UDK 636.4.033

Izlaganje sa znanstvenog skupa
Conference paper

MAINTENANCE REQUIREMENTS IN IMMATURE PIGS WHEN CORRECTED FOR CHANGES IN BODY COMPOSITION; A BREED COMPARISON

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Abstract

Breed differences in maintenance requirement were examined in pigs of Norwegian Landrace and Duroc of Canadian origin. The two breeds are known to differ in selection history for economically important traits. Differences in economically important traits might be caused by differences in underlying traits influencing maintenance requirement. Immature Duroc and Landrace pigs were fed ad libitum to reach live weight of 58 kg. The following eight weeks they were fed to keep constant live weight. Accurate repeated measures of body composition within the animal were achieved using Computer Tomography. Body composition was measured in the beginning, in the middle and at the end of the eight weeks. The results of the maintenance period showed significant breed differences in time trend in daily feed energy per $W^{0.75}$ ($p<0.0001$) but no differences in level. Landrace mobilised more body fat compared to Duroc (6.64 vs. 5.21 kg). Different fat depots were mobilised at different rates. Internal fat was less available for mobilisation compared to subcutaneous and inter/intra muscular fat.

Introduction

Maintenance can be defined as the state in which there is neither gain nor loss of nutrient by the body. Maintenance requirement is the estimated amount of nutrient needed to achieve such equilibrium state. Maintenance costs can be divided into three components, basal metabolic rate, maintaning body temperature and activity. Age, growth, production level, feed intake, thermal environment and health status are factors influencing basic metabolic rate in addition to the weight of the animal (Greeg & Malligan, 1982, Milligan & McBride, 1985). The ability and need for regulation of body temperature is influenced by body composition in addition to digestive activity,

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Paper presented at 46th Annual Meeting of European Association for Animal Production, Prague, Czech Republic, September 4-7, 1995.

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environmental temperature and activity. Energy costs for activity is related to body weight, production level and sensitivity towards stress (Luiting, 1994). A fourth factor is maintenance of body composition. Differences in relative proportions of body tissues will cause differences in maintenance efficiency between animals as maintenance costs varies between tissues. Heat production is strongly related to protein metabolism, while fat metabolism contributes to a little extent (Tess et al., 1984, Webster, 1981). Webster (1981) found energy for maintenance (E_m) to be less per kg metabolic body weight in obese compared to lean rats. The differences did however disappear when E_m was expressed as a function of lean mass. It is known that fractional protein turnover rate is higher in visceral organs compared to carcass lean (Reeds et al. 1993). As visceral organ proportions declines with age this together with icreased fat content can partly explain reduction in metabolic rate with increasing age.

Based on this knowledge one can question the validity of the presumptions of maintenance energy expenditure per unit metabolic body size. Animals might explore variation in all the above mentioned traits making it difficult to predict energy expenditure in simple and general ways across animals of different physiological state and genetic backgroudn. Genetic variation is proven in several studies on metabolic efficiency in poultry, sheep, cattle and pigs (Taylor and Young, 1967, Vangen, 1980, Luiting, 1991, Katle, 1991, Vangen & Thompson, 1992, Luiting tal., 1992, Jopson, et al., 1994, Luiting et al., 1995).

Tess et al. (1984) confirm the results of Sundstl et al. (1979) showing that genetically obese and slower growing pigs produced significantly less heat per unit of metabolic body size compared to lean and faster growing pigs. Vangen (1980) found that the genetically lean and high performing line was able to maintain a higher body weight compared to the obese line on equal amounts of feed. Results of Sather et al. (1978) point in the same direction, finding that high performance lines exhibited increased efficiency.

The present paper presents results from experiment on maintenance requirement in pigs comparing two breeds of different growth potential and body composition (Norsvin, 1994). The experimental design was introduced by Taylor and Young (1967) for measuring genetic variation in maintenance efficiency in cattle and repeated successfully for measuring maintenance requirement in pigs (Vagen, 1980, Enting et al. 1990). Changes in body composition during the maintenance test period were measured using computer tomography combined with newly developed Catman program for image analysis (Thompson and Kinghorn, 1992). This method is powerful in estimating tissue and component weights on live animals compared to results from dissection and chemical analysis, with r^2 values ranging from 0.85 to 0.99 (Afonso, 1992).

Materials and Methods

Animals

The population of Norwegian Landrace has during the last 35 years been intensively selected for rapid gain and reduced backfat thickness. The Duroc population in Norway is of Canadian origin, and it's limited number does not allow intensive selection programs. The two breeds are known to differ considerable in growth potential, body composition and fat distribution partly because of different selection history. Results from Norwegian performance testing of boars in 1993 and 1994 show differences in backfat thickness of about 3.35 mm in favour of Landrace. Growth rate was about 145 g/day higher in Landrace, and feed conversion ratio was 2.27 in Landrace compared to 2.49 in Duroc (Norsvin, 1995). Duroc pigs are also known for their high content of intra muscular fat (Wood and Cameroon, 1994). Comparing those genetically very different breeds would give indications of existing genetic variation in maintenance efficiency and how this is related to growth potential and body composition.

Housing and feed composition

When entering the experiment the animals were individually penned without sawdust. All pens contained drinking nipples offering free access to water.

Standard slaughter feed used in commercial pig meat production at the time of the experiment was chosen as experimental feed. Although the composition differed somewhat between the batches, the energy content of 94 feed units/100 kg feed was guaranteed.

Experimental design

Based on the concept of Taylor and Young (1967) a total of 92 pigs from three batches of respectively 28, 32 and 32 pigs equally divided on breeds and sex within breed were included in a study on maintenance requirement in pigs. The pigs entered the experiment at about 58 kg at an age of 114 days in Landrace and 131 days in Duroc pigs. Initial allowance for maintenance was calculated as a functin of metabolic body weight for growing pigs according to ARC (1981) $460W^{0.75}$ kJ accounting for activity by adding 10%. Two times a week, totally 15 times, weights were recorded and feed adjusted if needed to keep constant live weight. This desig differed slightly from Vagen (1980) and

Enting et al. (1992) as they studied differences in weight maintained between genetic groups of pigs fed constant amounts of feed.

CT measurements

Computer Tomography allows us with high precision to measure body composition on live animals (Vagen, 1988, Thompson & Kinghorn 1992, Afonso, 1992). With this information available maintenance requirement can be corrected for changes in body compositon and the true energy requirement and maintenance efficiency can be estimated.

The pigs were scanned at entrance, after four weeks and at the end of the experimental period, totally three times. They were fasted for more than 16 hours before scanning. The anaesthetic Stresnil was administrated by intra muscular injection followed by a vascular injection of Phentotan sodium. This made them sleep for about 30 minutes preventing disturbing movements during scanning. Movements causes bad image quality and reduced accuracy. Most images were of high quality, but the movements of fast breathing could cause poor image quality. Cross sectional images were taken every 5th cm starting at a randomly chosen point around tarsus joint at the hind legs ending at the atlas vertebrae, a total of 20-25 images. The Catman program is developed for analysing tissue composition in CT images (Thompson & Kinghorn, 1992). Catman allows us to quantify areas of fat, lean and bone in each image as well as depots within tissues.

In the present study the traits of greatest interest were the fat depots subcutaneous fat, inter/intra muscular fat, internal fat and fat in bone, together with carcass lean, non-fat visceral components (NFVC) and bone tissue. These components can easily be recognised in the image and recorded with high precision.

Total weight of each depot and component is estimated from total volume and mean density. Total volume is determined using Cavalieri's principle by multiplying sum of areas in all images with the distance between each image assuming parallel sections separated by a known distance (Gundersen et al., 1988). Mean density is determined from a function relating Hounsfield unit value to tissue density according to equation (1) (Fullerton, 1980).

$$\text{Tissue density} = 1.0062 + (\text{mean tissue Hounsfield unit value} \times 0.00601) \qquad (1)$$

Calculations

Daily energy from feed needed to maintain constant body weight is expressed as daily feed energy-metabolic body weight ($W^{0.75}$) ratio. To estimate effects influencing changes in this ratio during the eight week period repeated measurement analysis in SAS glm based on a split plot model (2) was used. This is a multivariate analysis taking care of dependency between repeated measurements of dependency between repeated measurements within an animal (SAS, 1985). Above this overall analysis, this SAS routing gives also univariate analysis per measurement. Model (2) was also used for estimating effects influencing changes in different body tissues and components as well as weight trend during the same period.

$$Y_{ijklm} = b_1 W_i + b_2 A_i + Br_j + S_k + Ba_l + (Br \times Ba)_{jl} + (SxBa)_{kl} + el_{ijkl} + M_m + (MxBr)_{jm} + (MxS)_{km} + (MxBa)_{lm} + e2_{ijklm}$$

Y_{jklm} = dependent variable (energy/$W^{0.75}$ ratio), body compositional traits or live weight,

W_i = live weight treated as a covariate

A_i = age treated as a covariate

Br_j = effect of breed, j=1,2.

S_k = effect of sex, k=1,2.

Ba_i = effect of batch, i=1,2,3.

M_m = effect of time (repeated measurements).

Y=energy/$W^{0.75}$ or live weight, m=1, ...15.

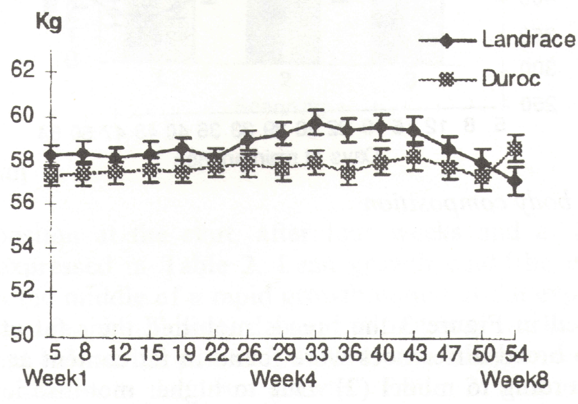
Y=body compositional traits, m=1,2,3.

el_{ijkl} = random animal effect within sex, batch, breed corrected for live weight and age.

$e2_{ijklm}$ = random error term within measurement and the interactions measurement by main effects.

Live weights was kept constant at about 57 kg by adjusting feed supply (Fig. 1).

Figure 1. - LIVE WIEGHTS DURING EIGHT WEEKS OF MAINTENANCE FEEDING



Results

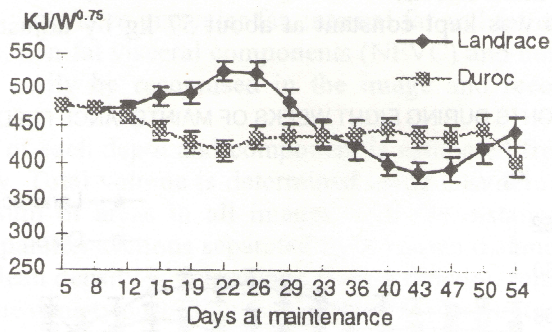
Live weight

Feed was adjusted throughout the experiment to keep the live weight constant. Still there were some minor changes (Fig. 1). Linear regression coefficient for each of the breeds is not significantly different from zero. Based on the same model, LS means of live weight for the whole period are 58.6 kg ± 0.4 and 57.8 kg ± 0.14 for Landrace and Duroc respectively.

Feed/W$^{0.75}$ ratio

Effects influencing daily feed energy/W$^{0.75}$ is analysed using model (2) without taking into account energy from mobilised body reserves. As illustrated in Figure 2 there is a general time trend ($p<0.0002$) and a significant time by breed effect ($p<0.0001$). The Duroc pigs seems to reach a stabile level early in the experiment while Landrace fluctuates relatively more. They need significantly more feed per kg metabolic body weight to keep constant live weight early in the experiment compared to Duroc pigs and significantly less during the second half.

Figure 2. - FEED/W$^{0.75}$ RATIO IN LANDRACE AND DUROC PIGS DURING EIGHT WEEKS ON CONSTANT LIVE WEIGHT



Changes in body composition

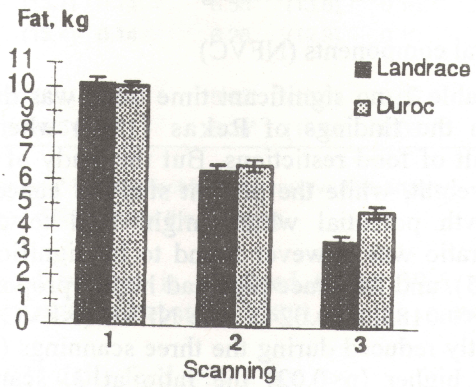
- Fat tissue

As illustrated in Figure 3 the breeds mobilied their fat at different rates ($p<0.0002$). No breed differences were found in fat content at the start of the experiment according to model (2). Due to higher mobilisation rate between second and third scanning (p<0.0021) Landrace contained significantly less fat at the end of the experimental period (p<0.009).

- Fat depots

Accordint to model 2 the breeds mobilise subcutaneous and internal fat differently (p<0.0021, p<0.0001) causing the above mentioned breed differences in absolute changes in total fat. Changes in each fat depot relative to the amount at scanning 1 are presented in Table 1. Inter/intra muscular fat is mobilised at high rates in both breeds; only 23.9% (L) and 38.7 (D) of the fat in this depot at scanning 1 remains at scanning 3. In subcutaneous fat depots the corresponding numbers are 23.7 and 41.7%, while internal fat remains with 56.8 and 72.1% of original amounts. Internal fat have the fastest decrease between 1st and 2nd scanning, while the other depots are reduced at the more constant speed throughout the whole period. Duroc shows a significantly higher level of inter/intra muscular fat corresponding with the typical characteristics of this breed (Wood & Cameron, 1995).

Figure 3. - TOTAL BODY FAT IN LANDRACE AND DUROC PIGS DURING EIGHT WEEKS ON CONSTANT LIVE WEIGHT



- Carcass lean

Body compositon at the start, after four weeks and at the end of the experiment is expressed in Table 2. Lean growth could be expected as the animals were in the middle of a rapid growth period at the experimental start. Carcass lean increases significantly during the first four weeks (p<0.0032) but not in the second half of the period (p<0.054) according to model (2). There are no breed differences in lean growth. Table 2 also expresses body components as % of total body mass measured by CT (CT weight). The proportion of lean is increasing significantly ($p<0.0008$) in both breeds on the expenses of fat also according to model (2).

Table 1. - ABSOLUTE AND RELATIVE CHANGES NI FAT DEPOTS DURING EIGHT WEEKS OF MAINTAINING CONSTANT LIVE WEIGHT (LS MEANS, MODEL 2)

	Scanning 1			Scanning 2			Scanning 3		
	Mean		Stderr	Mean		Stderr	Mean		Stderr
Subcutaneous fat,	kg	%		kg	%		kg	%	
Landrace[a]	5.49	(100)	0.13	3.57	(54.9)	0.16	1.54[c]	(23.7)	0.18
Duroc[b]	5.51	(100)	0.31	3.70	(67.2)	0.16	2.30[d]	(41.7)	0.18
Inter/intra muscular fat									
Landrace	1.97[c]	(100)	0.08	1.04[a]	(52.8)	0.06	0.47[c]	(23.9)	0.05
Duroc	2.25[d]	(100)	0.08	1.29[b]	(57.3)	0.06	0.87[d]	(38.7)	0.05
Internal fat									
Landrace[a]	2.64[c]	(100)	0.06	1.83	(69.3)	0.04	1.50	(56.8)	0.05
Duroc[b]	2.19[d]	(100)	0.06	1.74	(79.5)	0.04	1.58	(72.1)	0.05

[a,b] indiates significant scanning * breed effect from the multivariate analysis.

[c,d] indiates significant breed differences at the scanning.

- Non-fat visceral components (NFVC)

As shown in Table 2, no significant time trend was discovered in NVFC which differs from the findings of Pekas (1993) where digestive organs decreased as a result of food restictions. But the study of Pekas did include pigs at slaughter weight, while the present study is concerned with younger pigs of high growth potential which might lead to different responses. NFVC/CT-weight ratio was however found to be significantly decreasing in both breeds ($p<0.05$), and Landrace pigs had higher proportion of NFVC a 2. and 3. scanning ($p<0.0185$, $p<0.024$). The NFVC/(NFVC+carcass lean) ratio was also significantly reduced during the three scannings ($p<0.02$) the ratio at 3. scanning being higher ($p<0.02$) the ratio at 3. scanning being higher ($p<0.029$) in Landrace pgis.

The breeds went through significantly different changes in fat/(carcass lean+NFVC) ratio during the three scannings ($p<0.0019$). At 3. scanning Landrace pigs showed a significantly lower ratio ($p<0.029$).

Discussion

According to daily feed energy/$W^{0.75}$ Landrace pigs needs increasingly more feed per kg metabolic body weight to maintain constant live weight during the first four weeks compared to Duroc. In the second half, Landrace seems to have adapted to the situation of restricted feeding by getting more efficient. Including knowledge about changes in body composition during the maintenance period changes the picture. Figure 4 illustrates kJ MJ/$W^{0.75}$ ratio when accounting for changes in body energy.

Table 2. - LS MEANS OF BODY COMPONENTS AT THE START, MIDDLE AND THE END OF EIGHT WEEKS ON CONSTANT LIVE WEIGHT IN ABSOLUTE AMOUNTS AND IN PROPORTION OF CT WEIGHT ( ) BASED ON MODEL 2

	Scanning 1			Scanning 2			Scanning 3		
	Mean		Stderr	Mean		Stderr	Mean		Stderr
Fat	kg	%		kg	%		kg	%	
Landrace[a]	10.19	(19.9)	0.22	6.50	(13.5)	0.23	3.55[c]	(7.7)	0.25
Duroc[b]	10.03	(19.9)	0.22	6.78	(13.9)	0.23	4.82[d]	(10.1)	0.25
Inter/intra muscular fat									
Landrace	28.25	(55.3)	0.22	30.22	(62.5)	0.27	30.28	(65.8)	0.35
Duroc	27.70	(55.1)	0.22	30.37	(62.3)	0.27	30.88	(65.0)	0.35
Internal fat									
Landrace[a]	8.01	(15.7)	0.14	6.55	(13.6)	0.10	6.71	(14.6)	0.13
Duroc[b]	7.76	(15.4)	0.14	6.28	(12.9)	0.10	6.32	(13.3)	0.13
Bone tissue									
Landrace	4.66	(9.1)	0.07	5.07[a]	(10.5)	0.05	5.49	(11.9)	0.08
Duroc	4.79	(9.5)	0.07	5.34[b]	(10.9)	0.05	5.48	(11.5)	0.08

[a,b] indicates significant scanning* breed effect from the multivariate analysis

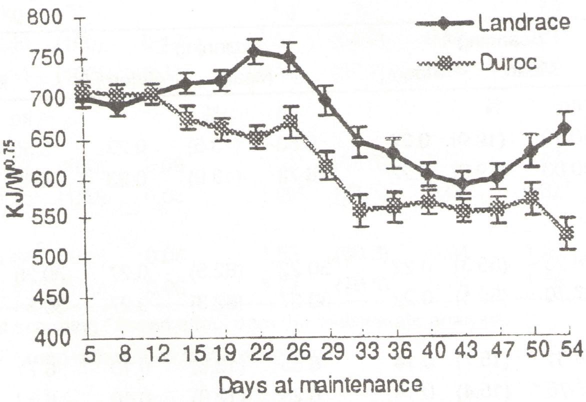
[c,d] indicates significant breed differences at the scanning

Energy in fat and protein is assumed to be 39.6 and 23.7 kJ ME/g respectively (ARC, 1981, Webster, 1980). Total energy expenditure is estimated by

Energy, MJ=12.03* daily feed + 39.6*kg daily mobilised fat - 23.7* kg daily deposited protein

Including changes in body energy to feed neede to maintain constant body weight resulted in significantly ($p<0.0001$) higher energy expenditure in Landrace pigs during the whole experiment. While Duroc pigs decreases total energy expenditure until reaching a quite stable level in the second half of the experiment, Landrace never reach such a level. It seems to have more difficulties in adapting to restricted feeding. The increase in energy expenditure in Landrace towards the end might be a consequence of long time stress from feed limitatios. The advantage of measuring changes in body composition during the experimental period is obvious. Without this knowledge one would have to assume the feed needed for maintaining constant body weight to be the real maintenance requirement. With use of CT we known the true energy spent in each animal.

Figure 4. - ME kJ/W$^{0.75}$ WHEN MOBILISED BODY RESERVES IS INCLUDED



True maintenance can be measured when body weight and body compositon is kept unchanged. The body composition did change as fat was mobilised and lean was gained. But the change in lean and NFVC content was not significant in the second half of the period. Knowing that heat production is strongly related to body protein and almost independent of fat content a state close to true maintenance was reached.

Results found in this experiment correspond well with Sundtøi et al. (1979) and Tess et al. (1984) showing that genetically leaner line is less efficient in the way feed is used for maintenance. Vagen (1980) found that the lean and high producing line was able to maintain a higher body weight on a constant amount of feed compared to the obese and low producing line, and concluded that there is a difference in maintenance requirement between the lines in favour of the lean high producing line. Information about changes in body composition was not included, and as clearly seen from the present experiment, this might lead to other conclusions. In a similar experiment on breed differences in maintenance requiremnt in Landrace and Duroc pigs Luiting et al. (1995) found no significant breed differences in weight maintained during eight weeks fed a constant maintenance ration. CT measurements of carcass parts of the body analysed by an alternative statistical technique, fitting mixture distributions to the CT-values, showed that Landrace pigs lost more carcass fat compared to Duroc pigs. There results correspond well with the present experiment, where the carcass fat depot subcutaneous fat contributed significantly to breed differences in fat mobilisation.

As stressed earlier, heat production differs between tissues. Organs connected with the digestive system are the most active tissues with considerably highe protein turnover (Webster, 1981). Different proportions of these organs would expoain differences in heat production and efficiency. The NFVC/CT-weight ratio was significantly higher in Landrace pigs at 2. and 3. scanning, and fat/protein ratio was significantly lower in Landrace during the second half of the experiment. Higher proportion of protein to maintain and more of the protein originating from non-fat visceral organs would increase energy needed for maintaining constant body weight in Landrace pigs. Higher proportions of visceral organs was also found by Cliplef and Mckay (1993) as a correlated response in lines of pigs selectef for reduced backfat thickness and increased growth rate. There is also a question whether there is a breed difference in protein turnover activity within a certain tissue independent of age and physiological state. Rate of protein and fat turnover and ion pumping activity accounts for considerably parts of energy expenditure in the body (Milligan & McBride, 1985). Those kind of questions can not be answered from the present experiment.

Differences in efficiency between the breeds can also be explained by diffeences in subcutaneous fat and the effect it has on preventing heat loss and on sensitivity towards external temperature variation. Backfat thickness, which is highly related to subcutaneous fat depot was in a breed comparison study of Henken et al. (1991) found to be lower in Norwegian Landrace compared to Large White and breed differences in surface temperature, body temperature and lower critical temperature could be explained by this. In the present experiment Duroc pigs contained more subcutaneous fat towards the end of experiment, a difference that could be of importance as the total amount of fat in both breeds was beginning to reach a critical limit for maintaining necessary functions.

Henken et al. (1991) also found that Landrace had slower growth rate, lower feed/gain ration, higher heat production and lower protein deposition than Large White and that the differences were related to higher level of activity in Landrace pigs. This resulted in lower maintenance requirements of Large White compared to Landrace. In a study of Susenbeth and Menke (1991) standing activity in a line selected for leanness was significantly higher than the fat line. Activity was not recorded in the present study, but there are reason to believe that this could be of importance as Landrace is known to be a more active breed. This breed is also considered more susceptible to stress (Luiting et al. 1995).

As the Landrace breed has gone through a more intensively selection compared to the Duroc breed, they might be compared at different stages of maturity. Selectin for increased growth rate is known to increase mature weight meaning that they are less mature at a certain weight now than they used to be. A physiologically younger pig has a higher protein turnover rate compared to a more mature pig, a therefor higher maintenance costs. This might contribute to differences in maintenance requirements the present experiment.

Breed differences in maintenance efficiency indicate existing genetic variation in this trait. The fact that Landrace is the fastest growing breed but also a breed of lower maintenance efficiency demonstrates that selection for improved production and growth rate might result in decreased efficiency in how energy is spent on other functions than growth. Including maintenance efficiency in breeding programs might be necessary to achieve increased efficiency in pig meat production as we are reaching limits for leanness and growth rate.

The question to be asked is which of the components basal metabolic rate, activity, temperature regulation and body composition are of greatest importance when genetic variation in maintenance efficiency is to be explained. Body composition seems to be of significant importance during the second half of the experiment and closely connected to the other components mentioned. Firstly, differences in distribution on tissues with different metabolic activity results in differences in basal matabolic rate for the whole body. The present study show this to be of significant importance. Secondly, body composition might be important for activity as lean animals seems to be more active and more susceptible for stress. Temperature regulation is also connected to body composition, more specifically to fat amount and distribution. Further investigations are needed to quantify these relationships including CT measurements combined with studies of activity, stress susceptibility and temperature regulation.

Breed differences in maintenance efficiency during the first half of the experiment can not be explained by differences in body composition as there was no significant breed differences at scanning 1. Other factors of importance can be rates of protein turnover and maturation. A deeper understanding of these factors is needed to quantify their contribution to genetic variation in maintenance efficiency.

Acknowledgements

The authors gratefully acknowledge the inspiring discussions and valuable knowledge shared by N. Jopson and P. Luiting and the skilled technical assistance given by A. Mehl, K. Skoglund, A. Nyhus and K. Dalen at the Agricultural University of Norway, As.

REFERENCES

1. Afonso, J.J.M. (1992): Factors affecting growth and body compositon in sheep. PhD thesis. University of New Englend, Armidale, New Zealand. 253 pp.
2. Cliplef, R.L. and McKay, R.M. (1993): Visceral organ weights of swine slected for reduced backfat thickness and increased growth rate. Can. J. Anim. Sci. 73:201-206.
3. Enting, H., Sehested, E. and Vangen, O. (1990): Maintenance requirement and changes in body composition and carcass compositon of Duroc and Norwegian Landrace pigs measured by respiration experiments and computer tomography. Commission on pig production, 41st Meeting of the European Association for Animal Production, Toulouse, France, 1990.
4. Greeg, V.A. & Milligan, L.P. (1982): O_2 consumption and Na+, K+-ATPase-dependent respiration muscle of lambs and lactating and non-lactating ewes. In: Ekern, A. & Sundsol, F., Eds. Energy Metabolism of Farm Animals. European Association for Animal Production Publication No. 29:66-69.
5. Gundersen, H.J.G., Bentsen, T.F. Korbo, L., Marcussen, N., Moller, A., Nielsen, K., Nyengaard, J.R., Parkenberg, B., Sorensen, F.B., Vesterby, A. and West, M.J. (1988): Some new, simple and efficient stereological methods and their use in pathological research and diagosis. *Acta Phatol, Microbiologica Scandinavia,* 96:379-394.
6. Henken, A.M., Brandsm, H.A., van der Hel, W. and Verstegen, M.W.A. (1991): Heat balance characteristics of limit-fed growing pigs of several breeds kept in groups at and below thermal neutrality. J. Anim. Sci. 1991, 69:2434-2442.
7. Henken, A.M., Brandsm, H.A., van der Hel, W. and Verstegen, M.W.A. (1991): Differences in energy metabolism and protein retention of limit-fed growing pigs of several breeds. J. Anim. sci.,, 69:1443-1453.
8. Katle, J. (1991): Selection for efficiency of food utilisation in laying hens. Doctoral Thesis, Agricultural University of Norway, As, Norway. 78pp.
9. Katle, J. & Kolstad, N. (1991): Selection for efficiency of Food utilisation in Laying hens: Direct Response in Residual Food Consumption and correlated Responses in Weight Gain, Egg Production and Body Weight Gain. *British Poultry Science.* 32:939-953.
10. Luiting, P. (1991): The value of feed consumption data for breeding in laying hens. PhD Thesis, Wageningen Agricultural University, The Netherlands, 183 pp.
11. Luiting, P. (1994): Selection for feed efficiency and consequences for stress susceptibility. 45th Meeting of the European association for Animal Production, Edinburgh, UK. Sessin V: Animal Genetics.
12. Luiting, P., Kolstad, K., Enting, H. and Vangen, O. (1995): Breed comparison for body composition in pigs fad at maintenance. In press. Livestock Production Science.
13. Milligan, L.P. & McBride, B.W. (1985): Energy Costs of Ion Pumping by Animal Tissues. Journal of Nutrition 115:1374-1782.
14. Norsvin (1994): Norsk Svineavlslag, Hamar, Norway
15. Pekas, J.C. (1993): Maintenance feeding of 100 kg pigs; effect on carcass lean and fat yield and on gastrointestinal organ size. Anim. Prod. 57: 455-464.
16. Reeds, P.J., Burrin, D.G., Davis, T.A., Fiorotto, M.A., Mersmann, H.J. and Pond, W.G. (1993): Growth regulation with particular references to the pig. In Growth of the Pig, Ed. G.r. Hollis.
17. Sather, A.P. & Fredeen, H.t. (1978): The importance of selection for lean growth rate upon feed utilisation by the market hog. Can. J. Anim. Sci. 58, 285-289.
18. Sundstøl, F., Standal, N. & Vangen, O. (1979): Energy metabolism in lines of pigs selected for thickness of backfat and rate of gain. Acta Agric. Scand. 29: 337-345.

19. Susenbeth, A. and Menke, K.H. (1991): Energy requirement for physical activity in pigs. In *Energy Metabolism of Farm Animals*. Proceedings of the 12th Symposium, Eds. C. Wenk and M. Boessinger, EAAP Publication No. 58, 416-419.

20. Taylor C.S. & Young, G.B. (1967): Variation in growth and efficiency in twin cattle on constant feeding levels. Anim. Prod. 9:295-311.

21. Tess, M.W., G.E. Dickerson, J.A. Nienabert and C.L. Rerrell (1984): Energy costs of protein and fat deposition in pigs fed ad libitum. J. Anim. Sci. 58:99-111-122.

22. Thomposn, J.M., and Kinghorn, B.P. (1992): Catman - A program to measure CAT-Scans for prediction of body components in live animals. Austr. Ass. of Animal Breeding and Genetics. Proc. of the 10th Conf., Rockhampton, Australia. 5pp.

23. Vangen, O. (1980): Studies on a two Trait Selection Experiment in Pigs. IV Estimating maintenance requirement from feeding experiment. Acta Agric Scand. 30:142-148.

24. Vagen, O. (1988): Experience from several years of using computer tomography (CT) in animal breeding research. VI World Conference on Animal Production, Helsinki, Finland, 1988.

25. Vangen, O. & Thompson, J. (1992): The use of CAT-scanning to measure maintenance efficiency in genetic lines of sheep. Commission on Sheep and Goat Production. 43rd Meeting of the European Association for Animal Production. Madrid, Spain. Genetic comm.

26. Webster, A.J.f. (1981): The energetic efficiency of metabolism. Poc. Nutr. Soc. 40:121-128.

27. Wood, J.D. & Cameron, N.D. (1994): Genetics of meat quality in pigs. Proceedings of the 5th Wordl congress on genetics applied to livestock production, vol. 19:458-463.

UZDRŽNE POTREBE SVINJA S KOREKCIJOM NA PROMJENE TJELESNOG SASTAVA; USPOREDBA PASMINA

Sažetak

Pasminske razlike u uzdržnim potrebama ispitivane su na svinjama Norveški Landrace i Duroc kanadskog porijekla. Poznato je da se ove dvije pasmine razlikuju u povijesti selekcije na ekonomski važne osobine. Razlike u osnovnim osobinama što utječu na uzdržne potrebe mogu prouzročiti razlike u ekonomski važnim osobinama.

Svinje Duroc i Landrace hranjene su po volji do težine od 58 kg žive vage. Slijedećih osam tjedana hranjene su da održe stalnu težinu. Točne ponavljane mjere tjelesnih sastava unutar životinje postignute su pomoću kompjutorske tomografije. Sastav tijela mjeren je na početku, u sredini i na kraju osam tjedana. Rezultati uzdržnog razdoblja pokazali su značajne pasminske razlike u vremenu u energiji dnevne hrane na $W^{0.75}$ ($P<0.0001$) ali bez razlike u razini. Landrace je mobilizirao više tjelesne masnoće u usporedbi s Durocom (6.4 prema 5.21 kg). Razna spremišta masnoće mobilizirana su različitom brzinom. Unutarnja masnoća bila je manje raspoloživa za upotrebu u usporedbi s potkožnom ili masnoćom unutar/između mišića.

Primljeno: 15. 2. 1997.