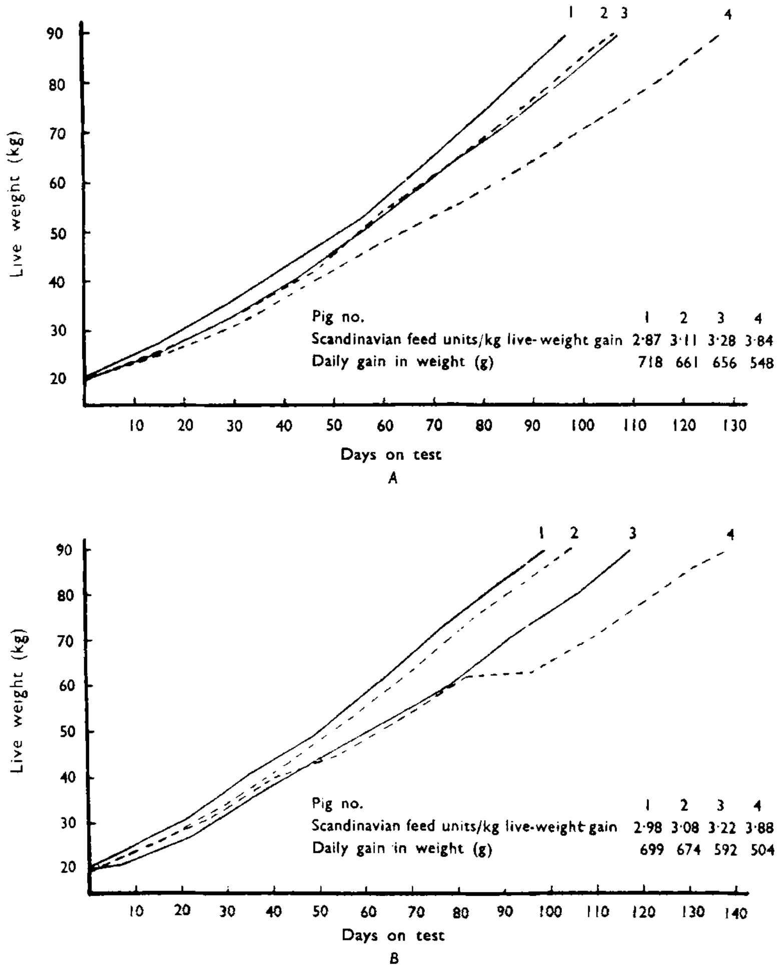


Fig. 4. Variation in food conversion rate and growth rate within a test group of pigs due to (*A*) genetic factors or (*B*) environmental factors—illness. (By courtesy of Professor H. Clausen of Denmark.)

Table 5. *Effect of breeding method on the efficiency of food utilization by pigs*

(According to Gregory & Dickerson, 1952)

| | Initial weight (lb.) | Final weight (lb.) | Daily gain/pig (lb.) | Food required/lb. gain (lb.) |
|---|---|---|---|---|
| Mean for inbreds | 28·7 | 195 | 0·90 | 4·06 |
| Mean for cross-lines | 34·8 | 207 | 1·11 | 3·80 |
| Mean for top-crosses | 30·7 | 207 | 1·19 | 3·59 |
| Mean for all non-inbreds | 32·4 | 207 | 1·17 | 3·70 |

practical pig keepers. Incidentally, the heritability of food conversion is said to amount to about 30%.

The extent to which disease can influence efficiency of food utilization can best be illustrated by evidence of Betts (1954) concerning the effect of virus pneumonia.

Some of his results are reproduced in Table 6. At this stage it is difficult to know whether these results, which deal with artificially infected pigs, are typical of what is happening in the field, but there can hardly be any doubt that the overall efficiency

Table 6. *Effects of virus pneumonia on growth rates and food conversion rates of pigs*

(From Betts, 1954)

| | Daily growth rate (lb.) | Food conversion rate (lb. food/lb. live-weight gain) |
|---|---|---|
| | Summer experiment | |
| Controls | 1·29 | 3·39 |
| Infected | 1·11 | 4·25 |
| | Winter experiment | |
| Controls | 1·19 | 3·85 |
| Infected | 0·92 | 4·90 |

may be markedly affected not only by clinical disease, but also by subclinical conditions of ill-health.

There is no doubt in my mind that the palatability of rations affects consumption by the animal, and thus has a bearing on the efficiency with which the ration is utilized. The whole subject has as yet not been properly investigated, but a number of ideas may find general application in the future. For example, evidence has been put forward that by feeding pellets instead of meal (e.g. the recent paper by Steffen, 1954, see Table 7), or by adding sugar to the diet of baby pigs (Nelson, Hazel, Moore, Maddock, Ashton, Culbertson & Catron, 1953), the efficiency of food utilization can be improved.

Table 7. *Comparison of meal and pellets in their effect on mean daily gain in weight and efficiency of food conversion by pigs. Four lots of eight pigs each on each treatment*

(From Steffen, 1954)

| | Meal | Pellets |
|---|---|---|
| Initial weight (lb.) | 81·97 | 81·12 |
| Final weight (lb.) | 186·22 | 191·55 |
| Daily gain (lb.) | 1·68 | 1·78 |
| Feed consumed/lb. gain (lb.) | 4·14 | 3·82 |

There is one further point which I wish to stress. Most of the fundamental work on the nutritional requirements of the pig has been carried out on the growing-fattening animal, and other classes of pigs have been very much neglected. Recently in our studies on the composition and yield of milk in the sow (Barber, Braude & Mitchell, 1955) we obtained some new data on the efficiency with which the very young pig utilizes its food. Although the values in Table 8 are based on three

Table 8. *Efficiency of food utilization in suckling pigs*
(Unpublished data of Barber, Braude & Mitchell)

| Age of pig (days) | Consumption/g live-weight gain Milk (g) | Meal (g) | Dry matter (g) |
|---|---|---|---|
| 0–7 | 3·78 | — | 0·76 |
| 8–14 | 4·01 | — | 0·80 |
| 15–21 | 4·30 | — | 0·86 |
| 22–28 | 5·07 | 0·15 | 1·15 |
| 29–35 | 4·84 | 0·14 | 1·09 |
| 36–42 | 3·96 | 0·38 | 1·13 |
| 43–49 | 3·46 | 0·63 | 1·25 |
| 50–56 | 1·87 | 0·84 | 1·11 |

litters (thirty-one pigs) only, they show an interesting trend. There is very great need for factual evidence on efficiency of food conversion in baby pigs, gestating, lactating and empty sows, and I hope it will not be long before such evidence is forthcoming.

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## Factors Affecting the Efficiency of Food Conversion in Poultry

By W. Bolton, *Poultry Research Centre, King's Buildings, West Mains Road, Edinburgh* 9

Experiments on the efficiency of food conversion by poultry can be subjected to several criticisms. First, the assessment of food intake has not been sufficiently detailed. Most workers have used gross food consumption, thereby ignoring the relative digestibilities of the ingredients; others have used gross digestible nutrients but have based their digestibility values on the tables published by Woodman

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