
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

PROTEIN PRODUCTION FROM PIGS

J. R. CARR
Massey University, Palmerston North

SUMMARY

Efficiencies of dietary energy and protein utilization for muscle protein synthesis are examined, in relation to variation in some principal factors that influence the efficiency of muscle protein production from pigs.

It is concluded that with existing techniques and knowledge, dietary crude protein and digestible energy intakes, per kilogram muscle crude protein gain, of 6.5 kg and 127 Mcal, respectively, should be attainable in practice, and that respective values of 5.6 and 107 should soon be reached.

THE PRODUCTION of pig meat may be divided, both in discussion and practice, into two phases—the *breeding* phase, concerned with the production of weaners and the *growing* phase concerned with production of the slaughter animal from the weaner. The combined efficiencies of the two phases determine the overall efficiency of protein production from pigs, and each is differentially influenced by a variety of genetic and environmental factors. Some of the more important of these are considered in this paper.

In view of the role of protein in human nutrition, any assessment of the efficiency of protein production for human consumption should be made in terms of essential amino acid yields. In this respect the following discussion will be inadequate. Most experimental data concerned with the efficiency of pig meat production provide information only in terms of liveweight change, with, at best, some indirect and superficial index of carcass "lean". Sources of inaccuracy in interpretation of such data in terms of carcass "lean" or protein contents have been documented (Cuthbertson and Pease, 1968; Lawrie, *et al.*, 1963; Osinska, 1968). The situation is further aggravated in that not all carcass protein is edible.

In the following account it is assumed that carcass "lean" and carcass protein contents are synonymous, and that changes in either are reflected by equivalent changes in muscle protein content. The latter is taken as an estimate of edible carcass protein. The inherent inaccuracies and limitations of these assumptions and the omission from consideration of amino acid production are recognized.

THE BREEDING PHASE

A share of the maintenance and service charges of the breeding herd must be borne as an overhead cost by each weaner at the start of the growing phase and ultimately by each kilogram of meat or protein produced. The magnitude of this cost is largely determined by the annual feed consumption of the sow herd, with which it is positively correlated, and by the number of weaners produced by the herd each year, with which it is negatively correlated. Some of the more important factors which influence these two determinants of breeding herd efficiency are considered below.

Feed Allowances for Sows

Depending upon slaughter weight of the progeny, feed intake of the breeding herd may represent 20 to 40% of the total feed consumed in the production of pig meat protein, which in turn may account for up to 80% of the total production costs. Variation in feed allowances for the breeding herd is thus economically important.

From recent studies to determine the absolute feed requirements of breeding sows and the effect of feed distribution between gestation and lactation on the efficiency of feed utilization for weaner production, it is now recommended (ARC. 1967) that daily feed allowances during gestation should be such that net sow gain over pregnancy approximates 20 kg, and that feed allowances during lactation should be sufficient to maintain body weight. Accordingly, a sow weighing a maximum of 135 kg is allowed approximately 1700 Mcal of apparent digestible energy during each cycle, of which 40% is given during gestation (5.5 Mcal/day), and 60% during a fifty-six day lactation (18.3 Mcal/day). Variation from this distribution of feed, may, on the one hand, result in reduced reproductive performance as the quantity given during gestation decreases, and, on the other, in reduced energetic efficiency as the gestation allowance increases. Consequently there is little margin for error in applying these recommendations, necessitating the provision of individual feeding facilities for sows at all stages of reproduction.

Both the total feed offered according to the above recommendations, and in particular that allowed during gestation, are appreciably less (11% and 50%, respectively) than quantities previously recommended (NRC, 1964). The former is also probably far less than had been commonly employed in the field—data of the Cambridge Pig Management Scheme for the 1962-3 period (cited by ARC, 1967) suggest by as much as 30 to 80%.

There is little doubt that reduced feed allowances for breeding sows have been progressively adopted in the field, but there still exists considerable scope for improvement in breeding herd efficiency by this means. Exploitation of individual feeding and penning systems for the pregnant sow must continue.

Rate of Litter Production

Shortening of the reproductive cycle by premature termination of lactation and artificial rearing of the offspring, provides a direct means for increasing the rate of litter production and the output of weaners each year. In addition, because daily feed requirements for lactation are approximately three times those for gestation, sequential reductions in feed consumption of the sow for each litter produced results as lactation is progressively shortened, although this advantage is partly offset by the feed consumed by the artificially reared offspring.

Traditionally lactation has proceeded for eight weeks, and given 15 to 20 kg weaned piglets. Weaning at any stage earlier than this has been termed "early weaning".

For the full advantages of early weaning to be realized, not only must the offspring be successfully reared artificially, but the subsequent reproductive performance of the dam must be normal.

Recent developments in baby-pig nutrition and in techniques of artificial rearing permit the successful rearing of piglets weaned at four or five days of age at about 3 kg liveweight, provided careful attention is directed towards disease and climate control (Braude, *et al.*, 1969, 1970a, b, 1971; Bengtsson *et al.*, 1970; Best, 1971). In this respect, then, there appears little limitation to the extent to which lactation may be shortened. However, while shortening of lactation to about three weeks has little if any adverse effect on the subsequent reproduction of the sow, it is reported (Best, 1971) that sows weaned within ten days of parturition suffer delayed onset of the first subsequent oestrus, reduced conception rates at this oestrus and reduced litter size following conception, which cumulatively nullify any advantages of very early weaning. For this reason it is concluded that there is no evidence to warrant weaning at much less than three weeks. At the same time there is no justification for weaning much later than at three weeks and in the field the scope for improved efficiency is probably considerable.

LITTER SIZE

Between-breed differences in litter size have been documented by Duncan and Lodge (1960). Of the improved European breeds, the Large White generally excels.

Heritability estimates of litter size are invariably less than 0.1 and direct selection for this trait seems hardly warranted (Strang and King, 1970). Litter size can however be improved immediately through heterosis by the adoption of hybridization programmes (Hill, 1971). The data of Smith and King (1964) indicate a 5 and 8% improvement in litter size at eight weeks of age, over the parental purebreed average, from two-way and backcross breeding systems, respectively, and that further improvement could be expected from three-way crossing involving cross-bred dams. Approximately 50% of these improvements reflect reduced post-natal mortality.

Although the future role of crossbreeding in pig meat production has been questioned (Braude, 1970), it has been generally accepted that the adoption of systematic crossbreeding programmes offers the most satisfactory approach to increased weaner output by the breeding herd through increased litter size (Hill, 1971). To obviate the need for selection for traits other than litter size in at least two distinct populations, which adds to the cost and complexity of the usual continuous crossbreeding systems, a progression from such systems could be the development of single synthetic populations by mating the hybrids *inter se*. However, Hill (1971) suggests that as little would be gained either in the short or long term from such a policy, it is probably advisable to keep populations apart so that they can be substituted if necessary as circumstances demand.

The foregoing simply illustrates ways by which the efficiency of weaner production may be improved, but gives no indication of absolute efficiency or of the possible magnitude of this improvement. An attempt to do so is made in Table 1, in which estimates of the efficiencies of dietary energy and protein utilization for muscle protein synthesis are presented in relation to age at weaning and litter size. In each case energy intakes of the sow are based

TABLE 1: ESTIMATES OF THE EFFICIENCIES OF APPARENT DIGESTIBLE ENERGY AND CRUDE PROTEIN UTILIZATION FOR MUSCLE PROTEIN SYNTHESIS IN WEANERS OF 17 KG LIVE-WEIGHT, IN RELATION TO AGE AT WEANING AND LITTER SIZE (EXCLUSIVE OF SIRE'S REQUIREMENTS)*

Age at weaning (days)	4		21		56	
Litters/sow/yr	2.70		2.40		1.95	
Weaners/litter	9	11	9	11	9	11
Weaners/sow/yr	24.3	29.7	21.6	26.4	17.6	21.5
LW gain of weaners (kg/sow/yr)	413	505	367	449	299	366
Muscle gain of weaners (kg/sow/yr)	159	195	141	173	115	141
Muscle CP gain of weaners (kg/sow/yr)	31.8	39.0	28.2	34.6	23.0	28.2
LW gain of sow (kg/yr)	27	27	24	24	20	20
Muscle gain of sow (kg/yr)	12	12	11	11	9	9
Muscle CP gain of sow (kg/yr)	2.9	2.9	2.1	2.1	1.7	1.7
ADE intake of sow (Mcal/yr)	2117	2122	2616	2647	3354	3420
CP intake of sow (kg/yr)	105	105	124	124	152	152
ADE intake of weaners (Mcal/yr)	1823	2228	1296	1584	660	806
CP intake of weaners (kg/yr)	133	162	86	106	79	97
Total ADE intake per kg muscle CP gain (Mcal)	113.5	103.8	129.1	115.3	162.5	141.3
Total CP intake per kg muscle CP gain (kg)	6.9	6.4	6.9	6.3	9.4	8.3

*Calculated from data of: Cuthbertson and Pomeroy, 1962; Lawrie *et al.*, 1963; Elsley, 1963; Brooks *et al.*, 1964; Elsley *et al.*, 1968; ARC, 1967; O'Grady, 1971.

CP — Crude protein; ADE — Apparent digestible energy.

on ARC (1967) recommendations for animals weighing a maximum of 135 kg.

In relation to the number of weaners produced per sow per year it is probable that the situation involving a fifty-six day lactation and nine weaners per litter exceeds current average levels of attainment in many countries, perhaps by as much as 20%. In New Zealand, where only 10 to 11 pigs are marketed per sow per year (Anon., 1971), it probably exceeds average levels of efficiency by about 70%. Realizing that shortening of lactation to twenty-one days is technically possible now on a commercial scale, the immediate scope for improvement in the efficiency of weaner production is substantial.

THE GROWING PHASE

Efficiency of production over the growing phase can be assessed in terms of feed conversion efficiency, rate of gain, and carcass quality. Variation in each of these characteristics arises from many interdependent environmental and genetic factors, *e.g.*, climate, feeding system, diet, group size, disease status, age, sex, genotype and breed. Only two of these will be considered here, namely, genotype as a function of breed improvement through selection, and disease status, as together these probably provide most scope for future improvement in productivity over this stage of production.

GENOTYPE

Heritability estimates of post-weaning rate of gain and feed conversion efficiency usually range from 0.3 to 0.5, and those for the metric traits relating to carcass composition from 0.4 to 0.8 (Fredeen, 1958; Smith *et al.*, 1962). Relatively rapid genetic change in these traits, particularly the latter, should result from recurrent mass selection.

Responses to selection either for reduced or increased back-fat thickness (Dillard *et al.*, 1962; Hetzer and Harvey, 1967) or for increased daily gain (Rahnefeld, 1971) have been obtained experimentally under conditions involving genetically stable control populations. The same cannot be said for applied breeding programmes, however. Fredeen (1953), Smith (1965) and Matthis (1966) report little or no improvement in meat production traits from breed improvement programmes operating in Canada, Britain and South Africa, respectively, over periods varying from five to twenty years. Fredeen (1966) interprets such information "either as a deficiency in the simplifying assumptions underlying the applied genetic theory or as a failure to establish lines of communication between science and practice." He considers that in view of the steady and even spectacular improvement in the Danish Landrace over the past few decades (Fredeen, 1958), at least a part of which may be attributed to genetic change (Smith, 1963), the reason for the apparent failure of all other schemes is probably related to a lack of communication and organization. In these latter respects the Danish scheme is unique (Fredeen, 1966). It must be concluded then that if genetic improvements in meat production traits are to be attained, more attention must be given in future selection programmes to education, organization and legislation. It is probably in these spheres, rather than in knowledge of quantitative genetics, that the key to breed improvement in the immediate future lies. In addition, the need for randomly-bred control populations in future programmes has been stressed (Smith, 1963), while the dangers of over-simplification are illustrated by the results of Jensen, *et al.* (1967), from which the authors recognize the necessity in future programmes for direct selection for meat quality, *e.g.*, water-holding capacity, intramuscular fat content. Their view is upheld by Lister (1970), who considers that continuous phenotypic selection for leanness will result in continuous deterioration of carcass muscle quality, resulting from abnormal post-mortem changes in muscle pH in stress-susceptible animals.

Properly organized, comprehensive selection programmes for purebreds should form the basis of crossbreeding programmes, not only to capitalize on heterosis as regards reproductive performance, but also to combine desirable meat production traits of two or more breeds. The possible role of specialized sire and dam lines in such a system has been discussed (Smith, 1964; Moav and Hill, 1966).

Disease Status

To satisfy the pig's climatic requirements and to avoid the repercussions of failure to meet them (Mount, 1968), the growing animal must be housed in totally or partially enclosed buildings. As the degree of enclosure increases and as the number of animals housed within a common air-space increases, so the disease risk increases. One of the most important diseases in this context is enzootic pneumonia, which is chronic in nature exerting its effect by depressing feed conversion efficiency, by causing marked variation in growth rate, and in general debilitation.

The incidence of the disease varies greatly from herd to herd. All or none of the animals may be affected, a common incidence in Britain being about 40 to 50% (Goodwin, 1971). One New Zealand report indicated an average incidence of about 80% in the North Auckland area (Rees, 1964).

Goodwin (1971) estimates that the average cost of the disease in Britain, in terms of feed utilization, is about $NZ2 per pig slaughtered, representing a deterioration in feed conversion efficiency (kg meal/kg liveweight gain) from 3.1 to 3.5, or a loss in efficiency of about 10 to 12%. To this direct cost of the disease must be added the less easily quantified costs associated with variable growth and depressed health.

Management procedures may be adopted to lower the incidence of enzootic pneumonia, but these invariably conflict with other prerequisites of intensive pig meat production. The only satisfactory approach is eradication, and hysterectomy procedures are effective in the establishment of primary disease-free stock (Goodwin, 1971), and have the added advantage of simultaneous eradication of other diseases and conditions.

To justify the cost of eradication every effort must be made to avoid reinfection. Unfortunately a significant proportion of herds in the past have contracted the disease within a comparatively short time of eradication (Goodwin and Whittlestone, 1967), although some have remained free for at least fifteen years (Goodwin, 1971). The cost of the strict precautionary measures necessary to avoid reinfection are relatively insignificant compared with the likely financial advantages of eradication (Goodwin, 1971).

One facet of disease eradication that has yet to be resolved concerns the implications of the concomitant development of closed-herd systems on breed improvement. It would seem reasonable to assume that an increased establishment of minimal disease herds must be accompanied by an increase in on-farm testing and artificial insemination.

Table 2 shows estimates of the absolute efficiencies of dietary energy and protein utilization for muscle protein synthesis over the growing phase, in relation to variation in feed conversion efficiency and carcass muscle content, arising perhaps from those factors considered above.

CONCLUSION

Some principal factors that influence the efficiency of muscle protein production from pigs, during the breeding and growing phases, have been considered. To present a clearer picture of the cumulative effects of variation in these factors on overall efficiency, Table 3 shows three contrasting situations (A, B, C) for which efficiencies of dietary energy and protein utilization have been calculated from data in Tables 1 and 2.

The efficiencies pertaining to situation C are similar to those given by Lodge (1970) for purposes of between-species comparison, and also to those which may be cal-

TABLE 2: ESTIMATES OF THE EFFICIENCIES OF APPARENT DIGESTIBLE ENERGY AND CRUDE PROTEIN UTILIZATION FOR MUSCLE PROTEIN SYNTHESIS IN PIGS GROWING FROM 17 TO 85 KG LIVEWEIGHT, IN RELATION TO FEED CONVERSION EFFICIENCY AND CARCASS MUSCLE CONTENT*

FCE (kg meal/ kg LW gain)		3.5			3.2			2.9	
Carcass muscle content (%)	45.0	47.5	50.0	45.0	47.5	50.0	45.0	47.5	50.0
ADE / kg LW gain (Mcal)		10.5			9.6			8.7	
CP/kg LW gain (kg)		0.53			0.48			0.44	
ADE/kg muscle CP gain (Mcal)	143.3	135.9	129.0	130.9	124.0	118.0	118.9	112.4	106.9
CP/kg muscle CP gain (kg)	7.3	6.9	6.5	6.5	6.2	5.9	6.0	5.7	5.4

*Calculated from data of: Cuthbertson and Pomeroy, 1962; Lawrie *et al.*, 1963; ARC, 1967.
FCE — Feed conversion efficiency; ADE — Apparent digestible energy; CP — Crude protein.

TABLE 3: ESTIMATES OF THE EFFICIENCIES OF APPARENT DIGESTIBLE ENERGY AND CRUDE PROTEIN UTILIZATION FOR MUSCLE PROTEIN SYNTHESIS IN PIGS SLAUGHTERED AT 85 KG LIVEWEIGHT, IN RELATION TO AGE AT WEANING, LITTER SIZE, FEED CONVERSION EFFICIENCY AND CARCASS MUSCLE CONTENT (INCLUSIVE OF DAM'S REQUIREMENTS BUT EXCLUSIVE OF SIRE'S REQUIREMENTS)*

	A	B	C
Age at weaning (days)	4	21	56
Weaners/litter	11	9	9
FCE (kg meal/kg LW gain — 17-85 kg LW)	2.9	3.2	3.5
Carcass muscle content (%)	50	47.5	45.0
Total ADE intake (Mcal/85 kg pig)	738	834	949
Total CP intake (kg/85 kg pig)	38.9	42.4	49.6
Muscle CP gain (kg/85 kg pig)	6.9	6.6	6.2
Total ADE intake per kg muscle CP gain (Mcal)†	107 (142)	127 (120)	152 (100)
Total CP intake per kg muscle CP gain (kg)†	5.6 (143)	6.5 (123)	8.0 (100)

*Derived from data given in Tables 1 and 2.
†Relative efficiencies in parentheses.
FCE — Food conversion efficiency; ADE — Apparent digestible energy; CP — Crude protein.

culated from Braude's (1970) data, relating to what he considered a current average level of efficiency. If situation C can be considered average, the data in Table 3 give some indication of the scope for improvement. Currently there is no reason why efficiencies similar to those of situation B cannot be achieved; in fact they probably are being achieved on some farms. With a more systematic approach to breed improvement, a greater awareness of disease control, and the solution of current problems with very early-weaned sows, it is likely that in the foreseeable future efficiencies similar to those of situation A will be achieved. In fact Braude (1970) predicts that efficiencies approximately 40% greater than these will ultimately be attained.

While it is useful to theorize on the comparative and potential metabolic efficiency of the pig, a further point should not be overlooked. The pig must be classified as completely inefficient if it competes with the human, either directly for a source of nutrient in short supply, or indirectly for land on which such a nutrient may be produced in some more efficient manner. This applies to any animal species, but the chance of such a situation developing with the pig is comparatively high in view of the similarity between its nutritional requirements and those of the human, particularly with respect to essential amino acids. It is for this reason, and in reference to the comparative efficiencies of protein production by the various animal species, that Reid (1970) speculates that the pig will be the first animal to be phased out of human food production.

REFERENCES

Anon., 1971: *19th Ann. Rept.*, N.Z. Pig Producers' Council, Wellington.

ARC (Agricultural Research Council), 1967: *The Nutrient Requirements of Farm Livestock. No. 3, Pigs.* Tech. Comm. Agric. Res. Counc., London.

Bengtsson, G.; Bachstrum, L.; Ringarp, N., 1970: *Svensk. Vet Tidn., 22*: 470.

Best, P., 1971: *Pig Farming, 19* (8): 30.

Braude, R.; Mitchell, K. G.; Suffolk, S. F., 1969: *J. Inst. Anim. Techns, 20*: 43.

Braude, R., 1970: *Proc. Nutr. Soc., 29*: 262.

Braude, R.; Mitchell, K. G.; Newport, M. J.; Porter, J. W. G., 1970a: *Br. J. Nutr., 24*: 501.

Braude, R.; Newport, M. J.; Porter, J. W. G., 1970b: *Br. J. Nutr., 24*: 827.

——— 1971: *Br. J. Nutr., 25*: 113.

Brooks, C. C.; Fontenot, J. P.; Vipperman, P. E.; Thomas, H. R.; Graham, P. P., 1964: *J. Anim. Sci., 23*: 1,022.

Cuthbertson, A.; Pomeroy, R. W., 1962: *J. agric. Sci. Camb., 59*: 251.
Cuthbertson, A.; Pease, A. H. R., 1968: *Anim. Prod., 10*: 249.
Dillard, E. V.; Robinson, O. W.; Legates, J. E., 1962: *J. Anim. Sci., 21*: 971.
Duncan, D. L.; Lodge, G. A., 1960: Diet in relation to reproduction and the viability of the young. Pt. 3, Pigs. *Tech. Comm. No. 21*. Commonwealth Agric. Bureaux, England. 106 pp.
Elsley, F. W. H., 1963: *J. agric. Sci. Camb., 61*: 233.
Elsley, F. W. H.; Macpherson, R. M.; Lodge, G. A., 1968: *Anim. Prod., 10*: 149.
Fredeen, H. T., 1953: *Publ. Dep. Agric. Can. No. 889.*
——— 1958: *Anim. Breed. Abstr., 26*: 229.
——— 1966: *J. Anim. Sci., 25*: 543.
Goodwin, R. F. W., 1971: *Vet. Rec., 89*: 77.
Goodwin, R. F. W.; Whittlestone, P., 1967: *Vet. Rec., 81*: 643.
Hetzer, H. O.; Harvey, W. R., 1967: *J. Anim. Sci., 26*: 1,244.
Hill, W. G., 1971: *Vet. Rec., 89*: 86.
Jensen, P.; Craig, H. B.; Robison, O. W., 1967: *J. Anim. Sci., 26*: 1,252.
Lawrie, R. A.; Pomeroy, R. W.; Cuthbertson, A., 1963: *J. agric. Sci. Camb., 60*: 195.
Lister, D., 1970: In *The Physiology and Biochemistry of Muscle as a Food — 2*. Ed. E. J. Briskey, R. G. Cassens, and B. B. Marsh. Univ. Wisc. Press, Wisconsin. p. 705.
Lodge, G. A., 1970: In *Proteins as Human Food*. Ed. R. A. Lawrie. Proc. 16th Easter School, Univ. Nott., Butterworths, London. 525 pp.
Matthis, D. B., 1966: *Proc. S. Afr. Soc. Anim. Prod., 5*: 163.
Moav, R.; Hill, W. G., 1966: *Anim. Prod., 8*: 367.
Mount, L. E., 1968: *The Climatic Physiology of the Pig*. Monograph Physiological Society, No. 18. Edward Arnold, London. 271 pp.
NRC (National Research Council), 1964: *Nutrient Requirements of Domestic Animals; No. 2. Nutrient Requirements of Swine*. Publ. 1,192. Washington D.C. 40 pp.
O'Grady, J. F., 1971: *Ir. J. agric. Res., 10*: 17.
Osinska, Z., 1968: In *Growth and Development of Mammals*. Ed. G. A. Lodge and G. E. Lamming. Proc. 14th Easter School, Univ. Nott., Butterworths, London. 527 pp.
Rahnefeld, G. W., 1971: *Can. J. Anim. Sci., 51*: 497.
Rees, H. G., 1964: *N.Z. vet. J., 12*: 91.
Reid, J. T., 1970: *Proc. Cornell Nutrition Conf. for Feed Manufacturers*, Cornell Univ. N.Y., p. 115.
Smith, C., 1963: *Anim. Prod., 5*: 259.
——— 1964: *Anim. Prod., 6*: 337.
——— 1965: *Anim. Prod., 7*: 133.
Smith, C.; King, J. W. B., 1964: *Anim. Prod., 6*: 265.
Smith, C.; King, J. W. B.; Gilbert, N., 1962: *Anim. Prod., 4*: 128.
Strang, G. S.; King, J. W. B., 1970: *Anim. Prod., 12*: 235.