Application of Growth Models for Pigs in Practice* -Review-

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ABSTRACT : Growth of pigs is influenced by many factors. To assist pig producers in the evaluation of alternative feeding and management strategies growth models have been developed. In the Netherlands the Technical Model Pigfeeding (TMV) is developed. This model predicts the influence of feed intake, feed composition, genotype, sex and climate on growth, body composition, gross margin and mineral excretion of healthy growing/finishing pigs. The purpose of TMV is to support information services, feed companies, researchers and students. In addition to providing accurate predictions, a model should also be user-friendly and wishes of the user should be taken into account to stimulate application of the model in practice. In this paper, the theoretical background of TMV and a methodology to stimulate application of models in practice will be described.
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Key Words : Growth of Pigs, Growth Models, Accurate Predictions

INTRODUCTION

Growth and body composition of pigs are influenced by many factors like nutrient intake, genotype, climate and disease (figure 1).

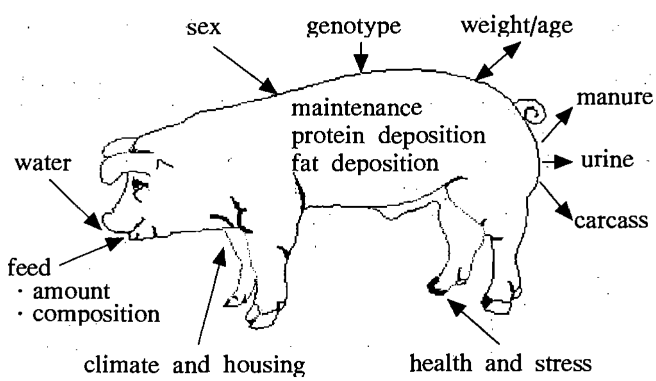

Figure 1. Factors influencing growth and body composition

In order to predict the effect of the different factors on growth and body composition, growth models are developed. Growth models can be an effective tool for optimising production and carcass quality and maximizing profitability. The last 15 years several pig growth models have been developed, including Whittemore (1983), Black et al. (1986), Moughan et al. (1987) and Pomar et al. (1991). To assist pig producers in the evaluation of alternative feeding and management strategies, in the Netherlands the Technical Model Pigfeeding (TMV) has been developed (Van der Peet-Schwering et al., 1994). TMV predicts the growth and body compostion of healthy growing/finishing pigs. Also the mineral excretion and the financial results are calculated. In this paper the technical background of TMV will be described. Then some practical applications of growth models will be considered. Finally, a methodology to stimulate application of models in practice will be discussed.

DESCRIPTION OF THE TECHNICAL MODEL PIG FEEDING

The model TMV consists of two parts, a basic model and a climate model. The basic model predicts the influence of feed intake, water intake, feed composition, genotype and sex on the growth, body composition, manure production, mineral excretion and financial results of healthy growing and finishing pigs. The climate model is based on the models of Bruce and Clark (1979) and Sterrenburg and Van Ouwerkerk (1986). It predicts the influence of housing and climate on growth and body composition. In figure 2, the model TMV is described, in the form of a flow diagram.

To predict the growth and body composition of growing/finishing pigs and to calculate the financial results and the mineral excretion, the model TMV requires the following information:

- liveweight at the start of the growing period; from this the initial chemical body composition is calculated;
- daily food intake;
- daily water intake;
- nutrient composition of the diet: energy (MJ ME), apparent ileal digestible amino acids (lysine, methionine and cystine, threonine, tryptophan and isoleucine), protein and total and digestible phosphorus; it is assumed that the intake of vitamins and other essential nutrients is sufficient for the utilization of energy and protein;
- maximum capacity for protein deposition (Pdmax);

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- marginal ratio (MR);
- liveweight at the end of the growing/finishing period or length of the growing/finishing period;
- prices of food, pigs and meat.

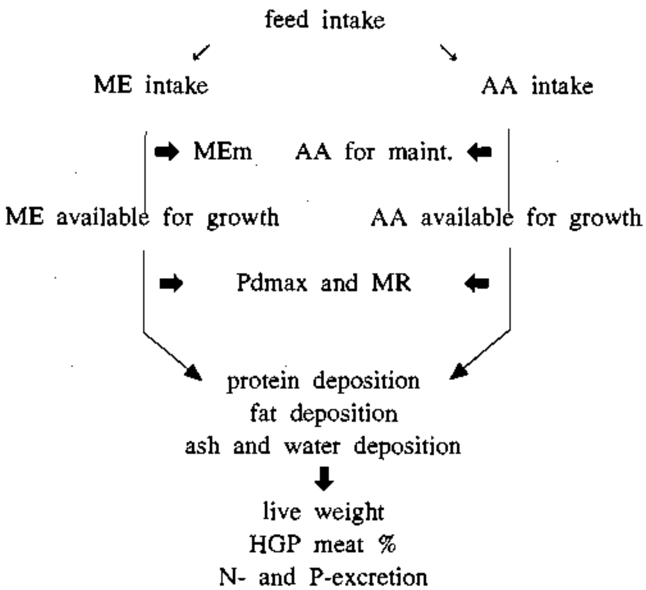

Figure 2. Description of the Technical Model Pigfeeding (Meaning of the symbols: ME = metabolizable energy; AA = amino acid; Pdmax = maximum capacity for protein deposition; MR = marginal ratio; HGP = hennesy grade probe; N = nitrogen; P = phosphorus)

To predict the influence of housing and climate on growth and body composition, some additional information is used:

- number of pigs in a group;
- floor type;
- daily air temperature, floor temperature, temperature of the ceiling and temperature of the drinking water;
- air velocity.

From the daily food intake and the dietary nutrient composition, the daily ME- intake and the daily ileal digestible amino acid intake are calculated. Part of the energy and amino acids are required for maintenance, the rest is available for growth. Depending on the maximum capacity for protein deposition and the marginal ratio, the daily protein, fat, ash and water depostion are predicted.
The most important output of the model is:
- daily deposition of protein, fat, ash and water;
- daily gain;
- daily and total energy intake and energy conversion ratio;
- Hennesy Grade Probe meat percentage;
- nitrogen and phosphorus excretion and manure production;
- feeding costs per kg growth.

Maintenance requirement

The maintenance energy requirement (MEm) depends on body weight (ARC, 1981): MEm = 0.719 MJ ME per $BW^{0.63}$ (BW = bodyweight). The maintenance requirement for ileal digestible amino acids are based on the concept for ideal protein. Estimates of ideal protein have been published by Wang and Fuller (1990), Fuller et al. (1989) and Lenis (1992). The maintenance requirement for ileal digestible amino acids in mg per kg $BW^{0.75}$ are: lysine 36, methionine 9, methionine + cystine 49, threonine 53, tryptophan 11 and isoleucine 16 (Fuller et al., 1989).

GROWTH AND BODY COMPOSITION

The genotype and sex of the pig are characterized by the maximum capacity for protein deposition (Pdmax) and the marginal ratio (MR). Pdmax and MR are necessary to predict the protein and lipid depostion.

Maximum capacity for protein deposition

Carr et al. (1977) have derived relationships between the protein deposition and liveweight. It is generally accepted that the protein deposition increases rapidly in early life, plateaus during the grower/finisher stages and then decreases towards zero at maturity (Moughan and Verstegen, 1988). It is assumed that there is an intrinsic upper-limit to body protein retention which is influenced by genotype and sex (Tullis, 1981; Whittemore, 1983; Moughan et al., 1987). In the growth models of Whittemore (1983), Moughan et al. (1987) and Van der Peet-Schwering et al. (1994) it is assumed that the maximum capacity for protein deposition (Pdmax) is constant between 20 and 110 kg liveweight. Pdmax is only realised when the energy intake and the intake of amino acids are not limiting.

There are differences in Pdmax between genotypes and sexes of pigs. Whittemore (1983) has reviewed studies in which the protein deposition could be considered close to Pdmax and gives values ranging from 90 to 175 g/d. Studies of De Greef (1992) and Bikker (1994) indicate that Pdmax for high genetic boars and sows may exceed 200 g/d and 180 g/d, respectively. According to Stranks et al. (1988), the Pdmax in boars and sows is 25% and 11% higher, respectively, than the Pdmax in castrates. For castrates, sows and boars, the Pdmax can range between 100 and 140 g/d, 115 and 155 g/d and 130 and 175 g/d, respectively (Stranks et al., 1988).

Marginal ratio

The marginal ratio is the ratio between the extra lipid and the extra protein deposition from one extra MJ of energy intake when the pig has not reached Pdmax. So, in fact it is the ratio between the slopes of the lines describing lipid and protein deposition with increasing energy intake. When the protein deposition equals Pdmax, the extra energy intake is used for fat deposition (figure 3). The marginal ratio depends on sex and bodyweight. A heavier animal will partition a higher proportion of extra energy to fat compared to a lighter animal (De Greef and Verstegen, 1995). Data from De Greef (1992) and Bikker (1994) suggest that there is a lineair relationship between MR and bodyweight: MR = b * bodyweight. Van der Peet-Schwering et al. (1994) proposed values for b of 0.04, 0.05 and 0.06 for boars, sows and castrates, respectively (Van der Peet-Schwering et al., 1994). A castrate from 100 kg liveweight for instance has a MR equal to 6 (= 0.06 * 100) (table 1). This means that the ratio between the extra lipid and the extra protein deposition from every extra MJ of energy intake is 6.

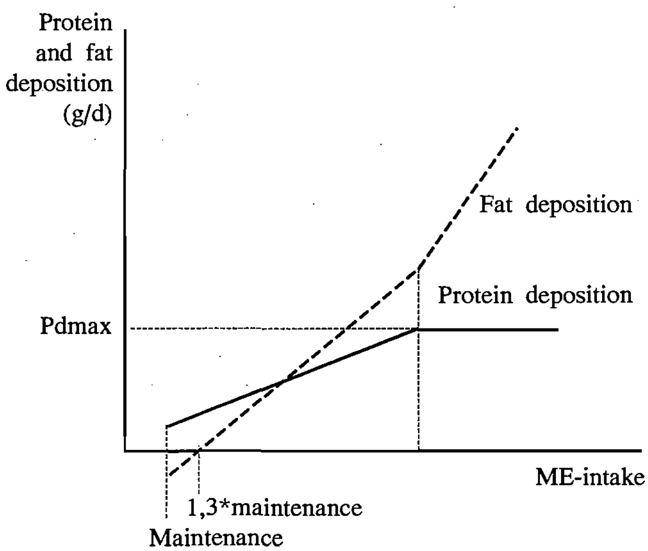

Figure 3. Protein and lipid deposition in relation to energy intake

Table 1. Marginal ratio in relation to live weight

Weight (kg)	Boar	Sow	Castrate
25	1.00	1.25	1.50
50	2.00	2.50	3.00
75	3.00	3.75	4.50
100	4.00	5.00	6.00

Protein and lipid deposition

When pigs are fed at a level that meets the energy requirement for maintenance (MEm), body fat is mobilized and protein is deposited (ARC, 1981; Black et al., 1986; De Greef, 1992). The lipid deposition is zero when pigs are fed at a level of 1.3 * MEm (Campbell and Taverner, 1988; Bikker, 1994). The efficiencies of utilization of dietary ME for lipid and protein deposition are 0.75 (ARC, 1981) and 0.45 (Van Es, 1979), respectively. This means that 53 MJ ME is required for the deposition of 1 kg protein and that 53 MJ ME is required for the deposition of 1 kg lipid.

For protein deposition not only energy is required but also amino acids are required. The requirements for ileal digestible amino acids are based on the concept for ideal protein for protein deposition (Fuller et al., 1989; Wang and Fuller, 1990). For the accretion of 1 gram protein: 68 mg lysine, 19 mg methionine, 36 mg methionine + cystine, 39 mg threonine, 12 mg tryptophan and 43 mg isoleucine are required. When the intake of amino acids is limiting the protein deposition will be reduced. In table 2, the ratio between lysine and the other ileal digestible amino acids is shown for maintenance and protein deposition.

Table 2. Estimated amino acid requirement for maintenance (mg per kg $BW^{0.75}$) and for body protein accretion (mg per g protein) (based on Fuller et al., 1989 and Wang and Fuller, 1990)

	requirement		ratio to lysine	
	mainte-nance	protein accretion	mainte-nance	protein accretion
lysine	36	68	1.00	1.00
methionine	9	19	0.25	0.28
methionine +cystine	49	36	1.36	0.53
threonine	53	39	1.47	0.57
tryptophan	11	12	0.31	0.18
isoleucin	16	43	0.44	0.63

Daily gain

In the model, each day the protein and lipid deposition are calculated. The ash deposition is calculated from the protein deposition: ash deposition = 0.191 * protein deposition (Jongbloed, 1987). The daily water deposition is also derived from the protein deposition (Kotarbinska, 1969; De Greef, 1992). Summation of the daily protein gain, daily lipid gain, daily water gain and daily ash gain results in the daily empty body weigth gain. From the empty body weight, the live weight gain can be calculated taken into account the gain in gut fill. The empty body weight is assumed to be 95% of liveweight (Whittemore, 1983). Unpublished data from De Greef, Bakker and Bikker also show that the average gut fill of growing and finishing pigs is around 5% for diets with normal fibre contents. They found no consistent pattern in the relationship between percentage gut fill with liveweight or feed allowance.

Objective of growth models

De Lange and Schreurs (1994) mentioned four main objectives of pig growth models in commercial pig production:

1. As an educational tool.
2. To develop production targets.
3. To answer general 'what-if' types questions.
4. To determine the most profitable feeding and management strategy for individual production units.

Another main objective of pig growth models, which is not mentioned by De Lange and Schreurs (1994), is the reduction of environmental problems like mineral excretion and manure production.

Growth models can be used to support information services, feed companies, researchers and students. Information services and feed companies can use the model to develop feeding strategies for growing/finishing pigs on a specific farm. For students and young advisors a growth model is an educational tool because it demonstrates the principles of nutrient utilisation and animal growth. Researchers can use the model in the design and interpretation of experiments on nutrition.

Application of TMV in practice

Some examples using TMV will be demonstrated. These are just some arbitrary examples. There are a lot of other possibilities using the model. The following calculations will be shown:

- performance of different genotypes;
- *estimation of the ileal digestible amino acid* requirement;
- reducing the nitrogen excretion.

In the first example, the performance of a pig with a low genetic potential (Pdmax = 130 g/d; MR = 0.06 × BW) and the performance of a pig with a high genetic potential (Pdmax = 160 g/d; MR = 0.04 × BW) is simulated (table 3). Both pigs receive the same amount of feed (0.99 kg/d in the beginning and 2.75 kg at the end) and the same diet.

Table 3. Performance of a pig with a low (pig A) and a high (pig B) genetic potential

	Pig A	Pig B
Maximum protein deposition (g/d)	130	160
Marginal ratio (x BW)	0.06	0.04
Weight at start (kg)	25.0	25.0
Weight at end (kg)	110.1	110.8
Number of days	114	109
Average daily gain (g)	746	787
Energy intake (MJ ME/d)	28.63	28.26
HGP Meat percentage	53.4	55.7
Nitrogen excretion (kg)	4.14	3.63
Phosphate excretion (kg)	1.60	1.46

The results in table 3 show that there is a difference in growth, body composition and mineral excretion between different genotypes. The pig with a high genetic potential excretes less nitrogen and phosphate than the pig with a low genetic potential. It is important to know the genotype of a pig, because the genotype determines the desired feeding strategy and the desired diet composition. A pig with a low genetic potential needs less ileal digestible amino acids then a pig with a high genetic potential (table 4) and could therefore be fed with another diet.

In table 5, an example is presented of a feeding strategy which reduces the nitrogen excretion. Pigs of the same genotype are fed with either two phase feeding or multi phase feeding. Both pigs are getting the same amount of energy. In a two phase feeding system, pigs are fed a starter diet the first five weeks and then a growing/finisher diet with 16% crude protein. In a multi phase feeding system, pigs are fed a starter diet the first five weeks and then a combination of two diets. Multi phase feeding involves a feed with a high content of nitrogen (16.5% crude protein) being mixed with a feed with a low content of nitrogen (14.0% crude protein). The two diets are mixed in another ratio every week.

Table 4. Estimated protein deposition (g/d) and ileal digestible lysine requirement (g/d) of a pig with a low[1](pig A) and a high[1](pig B) genetic potential

Week	kg feed/d	Pig A		Pig B	
		Pd	lysine requirement	Pd	lysine requirement
1	1.05	81	8.4	93	9.6
2	1.19	88	9.2	102	10.5
3	1.38	98	10.2	114	11.8
4	1.62	111	11.5	129	13.3
5	1.86	120	12.5	142	14.6
6	2.00	122	12.8	144	14.9
7	2.14	124	13.0	146	15.2
8	2.38	130	13.7	155	16.1
9	2.62	130	13.8	160	16.7
10	2.76	130	13.9	160	16.8
11	2.90	130	13.9	160	16.9
12	2.90	130	14.0	157	16.7
13	2.90	130	14.1	152	16.3
14	2.90	129	14.1	148	16.0
15	2.90	127	14.0	145	15.8
16	2.90	125	13.9	144	15.7

[1] Low genetic potential: Pdmax=130 g/d and MR=0.06 × BW.
[2] High genetic potential: Pdmax=160 g/d and MR=0.04 × BW.

Table 5 shows, that the N-excretion is reduced by 10% when pigs are fed with multi phase feeding.

Table 5. Estimated performance and nitrogen excretion of a pig fed with two phase feeding or fed with multi phase feeding

	two phase	multi phase
Weight at start (kg)	25.0	25.0
Weight at end (kg)	115.4	115.7
Number of days	119	119
Average daily gain (g)	766	762
Energy intake (MJ ME/d)	28.63	28.26
HGP Meat percentage	53.0	52.8
Nitrogen excretion (kg)	4.85	4.42

METHODOLOGY FOR APPLICATION OF MODELS IN PRACTICE

In addition to providing accurate prediction, a model should also be user-friendly to stimulate application of the model in practice and the wishes of the user should be taken into account. Therefore, TMV consists of two parts: the system TMV (source file and data base) and a user-friendly user interface (figure 4).

This makes it possible to implement new developments in research quite easily into the system TMV. On the other hand, suggestions of the user can be considered and if necessary, built into the user interface. In this way, a methodology, for both maintenance and application of models in practice is developed.

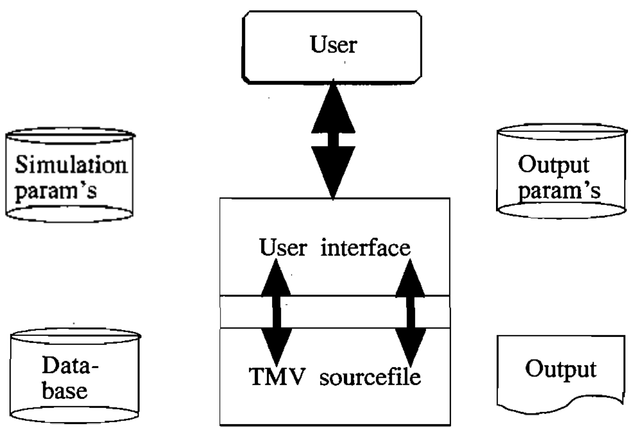

Figure 4. Communication between the user and the sourcefile via an user interface

CONCLUSION

Growth models can be helpful tools to assist pig producers in determing the most profitable feeding strategy and improving the production efficiency. From market research, it has been shown that a good understanding of the theory in models, including the limitations of the models, is very important for the application of models in practice (Van der Peet et al., 1996). Therefore, it is important to stimulate the use of models in education.

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