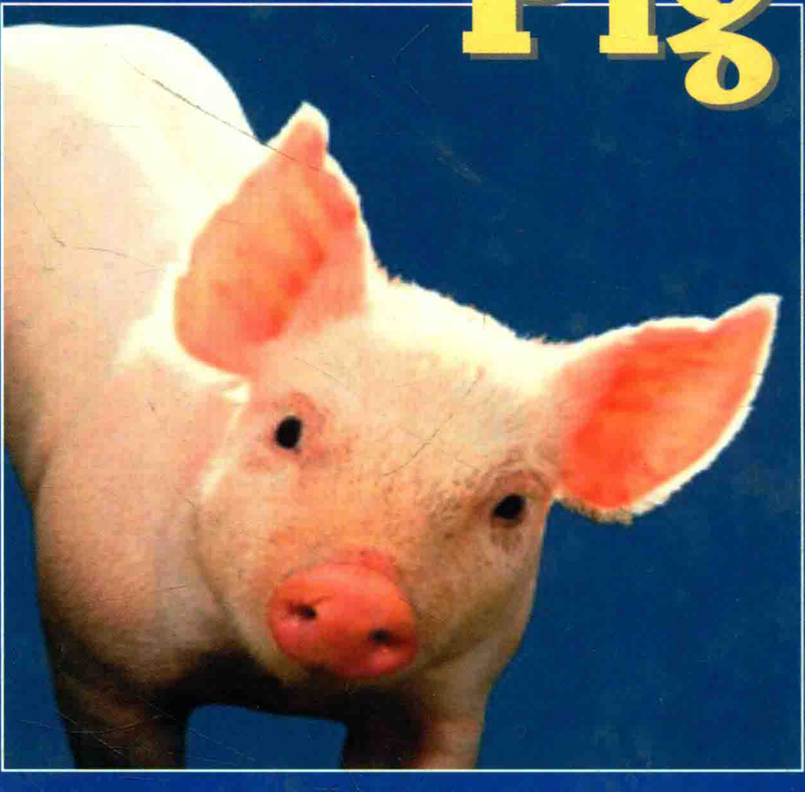
The Weaner Pig

NUTRITION AND MANAGEMENT



Edited by M.A. Varley and J. Wiseman

CABI Publishing

The Weaner Pig
Nutrition and Management

Edited by

M.A. Varley
SCA Nutrition, Thirsk, UK

and

J. Wiseman
University of Nottingham, UK

CABI *Publishing*

CABI *Publishing* is a division of CAB *International*

CABI Publishing
CAB International
Wallingford
Oxon OX10 8DE
UK
Tel: +44 (0)1491 832111
Fax: +44 (0)1491 833508
Email: cabi@cabi.org
Web site: http://www.cabi-publishing.org

CABI Publishing
10 E 40th Street
Suite 3203
New York, NY 10016
USA
Tel: +1 212 481 7018
Fax: +1 212 686 7993
Email: cabi-nao@cabi.org

A catalogue record for this book is available from the British Library, London, UK.

Library of Congress Cataloging-in-Publication Data

The weaner pig : nutrition and management / edited by M.A. Varley and J. Wiseman.
p. cm.
Papers from the occasional Meeting of the British Society of Animal Science, held at Nottingham University, Sept. 2000
Includes bibliographical references (p.)
ISBN 0-85199-532-2 (hardback : alk paper)
1. Piglets--Nutrition--Requirements--Congresses. 2. Piglets--Feeding and feeds--Congresses. I. Varley, M. A. (Mike A.) II. Wiseman, J. (Julian) III. British Society of Animal Science. Meeting (2000 : Nottingham University

SF396.5.W43 2001
636.4'085--dc21 2001035454

ISBN 0 85199 532 2

Typeset in 10/12pt Adobe Garamond by Columns Design Ltd, Reading
Printed and bound in the UK by Cromwell Press, Trowbridge

THE WEANER PIG

NUTRITION AND MANAGEMENT

Contributors

M. Bailey, Division of Molecular and Cellular Biology, Department of Clinical Veterinary Sciences, University of Bristol, Langford House, Langford, Bristol BS40 5DU, UK

P. Baynes, NuTec Ltd, Eastern Avenue, Lichfield, Staffordshire WS13 7SE, UK

J.D. Beal, Seale-Hayne Faculty, University of Plymouth, Newton Abbot, Devon TQ12 6NQ, UK

P.W. Bland, Department of Functional Anatomy, Hannover Medical School, 4120 Carl-Neuberg Strasse, 30625 Hannover, Germany

P.H. Brooks, Seale-Hayne Faculty, University of Plymouth, Newton Abbot, Devon TQ12 6NQ, UK

E.M.A.M. Bruininx, Research Institute for Animal Husbandry, PO Box 2176, 8203 AD, Lelystad, The Netherlands

A. Campbell, Seale-Hayne Faculty, University of Plymouth, Newton Abbot, Devon TQ12 6NQ, UK

M. Cole, SCA Nutrition Ltd, Maple Mill, Dalton, Thirsk, North Yorkshire YO7 3HE, UK

V. Demeckova, Seale-Hayne Faculty, University of Plymouth, Newton Abbot, Devon TQ12 6NQ, UK

S. Done, Veterinary Laboratories Agency, Woodham Lane, Addlestone, Surrey KT15 3BP, UK

M. Evans, Pig Production Training Ltd, 3 Trevose Close, Walton, Chesterfield S40 3PT, UK

D.M. Green, University of Edinburgh, King's Buildings, Edinburgh EH9 3JG, UK

D.J. Hampson, Division of Veterinary and Biomedical Sciences, Murdoch University, Murdoch WA 6150, Australia

K. Haverson, Division of Molecular and Cellular Biology, Department of Clinical

Veterinary Sciences, University of Bristol, Langford House, Langford, Bristol BS40 5DU, UK

S. Held, Centre for Behavioural Biology, Department of Veterinary Clinical Science, University of Bristol, Langford House, Langford, Bristol BS40 5DU, UK

D. Kelly, Rowett Research Institute, Bucksburn, Aberdeen AB21 9SB, UK

J.C. Kim, Division of Veterinary and Biomedical Sciences, Murdoch University, Murdoch WA 6150, Australia

T.P. King, Rowett Research Institute, Bucksburn, Aberdeen AB21 9SB, UK

J. Le Dividich, INRA, Unité Mixte de Recherches sur le Veau et le Porc, 35590 St-Gilles, France

D.E. McDonald, Division of Veterinary and Biomedical Sciences, Murdoch University, Murdoch, WA 6150, Australia

L. Melin, Department of Ruminant and Porcine Diseases, National Veterinary Institute, 751 89 Uppsala, Sweden

M. Mendl, Centre for Behavioural Biology, Department of Veterinary Clinical Science, University of Bristol, Langford House, Langford, Bristol BS40 5DU, UK

B.G. Miller, Division of Molecular and Cellular Biology, Department of Veterinary Clinical Sciences, University of Bristol, Langford House, Langford, Bristol BS40 5DU, UK

C.A. Moran, Seale-Hayne Faculty, University of Plymouth, Newton Abbot, Devon TQ12 6NQ, UK

G. Partridge, Finnfeeds International Ltd, PO Box 777, Marlborough, Wiltshire SN8 1XN, UK

C.M.C. van der Peet-Schwering, Research Institute for Animal Husbandry, PO Box 2176, 8203AD, Lelystad, The Netherlands

D.W. Pethick, Division of Veterinary and Biomedical Sciences, Murdoch University, Murdoch WA 6150, Australia

J. Pickard, Division of Agriculture and Horticulture, School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough, Leics LE12 5RD, UK

J.R. Pluske, Division of Veterinary and Biomedical Sciences, Murdoch University, Murdoch WA 6150, Australia

H.-J. Rothkötter, Department of Functional Anatomy, Hannover Medical School, 4120 Carl-Neuberg Strasse, 30625 Hannover, Germany

J.W. Schrama, Wageningen University and Research Centre, Department of Animal Science, PO Box 338, 6700 AH, Wageningen, The Netherlands

B. Sève, INRA, Unité Mixte de Recherches sur le Veau et le Porc, 35590 St-Gilles, France

H.A.M. Spoolder, Research Institute for Pig Husbandry, PO Box 83, 5240 AB Rosmalen, The Netherlands

M. Sprent, SCA Nutrition Ltd, Maple Mill, Dalton, Thirsk, North Yorkshire YO7 3HE, UK

C.R. Stokes, Division of Molecular and Cellular Biology, Department of Clinical

Veterinary Sciences, University of Bristol, Langford House, Langford, Bristol BS40 5DU, UK

J.W.G.M. Swinkels, Research Institute for Pig Husbandry, PO Box 83, 5240 AB Rosmalen, The Netherlands

M. Varley, SCA Nutrition Ltd, Dalton, Thirsk, North Yorkshire YO7 3HE, UK

M.A. Vega-Lopez, CINVESTAV-IPN, Experimental Pathology Department, Av. IPN 2508, Mexico 07360 DF, Mexico

H.M. Vermeer, Research Institute for Pig Husbandry, PO Box 83, 5240 AB Rosmalen, The Netherlands

P. Wallgren, Department of Ruminant and Porcine Diseases, National Veterinary Institute, 751 89 Uppsala, Sweden

C.M. Wathes, Silsoe Research Institue, Bio-Engineering Division, Wrest Park, Silsoe, Bedford MK45 4HS, UK

C.T. Whittemore, University of Edinburgh, King's Buildings, Edinburgh EH9 3JG, UK

J. Wiseman, Division of Agriculture and Horticulture, School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough, Leics LE12 5RD, UK

L. Zarkadas, Division of Agriculture and Horticulture, School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough, Leics LE12 5RD, UK

Preface

This book is the proceedings of a conference organized by the British Society of Animal Science (as part of their 'Occasional Meetings' series) held at the University of Nottingham, UK, in September 2000.

The post-weaned piglet presents a particular challenge both in modern production terms and in the context of the sciences related to production. The systems used in most of the pig-producing countries of the world include weaning at between 16 and 30 days of age using controlled environment housing and highly specialized diets. Whilst early weaning generates significant advantages for annual sow productivity, the system also demands a high level of management skills to make it work successfully.

The principal objective of the meeting was therefore to focus attention on the various disciplines involved in weaner science and production, and to review the research and development carried out recently in these areas. Accordingly the present work includes sections on: growth patterns, nutrition, feeding requirements, gut physiology, enteric health and the environmental requirements of the young post-weaned piglet. The papers were presented by acknowledged experts from around the globe and provide a solid foundation both for future research directions and also as guidelines for managers and consultants looking to improve their systems.

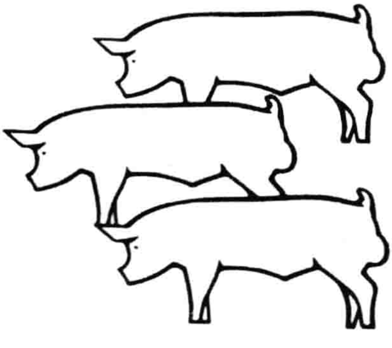
In addition to formal papers, the meeting also had submitted posters, abstracts for which can be found at: www.bsas.org.uk

Dr Mike Varley, SCA Nutrition Ltd, UK
Dr Julian Wiseman, The University of Nottingham, UK

Acknowledgements

ELANCO
ANIMAL HEALTH
TM

International
Additives
WHERE ART BECOMES SCIENCE



NuTec

QUALITY
EQUIPMENT

SCA

Contents

Growth of the Young Weaned Pig

1

C.T. Whittemore and D.M. Green

University of Edinburgh, King's Buildings, Edinburgh
EH9 3JG, UK

The Potential for Growth

Without human intervention, the pig will become nutritionally independent of its dam at 15–20 kg liveweight. Natural weaning will occur at 70 days or so of age. Earlier weaning than this creates a disruption to the growth of the weaned pig that is inversely proportional to pig age. The competence of the digestive system of the suckled pig to handle a non-milk diet begins to develop (aided by challenge/response) between 14 and 28 days of age. Under conditions of gradual diet change from liquid to solid feed, growth is likely to be fully supportable without sucked milk from around 56 days. The presentation of a mixture of milk and externally sourced solid feed to the gut of the young pig is relevant to natural development.

Abrupt weaning at 21 days of age is not conducive to the achievement of normal growth in pigs. Fifty years ago, conventional European practice was to wean at 56 days of age. Advances in nutritional knowledge and the manufacture of specialist housing for young pigs led to a rapid reduction in weaning age. After a number of failed flirtations with 7-day, 10-day and 14-day weaning, the 'industry standard' in the UK settled at 21-day weaning. A substantial proportion of successful practitioners nevertheless chose not to wean at ages below 28 days, and in other European countries 35-day weaning remains common. The UK industry standard has, since the 1980s, drifted upward from 21 days towards 28 days, with an apparent advantage in terms of numbers of pigs born per sow per year.

The description of growth following weaning requires at its core a prediction of protein mass and of its incrementation. Description of body composition further requires quantification of lipid mass and an understanding of any relationship that may exist between protein and lipid retention in the course of positive (and, in the case of the weaned pig, negative) growth.

The Weaner Pig: Nutrition and Management
(eds M.A. Varley and J. Wiseman)

Theoretical considerations

There is dissent over the nature of the curve that might best describe protein growth over time and weight. The conventional assumption of a sigmoidal form requires the rejection of the proposition still held by the de Lange school at Guelph (C.F.M. de Lange, personal communication, Guelph, 2000), which follows from the reviews of Kielanowski (1969) and Rerat (1972) and suggests that a single value be used to describe maximum daily potential protein retention rate (Pr_{max}) at all times during the active growing life of the pig. That the (single value) potential for growth is not achieved in early life, and particularly after weaning, may be ascribed to a failure on the part of the pig to be able to ingest sufficient feed. In addition to Pr_{max}, the original models of Whittemore and Fawcett (1974, 1976), and those that later sprang from them, required a second parameter: that of a minimum ratio between the daily rate of retention of lipid and protein in the gain ($Lr{:}Pr$). This latter was argued for on the grounds of a physiological imperative, and had the further (beneficial) effect of restraining the simulated daily rate of achieved protein retention (Pr) below Pr_{max} in young pigs, when appetite was limiting. The rule effectively enforces partitioning of energy from Pr to Lr. The setting of the minimum ratio of lipid to protein in the gain was necessary for the achievement of fit of the 'single value' model to recently weaned and young growing pigs, which would otherwise be predicted to perform at extravagant rates of protein growth. The $Lr{:}Pr$ ratio was subsequently argued against (Whittemore, 1995), on the grounds that it was superfluous to modelling requirement to restrain early protein growth if a sigmoidal (Gompertz) function rather than a single value were used to describe Pr_{max}. The Gompertz function had an evident effect of limiting early protein growth potential. In both the original and amended (Whittemore,1995) eventualities, potential lipid retention (Lr_{max}) was unrestrained, and achieved lipid retention (Lr) was a function of energy supply. Emmans (1988) proposed that potential lipid retention (Lr_{max}) may also be described by the Gompertz function.

Functions other than the Gompertz in the sigmoidal series have been discussed by such as Huxley (1932), Hammond (1940), Brody (1945) and Schinckel (1999). The common characters of the sigmoidal descriptor are: (i) a period of increasing growth rate in early life; (ii) a period of decreasing growth rate in later life; (iii) a point of inflection (linearity) between the two; and (iv) an asymptote, at which point maturity is approached and growth ceases. The weaner pig finds itself in the middle of the phase of increasing growth rate, which in practice it rarely achieves.

The Gompertz (1825) function may be employed with the growing tissue (whole body, protein, or lipid, etc.) on the y axis, and the scale against which growth is to be expressed (time, or a body tissue) on the x axis. The function requires as parameters the asymptote of the y axis (an approximation of maturity for the tissue concerned) and a growth coefficient. Importantly, the y-coordinate of the point of inflection is fixed at 1/e of the asymptote. The general equation is:

$$y = A^{*} \exp\{-\exp[-B(x - x^{o})]\}$$

where A is the asymptote for y, x^{o} is the point of inflection measured on the x-axis and B is the growth coefficient.

It is of interest to express growth rate (dy/dx) as a function of both time and weight, either being potentially useful depending on circumstance.

Differentiation with respect to time of the general equation where y = weight and x = time leads to the derivative for gain as a function of time (x):

$$dy/dx = A^*B^* \exp \{-B^*(x - x^o) - \exp [-B^*(x - x^o)]\}$$

and for gain as a function of weight (y):

$$dy/dx = y^*B^* \ln(A/y)$$

where dy/dx is the gain, and A is the value for $y(W)$ when dy/dx (daily gain) has diminished to zero.

Whittemore (1998) suggested various values for B and A according to sex and genotype. These values range from 0.010 and 220 to 0.014 and 330, respectively, where A is expressed in terms of liveweight. Potential growth rates for pigs of 5 kg, 10 kg and 15 kg are predicted to be 189 g, 309 g and 402 g for the lower values and 293 g, 490 g and 649 g for the higher.

Alternatives to the Gompertz equation have been examined (and largely rejected) by Whittemore *et al.* (2001a). Amongst these were the functions of Bridges and Richards. The Bridges equation (Bridges *et al.*, 1986) differs from the Gompertz mainly in not having the inflection point fixed at 1/e. The Bridges equation is:

$$y = y_0 + A^*\{1 - \exp[-(m^*x^b)]\}$$

where y_0 is the start point for y (weight of growing tissue), A is the weight at maturity, m is the 'exponential growth decay constant', x is time and b is the 'kinetic order constant'.

The Richards equation (Richards, 1959; and described by France and Thornley, 1984) is more generalized and also has a variable inflection point, which gives it the flexibility to describe different pig types with points of inflection at differing proportions of their mature age (or weight). The Richards equation is expressed as:

$$y = (y_0{}^*A) / \{y_0{}^n + (A^n - y_0{}^n)^* \exp[-(k^*x)]\}^{1/n}$$

where, if y would be weight, y_0 is the start weight, A is the asymptote for y, and x measures time. Bridges and Richards are of interest as, although by no means as convenient as Gompertz, they can better describe data sets that do indeed have different inflection points. However, Knap (2000) found, rather convincingly, that although the point of inflection (as proportion of mature weight) did vary with data sets differing in their provenance, it did not deviate importantly from the 1/e determined with the Gompertz.

The description of growth through the relationship between a component (such as total protein, Pt) and the whole (such as live bodyweight, W) was suggested by Huxley (1932) and has been used with good effect by countless others since. The form used is:

$$z = a^*y^b$$

Whittemore *et al.* (1988) determined allometric relationships (commented upon by Schinckel, 1999) for z = protein (Pt), lipid, water and ash mass, and y = bodyweight. The pattern of daily protein retention rate, Pr, or dPt/dx, with increasing bodyweight was determined as follows. Daily liveweight gain, dy/dx, was first described with the Gompertz function:

$$dy/dx = B^{*}y^{*}\ln(A/y).$$

Subsequently, Pt was taken as a simple allometric function of weight ($Pt = a^{*}y^{b}$). It follows that:

$$Pr = [a^{*}b(y)^{b-1}]^{*}[B^{*}y^{*}\ln(A/y)].$$

As pointed out by Schinckel and de Lange (1996), the simple $z = ay^{b}$ allometric is potentially faulted in the assumption that the body component changes according to whole bodyweight in a uniform way.

Early growth as a special case

Being born with a body-fat content of perhaps 10–20 g kg^{-1}, the suckling pig partitions nutrients in favour of lipid deposition to reach 150–160 g kg^{-1} at the time of weaning, the ratio of lipid to protein in the body being around 1:1 at this time. The modern meat pig, slaughtered at less than 120 kg liveweight, is unlikely ever to be as fat again. Post-weaning feed intake inadequacies together with stress and disease challenge ensure a rapid loss of body lipid in support of maintenance (and protein synthesis). Whittemore *et al.* (1978) found no liveweight gain for 7 days in pigs weaned at 14 days of age. At 21 days of age, the body composition of these pigs comprised 150 g protein kg^{-1} and 76 g lipid kg^{-1}, compared with 146 g protein kg^{-1} and 148 g lipid kg^{-1} in unweaned 21-day-old pigs. In the case of both groups of weaned pigs (14- and 21-day weaned), the gains that occurred subsequent to post-weaning weight stasis and lipid loss were made in favour of protein (and not any recovery of body lipid). Lipid and protein gains after weaning were made in approximately equal proportion. Thus, by 50 days of age the composition of the body was little changed, with some 60–70 g lipid kg^{-1} and 150–180 g protein kg^{-1}. These authors noted that lipid losses had taken place commensurate with weight stasis (not weight loss), and concluded that water enhancement had compensated for the removal of lipid. This proposition was put to a more severe test by Whittemore *et al.* (1981), who found that zero daily weight change was associated with 56 g of lipid loss and 53 g of water gain. Only when the daily weight gain exceeded 193 g did lipid gains begin to become positive.

Water gain (g day^{-1}) = 0.56 empty bodyweight gain + 53
Lipid gain (g day^{-1}) = 0.29 empty bodyweight gain − 56
Protein gain (g day^{-1}) = 0.15 empty bodyweight gain − 4

Between zero and 200 g daily liveweight gain, it would appear that the pigs catabolized body lipid in favour of the anabolism of body protein. Not until the rather appreciable rate of gain of some 60% of what would normally be expected at this time did the pigs return to lipid retention. Whittemore *et al.* (1978) also noted the relative intransigence of the body proportion made up of protein and the stability of protein content in the face of perturbations in feed intake.

Whittemore (1998) pointed out that, given appropriate conditions, weaned pigs will grow at rates substantially above the commercial norm (Table 1.1). Healthy pigs of little more than 5 kg have the potential, given unrestrained feed intake, to grow at 500 g daily, and *B* coefficients for the Gompertz function as high as 0.020 have been measured at Edinburgh. It would seem, therefore, that the negative consequences of post-weaning growth suspension are in part, or in whole, avoidable.

Given the propensity of contemporary pig-keeping systems to predispose weaned pigs to a period of slow, zero or negative growth, it is natural that great interest is shown in the possibility of compensatory growth. By such means may nature gratuitously make amends for the inadequacies of husbandry. That animals will grow faster when feed is plentiful, and make provision for times when feed is scarce, is undeniable. It is also undeniable that lipid losses in support of tissue accretions is physiologically normal (as, for example, in lactation). The seminal question in the case of the weaned pig, however, is whether or not supra-normal gains following a period of deprivation can make good the earlier growth losses and whether, in addition, these gains can be achieved at supra-normal efficiency. This, of course, makes 'normal' a begged definition.

Tullis and Whittemore (1986) conducted a carefully constructed trial, some of the findings of which are given in Table 1.2. Pigs on restricted feeding from 25 to 55 days expressed reduced liveweight gains and little or no lipid gains, but achieved no greater liveweight gains on realimentation, nor gains of differing composition, than unrestricted pigs. Compensatory gains were not in evidence. Kyriazakis and his group at Edinburgh have put forward the concept of the young pig having a preferred ratio of lipid to protein in the body. Post-weaning feed restriction will move the pig away from that preferred ratio through the catabolism of lipid, and there will be a natural predisposition to readjust the balance. It should not be assumed, however, that the lipid content of the body at weaning is necessarily expressive of a preferred ratio; the storage of lipid in excess of this ratio (in case of hard times to come) would be a normal expectation. Were compensatory growth to be found, its benefaction would lie in the recovery of protein mass by an enhancement in the rate of protein deposition. The difficulty with the test is in proving that the 'control' group was maximizing in the first place. Animals may readily show

Table 1.1. Post-weaning growth performance at University of Edinburgh.

Liveweight at start (kg)	Liveweight at finish (kg)	Days	Daily feed intake (g)	Daily liveweight gain (g)
6	12	13	500	450
6	24	31	800	581
8	16	14	650	590
12	24	16	900	760

Table 1.2. Growth of weaned pigs (g day^{-1}) following feed intake restriction from 25 to 55 days of age and fed to appetite from 55 to 70 days of age. (The percentage of lipid in the gain is given in parentheses.)

Days of age	Fed to appetite 25–70 days	Restricted 25–55 days
25–40	321 (9.6)	192 (4.8)
40–55	532 (9.0)	162 (0.6)
55–70	601 (14.5)	508 (16.5)

enhancement of appetite and growth above that achieved under previous restriction, and no 'compensatory' benefit could be claimed. Further, over the total period under review (restriction followed by compensation) there is no likelihood of any recovery of the efficiency lost in the former period. As a management tool of convenience, compensatory growth must therefore be rejected, however attractive its acceptance might be to those espousing less than adequate husbandry techniques. This is not to deny the propensity of the pig to make the most of growth opportunities. In a classical experiment Kyriazakis *et al.* (1991) fed young pigs to achieve luxury levels of lipid deposition, and then presented the pigs with a diet of exceptionally high protein content. The pigs used body stores of lipid to augment ingested energy levels (limited by the constraints of gut capacity) and achieved remarkable rates of protein retention and liveweight gain. Whether the 925 g of daily liveweight gain attained at a live bodyweight of 13 kg should be considered as indicative of a potential normally available or of compensatory gains remains conjecture.

It may be concluded that, in the case of the young weaned pig, the driver for growth is feed intake and that this inevitably constrains growth to a level that is below potential.

Feed Intake

Although gut capacity is dependent on body size, Parks (1982) states the inevitable truth that in the actively growing animal it is the (increasing) bodyweight that is dependent on feed intake:

$$W = (A - W_0)\{1 - \exp[-(AB)F/A]\} + W_0$$

where W is liveweight (accumulated gain), A is the liveweight at maturity, W_0 is the initial liveweight, B is the efficiency coefficient and F is the accumulated feed intake. Whittemore *et al.* (1978) showed that a 1 g increment in the intake of digestible crude protein was associated with 2.5 g bodyweight gain, 0.49 g protein gain and 0.28 g lipid gain. An increment of 1 MJ in digestible energy (DE) intake was associated with 22 g bodyweight gain, 3.3 g protein gain and 8.2 g lipid gain. These functions emphasize that it is feed intake that regulates growth in the weaner pig, and growth is invariably curtailed below the potential through the adverse modulation of a constrained appetite.