Allometric vs. dynamic models in the investigation of pig growth

G. Kusec[1*], I. Djurkin[1], G. Kralik[1], U. Baulain[2] & E. Kallweit[2]
[1]Department of Special Zootechnics, Faculty of Agriculture in Osijek, Josip Juraj University of Osijek, Trg Svetog Trojstva 3, 31000 Osijek, Croatia.
[2] Friedrich-Loeffler-Institut, Institut für Nutztiergenetik, Höltystraße 10, 31535 Neustadt, Germany.
*E-mail: gkusec@pfos.hr.

Abstract

A total of 68 barrows, divided into 4 groups regarding the MHS genotype and feeding regime (intensive and restrictive). Data on muscle and fat growth were obtained by magnetic resonance imaging (MRI). Allometric growth analysis showed that muscle tissue grew proportionally with the increase of live weight; fat grew faster in relation to live weight in all investigated groups of pigs. Significant differences in growth coefficients for fat were found only between feeding groups. The analysis by asymmetric S-function was more informative. Muscle growth pattern significantly differed between the groups of investigated pigs (Nn pigs performed better under intensive feeding than under restrictive feeding regime, while no difference was found between NN pigs from two feeding regimes). The optimal slaughter weight of pigs calculated on the basis of live weight and muscle growth (130 and 126 kg for intensively fed NN and Nn pigs, respectively, and about 114 kg for both genotypes from the restricted group of pigs). Growth patterns of fat differed significantly only between the feeding groups. It appears that asymmetric S-function is more accurate and informative model than a simple allometric function, providing a more robust base for important decisions in fattening of pigs.

Introduction

The phenomenon of growth is a very complex problem which has been studied from many different approaches, most common of them being allometric or differential growth and temporal growth. The allometric approach was useful in the investigation of relative development of muscle, fat and bone in different types of pigs (Gu *et al.*, 1992; Kouba *et al.*, 1999). The concept of temporal growth, using the functions which have a characteristic S-shape ("sigmoid" or S-curve) may be a good tool to overcome the limitations of linear allometric models. Kuhn *et al.* (1985) used the Gompertz function, while López *et al.* (2000) used Gompertz, Richard's and the generalised Michaelis-Menten function to describe the growth of several species. Kralik *et al.* (1999) showed that the asymmetric S-function was quite appropriate in growth analyses of different pig breeds, allowing accurate predictions of live weight growth. Magnetic resonance imaging has been proved as the useful tool to estimate muscle and fat content in pig breeding (Baulain, 1997). The aim of the present study was to compare the growth characteristics of barrows of two different MHS-genotypes kept in two feeding regimes using the allometric and temporal approach.

Material and methods

A total of 68 male castrated pigs from the Federal Hybrid Pig Breeding Programme from Germany were investigated in this study. The pigs were divided according to MHS-genotype into homozygous negative (NN) and heterozygous carriers and further into two feeding regimes: intensive, designed to support the full growth potential, and restrictive, fed diets designed according to the German recommendations. The data needed for tissue volume determination were obtained in the process of MRI.. The measurements were performed at 4 week intervals, starting at the age of 10 weeks up to the final live weight of approximately 120 kg. For the depiction of differential growth, a simple allometric function was used: log Y= log a + b * log X, where Y is the weight of tissue or a main part and X is the body weight; *a* is an intercept and *b* is the allometric coefficient. If b=1, isometric growth is assumed; Y grows at the same rate as X; if b>1, Y grows faster than X, and the opposite is true if b <1.

For modeling the growth dynamic (temporal growth) of the live weight as well as the growth of muscle tissue and fat, an asymmetric S-function with one flexible inflection point as a generalized form of logistic function was used:

$$f(t) = \frac{A}{(1+be^{-c\gamma t})^{1/\gamma}}$$

Parameters b and c in this function were calculated on the basis of collected data, A denotes the maximum live weight or maximal weight of a certain tissue. This value stands for a maximum weight in a period of interest. Symbol γ is the coefficient of asymmetry which regulates the influence of *f (t)* and *(A-f (t))*. The stages of growth are determined by points t_B and t_C, while point of inflection marks the moment at which progressive growth ceases and regressive growth starts. Statistical and mathematical analyses were performed by STATISTICA program package (version 7.1; StatSoft, Inc. 2005).

Results and discussion

Differential growth – allometric model

Relative growth rates of muscle and fat volumes in relation to live weight expressed as allometric coefficients (b) calculated for pigs of both genotypes (NN and Nn) together, kept in different feeding regimes are shown in Table 1.

Significant differences ($p<0.05$) between growth coefficients were found only for fat volume between feeding groups. The allometric relations between the feeding groups are presented in fig1.

Table 1. Allometric coefficients (b), standard errors (SE_b) and coefficients of determination (R^2) for muscle and fatty tissue of pigs by feeding regime and genotype

Tissue	Intensive			Restrictive		
	NN + Nn			NN + Nn		
	b	SE_b	R^2	b	SE_b	R^2
Muscle	0.973	0.0113	0.979	1.021	0.0128	0.975
Fat	1.288[a]	0.0152	0.978	1.174[b]	0.0153	0.973

[a, b] Row means with common superscripts do not differ ($p>0.05$)

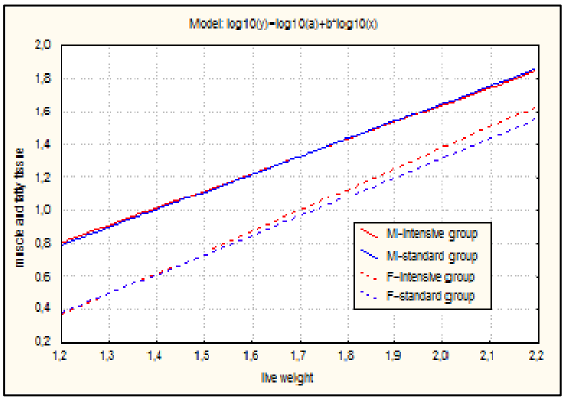

Figure 1. Differential growth of muscle (M) and fat (F) of the pigs from two different feeding groups.

Temporal growth - live weight

Parameters of growth functions calculated for the pigs of different MHS genotype kept two different feeding regimes are shown in Table 2. The growth curves for both genotypes of intensively and restrictively fed pigs are presented in fig. 2.

Table 2. Means and standard errors (in brackets) for parameters of growth curves for pigs of different MHS genotype kept in two different feeding systems

Parameters	Intensive		Restrictive	
	NN	Nn	NN	Nn
b	0.081285[a]	0.081469[a]	0.066558[b]	0.065217[b]
	(0.002751)	(0.005016)	(0.004037)	(0.002318)
c	1.413875	1.363169	1.349053	1.312191
	(0.036049)	(0.044037)	(0.063789)	(0.035882)
Points (days)	NN	Nn	NN	Nn
t_I	148.21[a]	152.46[a]	139.85[b]	142.80[ab]
	(2.083696)	(1.808781)	(2.560506)	(2.250380)
t_B	79.01[a]	80.52[a]	65.22[b]	68.16[b]
	(1.220355)	(2.095071)	(2.546449)	(1.699829)
t_C	217.41	224.40	214.47	217.45
	(3.798824)	(3.508109)	(6.369127)	(4.122154)

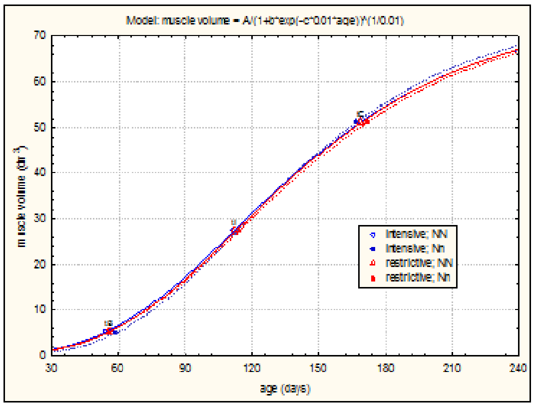

Figure 2. Live weight growth curves of two MHS-genotypes (NN and Nn) of the pigs kept on the intensive and restrictive feeding regime.

The results demonstrate that pig live weight growth patterns are influenced only by the feeding regime. The growth of MHS-negative (NN) and carrier (Nn) pigs from the intensively fed group was described by a model with fixed values of A (220 kg), and restricted group had this value set to 160 kg.

Temporal growth - muscle

Parameters of the asymmetric S-function describing muscle growth for pigs from investigated groups are presented in Table 3; the muscle tissue growth curves for the intensive and restrictive group of pigs are shown in fig 3. For all investigated pig groups, the A value in the model was set to 70 dm3.

Table 3. Means and standard errors (in brackets) for parameters of growth curves for the muscle tissue of pigs of different MHS genotype kept in two feeding regimes

Parameters	Intensive		Restrictive	
	NN	Nn	NN	Nn
b	0.069[b]	0.081[a]	0.071[ab]	0.070[b]
	(0.003)	(0.006)	(0.004)	(0.003)
c	1.711	1.834	1.728	1.693
	(0.042)	(0.074)	(0.040)	(0.040)
Points (days)	NN	Nn	NN	Nn
t_I	111.94	113.01	112.45	114.39
	(0.987)	(1.971)	(1.409)	(1.939)
t_B	54.85	59.080	55.99	56.72
	(1.292)	(2.160)	(1.882)	(1.760)
t_C	169.02	166.94	168.91	172.06
	(2.037)	(3.568)	(1.992)	(2.931)

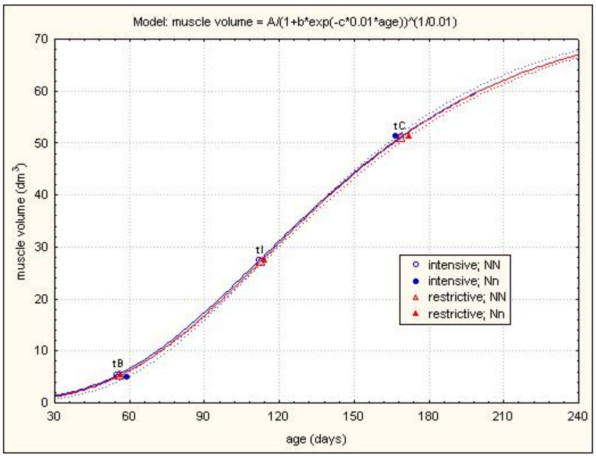

Figure 3. Muscle growth curves of two MHS-genotypes (NN and Nn) of the pigs kept on the intensive and restrictive feeding regime.

It is evident that, except for the curve parameter b, there were no significant differences in results from muscle growth analysis between the pigs under investigation. The growth pattern related to the b-value significantly differed between genotypes (NN and Nn) within the intensive feeding regime, but also between feeding groups in Nn pigs. At least in the progressive growth phase (up to the inflection point), MHS-gene carriers showed faster muscle growth when fed intensively. Intensively fed NN and Nn pigs reached the point of muscle growth saturation in 169 and 167 days, respectively. In the restrictive feeding group of pigs, these values were 169 and 172 days for NN and Nn genotypes, respectively. When live weight curve parameters are used, optimal live weights were 130 and 126 kg, respectively for intensive group of pigs; while for the restricted group calculated optimal live weight was about 114 kg.

Temporal growth - Fat

The growth curve parameters for fat growth of investigated pigs are presented in Table 4; the growth curves are presented in Figure 4.

Table 4. Means and standard errors (in brackets) for parameters of growth curves of fatty tissue of pigs of different MHS genotype kept in two feeding regimes

Parameters	Intensive		Restrictive	
	NN	Nn	NN	Nn
b	0.081285[a]	0.081469[a]	0.066558[b]	0.065217[b]
	(0.002751)	(0.005016)	(0.004037)	(0.002318)
c	1.413875	1.363169	1.349053	1.312191
	(0.036049)	(0.044037)	(0.063789)	(0.035882)
Points (days)	NN	Nn	NN	Nn
t_I	148.21[a]	152.46[a]	139.85[b]	142.80[ab]
	(2.083696)	(1.808781)	(2.560506)	(2.250380)
t_B	79.01[a]	80.52[a]	65.22[b]	68.16[b]
	(1.220355)	(2.095071)	(2.546449)	(1.699829)
t_C	217.41	224.40	214.47	217.45
	(3.798824)	(3.508109)	(6.369127)	(4.122154)

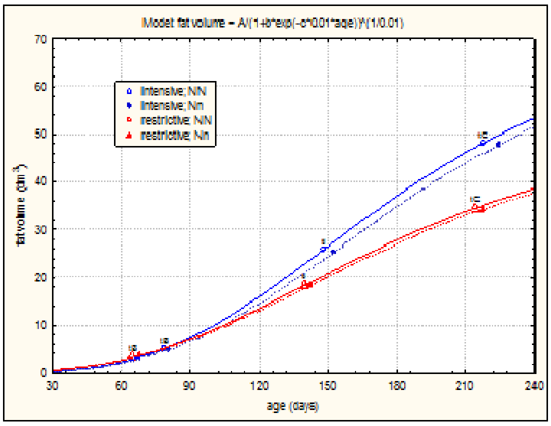

Figure 4. Fat growth curves of two MHS-genotypes (NN and Nn) of the pigs kept on the intensive and restrictive feeding regime.

From the results it is obvious that the patterns of fat growth are clearly influenced by feeding regime. Values of parameter *b* were significantly different between the feeding groups ($p<0.01$), but not between the MHS-genotypes within them. The growth of pigs from the intensive group was described by a model with an A value of 70 dm^3, while restrictively fed pigs had a different value of A (50 dm^3).

Conclusions

Analysis of growth by allometric equation and asymmetric S-function showed that the applied restricted feeding utilized the muscle growth capacity sufficiently compared with the more expensive intensive fattening regime. Contrary to asymmetric S-curve analysis, application of the allometric function did not show significant differences in growth patterns. For intensively fed NN and Nn pigs optimal slaughter weights were 130 and 126 kg, respectively; while for the restricted group optimal live weights were about 114 kg. Although the allometric equation and the asymmetric S-function showed similar patterns of growth for investigated tissues, the latter proved to be more informative, providing a base for important decisions in fattening of pigs.

Acknowledgments

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