THE NUTRITIONAL REQUIREMENTS OF SWINE

D. M. SMITH

Ruakura Animal Research Station, Hamilton.

SUMMARY

Three basic aspects of the nutritional complex of swine are considered:

(1) The maintenance requirements of pigs and methods which could be used to reduce these.
(2) The productive portion of rations and methods of making more efficient use of this.
(3) The effect of such increases in efficiency upon the end product, when the herd rather than the animal is considered as the unit of production.

IT IS NOT the purpose of this paper to discuss the requirements of swine in terms of minerals, vitamins, amino acids, or protein-energy relationships. These aspects have been adequately dealt with in three excellent reviews recently published by Lodge and Lucas (1959), Lucas (1960), and Duncan and Lodge (1960).

Rather than discuss these aspects, this paper will be concerned with developing the thesis that the aim of the research worker in the field of pig nutrition should be to determine the animal, the practice, or the product, which, within practical limits, lends itself to the most efficient use of the nutrients supplied, rather than devote his time to determining the most efficient way of carrying out standard practices, or producing conventionally desirable products. In developing this thesis three basic aspects of the nutritional complex will be considered.

(1) The maintenance requirements of pigs and methods which could be used to reduce these.
(2) The productive portion of rations and methods of making more efficient use of this.
(3) The effect of such reductions upon the end product when the herd rather than the animal is considered as the unit of production.

MAINTENANCE REQUIREMENTS

When an attempt is made to find reliable estimates or determinations of the maintenance requirements of pigs in the published literature, it quickly becomes apparent that few exist and even these are not consistent. Since all animals must be maintained and since a great deal of the feed expended in the animal industry of the world is devoted to this purpose, it is surprising that more research effort has not been directed to the study of this quantitatively important aspect of animal husbandry. Some of the estimates in common use are extremely misleading. For example, the data published by Woodman (1957) which indicate the feed required for maintenance of pigs between 50 and 300 lb liveweight, when used to calculate the proportion of the metabolizable energy of the production ration which is recovered in the carcass, using Mitchell and Kelley's (1938) data for the energy content of gain, p[illegible]te doubtful information that the energy storage from a pound of liveweight gain on pigs between 50 and 150 lb is somewhat greater than the metabolizable energy required to produce that gain.

This would indicate that the estimates used for maintenance are unduly high, as pointed out by Mitchell and Kelley (1938). The problem arises from the method of determination of the basal metabolism of pigs and the difficulty lies in making accurate assessments of the energy expenditure for muscular activity which must be added to the basal energy expenditure to arrive at the maintenance requirement. In this paper, Mitchell and Kelley's conclusion that the basal energy measurement should be increased by 20% to allow for movement has been accepted for growing and fattening pigs while the allowance for grazing sows has been taken as 100% above basal.

It would appear, therefore, that the activity factor in animal maintenance is one that requires a great deal more study. In the meantime, it is one which is subject to some control in the fattening pig, and measures to reduce unnecessary activity to a minimum are worthy of study. Wood (1926) has stated that fighting at the trough or distress from heat will cause a substantial rise in maintenance requirements. More obviously the energy expenditure by the sow in moving a mass of 300 to 600 lb round a pasture or dry-lot must be very substantial.

The questions may, therefore, be asked (a) whether smaller sows, deliberately prevented from reaching high mature size and weight, would not be more economical than large sows, and (b) whether exercise is essential to the pregnant or lactating animal. The weight of a gilt at puberty or mating and her subsequent changes in weight are essentially dependent upon the level of nutrition to which she is subjected. It has always been considered "sound practice" to mate gilts only after they have reached 230 to 250 lb liveweight, to feed them at a level which will enable them to gain 120 to 150 lb during the first pregnancy and 100 to 120 lb in subsequent pregnancies. It has also been considered usual for gilts and sows to lose between 30 and 70 lb during lactation.

Recent work has shown (Self, Grummer and Casida, 1955) that gilts fed on a low ration (two-thirds of self-fed mates) reached puberty at 208 days weighing 166 lb while those fed on a high ration were 223 days of age and 211 lb at puberty. Haines, Warwick and Wallace (1959) found that gilts gaining 0.3 lb per day were 217 days of age at first puberty and 160 lb while those gaining 1 lb per day were 195 days of age at puberty and 196 lb. In the latter experiment, the treatments were imposed when the gilts were 122 days of age and between 114 and 130 lb liveweight.

It would appear, therefore, that puberty may be delayed in gilts if a level of feeding which provides for liveweight gains of only 0.3 lb per day is imposed.

This observation raises the question of the importance of age at puberty in breeding stock. If gilts are retained to replace their dams in the farrowing rotation, the normal age at mating would be 240 to 250 days. If the principle of mating at first post-pubertal heat is adopted in order to take advantage of the normal increase in ovluation rate which occurs between first and second heat, the severely restricted gilts in the above experiments would still fit into the replacement plan. There is no valid reason therefore, except aestheticism, for allowing gilts to reach higher weights than 160 lb at seven months of age.

Data from the above experiments, and also from those of Gossett and Sorensen (1959a), have shown that gilts raised to puberty and maintained on low rations between the first and second oestrus and thereafter until slaughter 25 days after mating at second oestrus shed fewer eggs at both heats but showed a greater embryonic survival than gilts well-fed throughout.

Subsequent work by Zimmerman *et al.* (1950) has shown that ovulation rate at second oestrus in gilts can be raised substantially by increasing the feed intake from 2½% of body weight to approximately 3.2% for 6, 10 or 14 days before second oestrus. The method which achieved the best results was to increase the energy intake by using lard. Previous work by Self *et al.* (1955) had shown that feeding levels of low, high, and low for the three periods, pre-puberty, first oestral cycle, and first 25 days of gestation, the animals being mated at second oestrus, resulted in a greater number of normal embryos than treatments consisting of low or full feeding throughout.

It is thus possible to obtain large litters from gilts which are raised to puberty on a low level of nutrition by flushing prior to the second heat and by again lowering the intake subsequent to mating. Such gilts need not weigh more than 160 to 190 lb at mating.

Information on the nutritional requirements of pregnant sows and gilts is available from a large number of experiments but no clear-cut conclusion can be drawn. In many of these experiments using sows, confusion is caused, by failure to distinguish between the level of nutrition required to replenish body reserves depleted during the preceding lactation. The present habit of research workers, of slaughtering sows and gilts after 25 days' pregnancy because embyro survival rate at this stage is highly correlated with size of litter at full term, is not only open to question (Gossett and Sorensen, 1959b), but has deprived the nutritionist of very useful data on the effect of feeding upon birthweight, viability and mortality, which are badly needed. In view of the paucity of information, the results of work by Ballinger (1940) and his subsequent unpublished data, together with present practice at Ruakura suggest that weight gains of 70 to 80 lb for gilts and 50 to 60 lb for older sows, including growth of uterine contents of the order of 25 to 35 lb for gilts and 40 to 50 lb for older sows, is adequate to ensure big and healthy litters. These gains are adequate only when the animals do not need to replace body tissues catabolized during the previous lactation, an aspect which will be discussed later.

On the basis of these figures, a pregnant gilt need never weigh more than 270 lb during first pregnancy and never more than 300 lb in any subsequent pregnancy.

The use of 300 lb sows in the herd in place of 400 lb sows would mean a saving of approximately 150 lb of meal equivalent in the course of a reproductive cycle, and, on present evidence, would not reduce litter size. The effect of the condition of the sow at farrowing upon the milk yield and milk energy yield during the subsequent lactation has been studied at Ruakura (Smith, 1960) The results of this study are shown in Table 1.

It may be concluded that sows in low condition at farrowing, but fed to maintain weight during lactation (low-high) produce more milk—but not more milk energy—than sows in high condition at farrowing but which lose weight during lactation (high-low). It would appear, therefore, that in terms of litter size and milk production, the nutritional restriction of the mature

TABLE 1: THE YIELD AND COMPOSITION OF THE MILK OF THE SOWS IN THE THREE GROUPS

Sow No.	*Milk Yield (lb)*	*Milk Energy (therms)*	*Fat %*	*Protein %*	*Lactose %*
TREATMENT:	HIGH-LOW:				
131	763	471	9.2	5.7	4.8
132	699	441	9.6	5.7	4.7
128	509	335	10.1	6.2	4.4
Mean/Sow:	657	415.6	9.6	5.8	4.6
Mean/Piglet:	68.0	43.0			
kcal/lb Milk:	633				
TREATMENT:	LOW-HIGH:				
129	925	487	6.7	6.0	4.0
130	591	365	9.3	5.5	4.9
127	795	416	6.7	5.9	4.9
102	732	404	7.3	6.2	4.7
Mean/Sow:	760.7	418	7.5	5.9	4.9
Mean/Piglet:	82.3	45.1			
kcal/lb Milk:	550				
TREATMENT:	LOW-LOW:				
133	610	376	9.1	5.9	4.6
134	810	495	9.0	6.0	4.5
122	547	317	8.0	6.4	4.6
120	229	141	8.9	6.2	4.6
107	698	417	8.5	6.1	4.7
Mean/Sow:	578.8	349.2	8.7	6.1	4.6
Mean/Piglet:	65.8	39.7			
kcal/lb Milk:	603				

size of sows would have no ill effects while conferring the advantage of lowered maintenance requirements. On the other hand there is no experimental evidence that supports the present concept of "sound practice".

The problem of gilt selection is one which must arise if females are not allowed to express their inherent growth rate to full market weight of 200 lb. Various estimates of the heritability of growth rate to 100 rather than 200 lb (Fredeen, 1953) suggest that, while some accuracy may be lost by selecting at the lower weight, the difference will hardly be sufficient to warrant the extra feed requirement of the resultant heavier pig. It is probable that more breeding troubles would arise where gilts were grown rapidly to 200 lb and then merely maintained at that weight until mating, as compared with selection at about 120 lb and slow growth made thereafter to mating.

Apart from the reduction in maintenance costs owing to smaller, lighter animals, sow maintenance during lactation can be further reduced by mating the sow while she is still suckling her litter. In this way the maintenance requirement of the sow during the period over which gestation and lactation are proceeding concurrently may be debited to the subsequent litter.

This system has been successfully developed at Ruakura (Smith, 1961a) by separating the sows from their litters for 12 hours daily, commencing 3 weeks after farrowing. Sows can be mated successfully four to six days after commencement of the treatment and present data indicate that the number and health of the resulting litters is in no way affected.

It is estimated that by this method the overhead cost of a suckling litter can be reduced by the equivalent of approximately 140 lb of meal for sows of 400 lb and 115 lb of meal for a sow of 300 lb. A further obvious method of reducing maintenance cost is to reduce the energy expenditure on muscular activity. Under a feeding regime which includes grazing by pregnant sows, this can be done by the use of strip grazing techniques on pasture which has been allowed to grow to a height of four to six inches and consists of palatable species. Under such a system selective grazing is apparently eliminated and the distance walked by sows is reduced to a minimum.

The provision of water wallows, sprays and shade to reduce or eliminate any increase in respiration rate in hot weather is an additional means of keeping muscular energy expenditure to a minimum.

When sows are not expected to graze, there is no evidence that exercise is of any benefit, or rather that lack of exercise is in any way detrimental to the sow or her developing litter (Vestal, 1938). Therefore, under dry-lot conditions unnecessary activity should be discouraged by confinement to small areas during pregnancy.

Recent reports of English farmers keeping sows in their farrowing crates continuously from farrowing until the litter is 14 to 21 days of age without any apparent ill effects suggest that there is also scope for reducing the muscular activity of the lactating sow.

The total or the lifetime maintenance requirements of pigs is one of special importance in relation to growing animals destined for slaughter at a pre-determined weight. Since maintenance is a daily energy cost, the fewer days spent in reaching slaughter weight the smaller are the total maintenance requirements.

There are obvious limits to this process which will be discussed later, but increased knowledge of the requirements of growing stock for nutrients such as minerals, vitamins, and amino acids, where applied, has speeded the growth rate and feed efficiency of pigs materially in the last 20 years and thus reduced maintenance costs.

MAKING THE MOST EFFICIENT USE OF THE PRODUCTIVE RATION

Once maintenance requirements are satisfied, the meat output from a herd per pound of feed expended depends upon the way in which the productive portion of the ration is used.

Table 2 was prepared to provide some indication of the relative returns from the feeding of the same quantity of productive ration (in the form of metabolizable energy) to various classes of stock within a herd.

TABLE 2: WEIGHT GAINS AND ENERGY INCREMENTS FROM 4,900 KCAL OF METABOLIZABLE ENERGY FED AS A PRODUCTIVE RATION

	Pregnant Sow	*Litter Gain through Sow*[*]	*Litter Gain from Creep*	*Fattening Pigs (lb)*		
				100	*150*	*200*
Liveweight gain (lb)	1.0	1.70	3.36	1.6	1.5	1.4
Gross energy in weight gain (kcal)	3,300	1,930	3,360	2,900	3,150	3,280
Carcass gain (lb)	0.8	1.27	2.5	1.3	1.2	1.1
Monetary value	x	$2x$	$2x$	$2x$	$2x$	$2x$
Relative return	100	320	600	320	300	250

[*]It is estimated that the sow would convert a productive ration of 4,900 kcal to 4,240 kcal of gross milk energy which the litter would convert to 1.7 lb of liveweight gain.

This table indicates that feed used in the creep or for early weaned litters yields the greatest carcass gain and monetary return; feed used for lactating sows and pigs up to 100 lb liveweight shows the second highest return, and that fed to pigs up to 150 and 200 lb shows progressively smaller returns, while feed used to increase the weight of pregnant sows shows the least return.

It is unfortunately necessary to use sows as incubators for developing foetuses which, when born, will be raised to marketable weights. It is similarly unfortunately necessary to use the lactating sow as a source of nutrients for the litter after birth, but neither of these practices is especially efficient, and the least possible amount of feed should be expended upon them. For this reason it is appropriate to re-examine the whole concept of reproduction in the sow and distinguish between standard practice and fact.

It is standard practice to feed pregnant sows at a level which will enable them to replace tissues catabolized during the previous lactation and in addition accumulate energy stores ready for the drain of the next lactation, apart from the needs of the developing litter which are small. The data in Table 2 suggest that this practice is wrong in the following respects:

(1) The feed expended in increasing the weight of the pregnant sows by one pound would produce more weight if fed to any other class of stock in the herd.

(2) The loss of one pound of liveweight by the lactating sow provides only 3,300 kcal of energy even assuming there are no catabolic losses. This energy will produce only 1.4 lb of gain in the litter, whereas the 4,900 kcal of feed energy required to produce a pound of gain in the pregnant animal, would, if fed to the lactating sow, enable her to produce sufficient milk to provide for a litter gain of 1.7 lb.

The practice of feeding sows so that they gain weight during pregnancy with the aim of utilizing the stored energy during lactation is thus both energetically and practically unsound. It follows that sows should be fed at a level which will allow them to maintain weight during lactation. It has been suggested that this is not possible under normal conditions. The weight changes of a sow during lactation are dependent upon two major factors:

(1) The level of milk production.

(2) The appetite of the sow.

One of the proclaimed aims of pig breeders is to breed sows capable of high milk production. Large sums of money are expended annually by pig recording organizations to help the breeder achieve this aim in the belief that high milk production in the sow is the surest and, by implication, the most economic method of ensuring heavy weaners. Smith (1960) has presented evidence that there is an inverse relationship between sow milk energy intake by the litter and creep consumption. It has also been shown (Table 2) that feed consumed by the litter directly from the creep is converted to liveweight more efficiently than feed processed by the sow and presented to the litter in the form of milk.

Ruakura data (Smith, 1952), suggest that sows producing about 950 lb of milk, receiving 6 lb of meal per sow and 1 lb for each pig suckled, lose approximately 70 lb during an eight-week lactation and their litters consume the equivalent of 20 lb of meal per pig from the creep. On the other hand, sows which produce approximately 770 lb of milk (Smith, 1960) maintain their weight on a ration level of 4½ lb of meal per sow and 1 lb per pig suckled and the litters consume between 30 and 35 lb of meal per pig from the creep to wean at a comparable weight to those suckling heavy yielding sows. There is reason, therefore, to believe that excessively high milk production is not conducive to efficient feed usage since the feed energy intake required to support high yields often exceeds the appetite of the animal with the result that there is an excessive weight loss. In addition, a high level of sow milk intake by the litter reduces creep intake. The aim of the breeder should, therefore, be adapted to fit the nutritional facts.

The data in Table 2 also indicate the nutritional soundness of early weaning as a method of improving the efficiency with which the productive ration can be used. There is no difference of opinion amongst nutritional workers on this matter. The problems are rather those of management and cost which further research will undoubtedly solve.

The efficient use of a productive ration when fed to growing, fattening stock is obviously tied closely to the weight of the animal being fed, the lighter animal producing a greater weight gain than the heavier from a given quantity of feed.

The weight gain per unit of feed can, however, be materially altered by the level of feeding practised. There is a well-established reduction in efficiency of utilization as intake is raised owing to decreased digestibility and increased specific dynamic action. There is also an interaction between daily weight increment and length of fattening life which in turn affects the total maintenance requirement of the animal. There should be an optimum level of feeding above which reduction in total maintenance through reduced fattening time will not offset increased losses from reduction in digestibility and increased S.D.A. Unfortunately, this point is not easily determined and will in any case vary with environmental temperature (Lucas and Calder, 1955), breed of pig (Deighton, 1929), and type of food (Brody, 1945).

At present there exist two schools of thought on feed allowances for growing pigs. One school holds the view that restricted feeding at least during the latter stages of growth (a) is more efficient and (b) results in a carcass containing less fat. The opposing school holds the view that pigs should be selected for efficiency of feed conversion and carcass quality under *ad lib.* feeding conditions so that the full growth potential, and, hence, the maximum saving in maintenance costs can be realized and the labour involved in hand-feeding reduced. It is general practice, however, under grain feeding conditions, to self-feed pigs from weaning to 120 lb liveweight, a fact which is of significance in relation to the following discussion.

THE HERD AS THE PRODUCTION UNIT

Most research workers are obliged, through restrictions in finance, space, available animals, essential services, or life expectancy, to confine their activities to a relatively few facets of pig production.

If research is to serve industry efficiently, the results from these rather unconnected fields must be integrated into the general concept of production, and an assessment made of their effects upon other phases of the production process.

The preceding discussion has dealt mainly with methods of reducing the nutrient requirements for reproduction. It has been suggested that, by using smaller lighter sows, by allowing minimum liveweight gains during gestation, by restricting muscular activity, by breeding sows for moderate rather than high milk yields, by feeding these sows at a level which enables them to maintain weight during lactation, by encouraging con-

TABLE 3: THE EFFECT OF EARLY WEANING UPON COMBINED SOW AND LITTER FEED ENERGY CONVERSION AND THE DISTRIBUTION OF FEED BETWEEN REPRODUCTION AND FATTENING (SMITH, 1961b). (Feed energy requirements calculated on total feed energy consumption.)

	Light Pork Production				*Bacon Production*			
	Reproductive Cycle		*Growth 40-100 lb*		*Reproductive Cycle*		*Growth 40-190 lb*	
Treatment	*Therms feed lb/ gain*[1]	*% of total feed*	*Therms feed lb/ gain*[2]	*% of total feed*	*Therms feed lb/ gain*	*% of total feed*	*Therms feed lb/ gain*[3]	*% of total feed*
Weaned at 8 weeks	5.6	52	3.3	48	5.6	24	4.6	76
Weaned at 20 days	4.4	49	3.3	51	4.4	20	4.6	80

(1) All calculations based on litters of 10 suckled and fattened.
(2) Based on a feed conversion of 2.5 lb of meal/lb of gain.
(3) Based on a feed conversion of 3.5 lb of meal/lb of gain.

sumption of supplementary feed by the litter, by initiating pregnancy during lactation or by early weaning, the feed expended in the production of a litter to weaning, in other words, sow overhead, will be materially reduced.

The effect of one of these measures, early weaning the litter at 21 days of age, upon the efficiency of feed utilization in weaner production and the consequent change in the proportion of total feed used for reproduction and for fattening are shown in Table 3.

The change in the relative efficiency of feed usage for reproduction and fattening where early weaning is practised results, in the case of bacon production, in 80% of the total feed expenditure being used less efficiently than the remaining 20%. This calls for re-examination of economic marketing weight and Fig. 1 illustrates the principle that as sow overhead is reduced, economic marketing weight is also reduced.

It is suggested that the major advances are likely to be made in reducing sow overhead, as outlined earlier, and these could lead to a modification of present breeding policies since pigs which are considered as having the optimum fat-lean ratio at 200 lb could be underfinished if it was found more economic to market them at 150 lb liveweight.

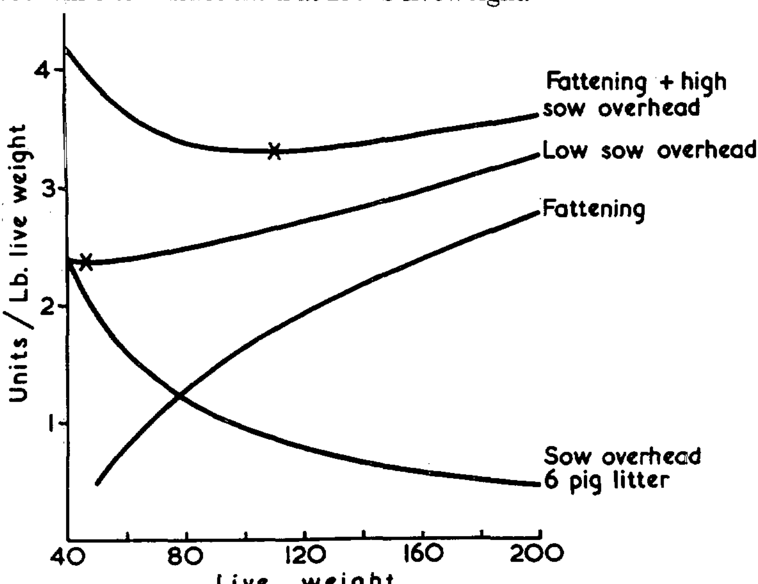

Fig. 1: The effect of lowered sow overhead feed requirements upon economic market weight.

Marketing and processing methods which are geared to deal with heavy pigs would also need modification to deal with lighter pigs. It is possible, on the other hand, that, instead of changing breeding policy toward an early maturing pig, self feeding could be practised right up to a lighter market weight with present stocks, resulting in more rapid gains and reduced maintenance requirements. Any increase in efficiency in the fattening phase arising from such a change in practice would, of course, have the effect of raising the economic marketing weight, illustrating the constant interaction resulting from changes in efficiency in one or another phase of production.

It is believed that production and marketing methods and so-called consumer preferences are much more amenable to change than nutritional principles and that the quantitative nutritional requirements of swine will be substantially reduced only if these principles are not sacrificed to satisfy accepted practices.

REFERENCES

BALLINGER, C. E. (1940): *N.Z. J. Agric., 60*: 351.

BRODY, S. (1929): *J. agric. Sci., 19*: 140.

DUNCAN, D. L., LODGE, G. A. (1960): *Commonw. Bur. Anim. Nutr. Tech. Commun., No. 21.*

FREDEEN, H. T., (1953): *Genetic Aspects of Canadian Bacon Production.* Dept. Ag. Canada. Publication 889.

GOSSETT, J. W., SORENSEN, A. M. (1959a): *J. anim. Sci., 18*: 40.

——— (1959b): *J. anim. Sci., 18*: 48

HAINES, C. E., WARWICK, A. C., WALLACE, H. D., (1959): *J. anim. Sci., 18*: 347.

LODGE, G. A., LUCAS, I. A. M. (1959): *Breeding and rearing pigs. Scientific Principles of Feeding Farm Livestock.* Farmer and Stockbreeder Publications Ltd., London.

LUCAS, I. A. M., CALDER, A. F. (1955): *J. agric. Sci., 46*: 56.

LUCAS, I. A. M (1960): *Proc. Conf. agric. res. Workers and agric. Economists.* Bath, England, p. 32.

MITCHELL, H. H., KELLEY, M. A. R. (1938): *J. agric. Res., 56*: 811.

SELF, H. L., GRUMMER, R. H., CASIDA, L. E. (1955): *J. anim. Sci., 14*: 573.

SMITH, D. M. (1952): *N.Z. J. Sci. Tech., 34A*: 65.

——— (1960): *N.Z. J. agric. Res., 3*: 745.

——— (1961a): *N.Z. J. agric. Res.* (in press).

——— (1961b): *N.Z. J. agric. Res.* (in press).

VESTAL, D. M. 1938): *Feeding and Management Experiments with Brood Sows and Litters.* Bull. 413. Ind. Agr. Expt. Sta.

WOODMAN, H. E. (1957) *Rations for Livestock.* Minist. Agric., Bull. 48, 14th ed.

WOOD, T. B. (1926): *J. agric. Sci., 16*: 425.

ZIMMERMAN, D. R., SPIES, H. G., SELF, H. L., CASIDA, L. E. (1960): *J. anim. Sci., 19*: 295