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Effects of Different Protein Concentration on Growth Performance, Nutrient Digestion and N-balance of Growing Minks

H.H. Zhang, M. Yu, G.Y. Li, T.T. Zhang, K.Y. Wang, J.B. Zhao and F.H. Yang
Institute of Special Animal and Plant Sciences, Chinese Academy of Agriculture Sciences, State Key Laboratory for Molecular Biology of Special Economic Animals, Changchun 130112, China

Corresponding Author: F.H. Yang, Institute of Special Animal and Plant Sciences, Chinese Academy of Agriculture Sciences, State Key Laboratory for Molecular Biology of Special Economic Animals, Changchun 130112, China Tel:+86043181919801 Fax: +86043181919800

ABSTRACT

The objective of this study was to examine whether growth performance, nutrient digestion and N-balance of growing minks were affected by different dietary protein levels from good protein feed resource. Eighty young male minks were allotted to five treatment groups (P36, P32, P28, P24 and P20) provided with diets containing approximately 36, 32, 28, 24 and 20% protein in Dry Matter (DM), respectively. From July to middle September the Body Weight (BW) was lower in group P20 than other groups ($p<0.05$). No significant difference of dietary protein on minks' BW and average daily gain (ADG) between groups P36 and P32 ($p>0.05$). The performance and digestibility of DM, Crude Protein (CP) and Crude Fat (CF) were similar when the dietary protein level decreased from P36 to P32 ($p>0.05$). N intake, urinary N excretion and Blood Urinary Nitrogen (BUN) increased linearly with increasing dietary protein level ($p<0.05$). No significant difference was found of serum Total Protein (TP) among all groups ($p>0.05$). Considering of all the factors, when minks fed good protein resource the level of dietary protein should be about 32% of DM (29.78% of ME) of diet could meet the requirement of growing minks. Furthermore, the urinary N could decrease 6.06% in growing period of minks.

Key words: Mink, protein levels, growth performance

INTRODUCTION

Considering today's growing environmental concerns and increasing feed costs, feeding appropriate dietary crude protein concentrations is of the utmost importance in the feedlot industry. For most animal species, the protein requirement is met with as little as 10% of the digestible energy (Crampton, 1964). The mink, as an obligate carnivore, has a demand for a large proportion of protein in its diet (MacDonald *et al.*, 1984). An animal's requirement for protein depends on many factors including energy intake, level of activity, physiological status, growth capacity, previous nutrition and genetic differences etc. An estimated protein requirement always depends on the physiological activity for which the requirements is met since the protein level (quantity and quality) required for top performance in one physiological process may not necessarily be sufficient for another physiological process.

The National Research Council provided the earliest recommendation of specific levels of protein for mink of the ranch year (Harris *et al.*, 1953). Multiple studies have been done on the protein requirements of the mink but the protein level of requirement for minks had a big range.

(Basset *et al.*, 1948, 1951; Sinclair *et al.*, 1962; Allen *et al.*, 1964; Skrede and Herstad, 1978; Tyopponen *et al.*, 1987; Kerminen-Hakkio *et al.*, 2000; Rasmussen and Borsting, 2000; Sandbol *et al.*, 2004). Earlier studies obviously indicated that the quality of protein in the mink's diet will determine the exact level of percentage of ME as protein required for top performance of the mink for the growth phase of the mink ranch year.

The objective of the present study was to observe if the minks feed good quality of protein diet, did it can get better performance and decrease N excretion and to investigate the effects of dietary protein levels on growth performance, nutrient digestion metabolism and serum biochemical parameters in growing mink and to find the optimal protein level.

MATERIALS AND METHODS

The experiment was carried out at the fur animal farm of the institute of special economic animals and plants, Chinese Academy of Agricultural Science in Northeast of China. The experimental minks were housed in the standard sheds with open sides.

Animals and experiment design: The experiment began on 9 July with a total of 80 weaned mink males. The average (±SD) age and weight of the animals at start were 57±3d and 820±36 g, respectively. The animals were allocated to the five treatment groups and 16 animals each. The experiment was preceded by 1 week adjustment period, during which the animals were accustomed to the experimental feed. The ingredients and compositions of experiment diets were shown in Table 1. Animals had free access to drink water and were fed twice a day with the experimental diets. All training and testing of the animals was performed by the same person. BW of animals was determined each 15 days. ADG, Average Daily Feed Intake (ADFI) and feed: gain ratio (F/G) was calculated at the end of study.

Blood samples were collected from 8 minks per experimental group during the growing period and brought to lab quickly and centrifuged for 10 minutes at 5000 rpm/min. then serum separated from blood and transferred into Eppendorf centrifuge tubes and kept at-20°C until analysis.

N-balance experiments: The N-balance experiments were carried out using nine 14-weeks old male kits from the respective treatment groups. The feces and urine collection period lasted three days. The animals were kept in metabolism cages constructed for separate collection of feces and urine, in principle as described by Jorgensen and Glem-Hansen (1973) and Glem-Hansen (1992). Feces and urine were collected quantitatively daily and kept frozen pending analyses. To avoid ammonia evaporation from the urine, 20 mL sulphuric acid (5% solution) was added to the urine collection bottles and the urine collection trays were sprayed with citric acid (20% solution) once per day. In the N-balance calculations, retained N was determined as ingested N-(fecal N+urinary N).

Chemical analyses: The chemical composition of feed and feces was analysed by standard methods. DM, ash and crude protein (CP: Kjeldahl-N×6.25), calcium and phosphorus contents were analyzed according to AOAC (2003) procedures. Crude Carbohydrate (CC) was calculated as the difference by subtracting ash, CP and EE from the DM content. The calculation of ME content and the proportional composition of ME were based on the digestibility coefficients achieved and the following values of ME: protein 18.8 MJ kg^{-1}, fat: 39.8 MJ kg^{-1} and carbohydrate 17.6 MJ kg^{-1}

Table 1: Ingredient and composition of experiment diets

Item	P36	P32	P28	P24	P20
Ingredients					
Extrusion corn	40.20	42.30	46.80	53.00	59.70
Corvina	31.40	26.50	19.30	14.20	9.90
Poultry offal	2.50	3.60	3.40	4.50	4.50
Eggs	5.80	4.50	3.10	3.10	3.10
Jarding pork	11.20	14.50	20.40	20.40	20.40
Hircine liver	7.90	7.60	6.00	4.80	2.40
NaCl	0.50	0.50	0.50	0.50	0.50
Premix[a]	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition					
Dry matter	26.06	26.78	27.47	27.69	28.18
In dry matter					
Ash	9.05	9.73	8.85	7.34	7.10
Crude protein	36.30	33.12	29.54	25.18	21.92
Crude fat	18.26	20.82	19.33	19.21	20.89
Carbohydrates	36.38	36.33	42.27	48.26	50.08
Metabolisable energy[b]					
Metabolizable energy (MJ)	20.49	20.91	20.69	20.87	21.25
Percentage from protein	33.29	29.78	26.84	22.68	19.39
Percentage from fat	35.46	39.64	37.19	36.63	39.13
Percentage from carbohydrates	31.25	30.58	35.97	40.69	41.48

[a]The premix provided the following per kg of diet: Ca (as $CaHPO_4 \cdot 2H_2O$), 6.4 mg, P(as $Ca(H_2PO_4)_2 \cdot H_2O$), 4.4 mg, Mg (MgO), 1.6 mg, Na (NaCl), 24 mg, Fe (as $FeSO_4 \cdot H_2O$), 16 mg, Cu (as $CuSO_4 \cdot 5H_2O$), 4.0 mg, Zn (as $ZnSO_4 \cdot H_2O$), 10 mg, Mn (as $MnSO_4 \cdot H_2O$), 12 mg, VA, 300 IU, VB1, 0.15 mg, VB2, 0.40 mg, VB6, 0.30 mg, folic acid, 0.30 mg, nicotinic acid, 1.60 mg, D-pantothenic acid, 1.3 mg, [b]ME calculated according to Hansen *et al.* (1991)

(Hansen *et al.*, 1991). Serum urea nitrogen concentration and serum total protein were measured according to the method of Bradford (1976) using kit (Nanjing Jiancheng Biotechnology Co., Ltd, Jiangsu, China) as the standard.

Statistical analyses: All data were analyzed using the GLM procedure of SAS (2002). A level of $p<0.05$ was set as the criterion for statistical significance. Data were represented as Mean±SD.

RESULTS

Performance and Nutrient digestibility: Effects of different dietary protein levels on performance and nutrient digestibility were shown in Table 2. The final weights and ADG were affected by different level of diets ($p<0.05$), the value decreased with dietary protein level reducing. The ADFI were not affected by different dietary protein levels ($p>0.05$), F/G had significant difference among all groups ($p<0.05$) but the ADFI and F/G were all increased with declining dietary protein levels. Digestibility of DM was similar among the groups. The CP digestibility increased with dietary CP level increasing and found the highest in P36 (90.07%) ($p<0.05$). the digestible protein level of 5 diets were 327.04, 294.83, 260.89, 216.87 and 188.47 g kg^{-1} DM. Apparent digestibility of CF was impaired with decreasing dietary protein level ($p<0.05$), reduced the dietary protein level decreased the digestibility of CF.

Table 2: Effects of different dietary protein levels on performance and nutrient digestibility of minks

Items	P36	P32	P28	P24	P20
Initial weights (kg)	0.82±0.07	0.82±0.12	0.82±0.08	0.82±0.11	0.83±0.07
Final weights (kg)	1.97±0.21[a]	1.95±0.22[a]	1.93±0.77[ab]	1.84±0.18[ab]	1.76±0.29[b]
ADG (g day^{-1})	19.16±1.66[a]	18.83±1.88[ab]	18.50±2.33[ab]	17.00±3.08[b]	15.50±2.77[b]
ADFI (g)	96.87±4.77	98.23±6.62	98.93±7.99	100.76±12.36	105.04±5.33
F/G	5.05±0.08[b]	5.21±0.11[b]	5.35±0.12[ab]	5.92±0.07[ab]	6.77±0.14[a]
Digestibility of DM (%)	84.42±9.52	84.39±4.40	83.69±1.37	82.11±3.81	81.52±3.11
Digestibility of CP (%)	90.07±2.56[a]	89.02±3.28[a]	88.32±1.81[ab]	86.13±1.11[b]	85.98±2.84[b]
Digestibility of CF (%)	94.88±2.54[a]	94.87±2.27[a]	94.03±1.35[ab]	91.56±4.59[bc]	89.96±2.94[c]

The values are the Mean±SD, for method of estimation, see text, Values within rows with different letters differ significantly ($p<0.05$)

Table 3: Effects of different dietary protein levels on N-balance of minks

Items	P36	P32	P28	P24	P20
N intake (g day^{-1})	5.63±0.27[a]	5.11±0.43[b]	4.46±0.51[c]	4.06±0.49[d]	3.69±0.18[d]
Fecal N (g day^{-1})	0.62±0.06[a]	0.61±0.06[a]	0.52±0.06[b]	0.58±0.04[a]	0.49±0.08[b]
Urinary N (g day^{-1})	2.66±0.55[a]	2.30±0.72[ab]	1.94±0.52[bc]	1.69±0.58[cd]	1.32±0.24[d]
N retained (g day^{-1})	2.31±0.46[a]	2.19±0.49[ab]	1.96±0.51[ab]	1.74±0.56[b]	1.70±0.21[b]
BUN (mg L^{-1})	236.69±6.36[a]	219.63±8.76[a]	216.28±4.42[a]	213.98±9.58[a]	180.32±9.95[b]
TP (mg mL^{-1})	64.10±2.78	67.02±8.78	60.13±13.21	66.93±7.07	64.78±8.73

The values are the Mean±SD, for method of estimation, Values within rows with different letters differ significantly ($p<0.05$)

N-balance: Effects of different dietary protein levels on N-balance were shown in Table 3. N intake and urinary N excretion increased linearly with increasing dietary protein level ($p<0.05$). In daily retention of N (g per mink) there were significant difference ($p<0.05$) but N retained was no significant difference among P36, P32 and P28 ($p>0.05$), N retained decreased with dietary protein level reducing, the values were 2.31 g day^{-1} per mink, 2.17 g day^{-1} and 1.96 g day^{-1}, respectively. Effects of different dietary protein levels on BUN and serum total protein (TP) were shown in Table 3. BUN were affected by different dietary protein levels ($p<0.05$). BUN decreased linearly with declining dietary protein level, the values were 236.69, 219.63, 216.28 and 180.32 mg L^{-1}, respectively. No significant difference was found of TP among all groups.

DISCUSSION

Conventional mink diets are largely based on by-products from the fishing industry and abattoirs and, therefore, are rich in protein and other N-containing constituents. The mink has a very short intestine (Kainer, 1954) and a feed passage time of only 4-6 hours (Hansen, 1978; Szymeczko and Skrede, 1990). Thus, ingested dietary protein is rapidly digested and absorbed, so we used good quality protein feed in currently study. The decline of the protein was achieved with a proportional decline of all protein-sources and they were regulated with maize starch.

In present experiment, the BW and ADG of all minks increased fleetly, the requirement for protein (g day kg^{-1} live weight or g kg^{-1} dietary DM) is higher during the early than the late phases of growth, as demonstrated earlier in blue foxes (Rimeslatten, 1976) and in mink, too (Skrede, 1978; Damgaard, 1997). Our research indicated that fed diets with low protein level showed lower body weight gain than the animals fed higher protein diets, no significant affects of dietary protein on minks' BW and ADG between groups P36 and P28. In the present study, we found that the content of dietary protein was not the higher the better, superfluous dietary protein would cause to waste, moreover, increased the N excretion. By contraries, deficient dietary protein could not satisfy the requirement of mink growth.

ADFI significantly increased with reducing dietary protein levels. ADG decreased linearly with reducing dietary protein level, by contraries, F/G increased linearly with declining dietary protein level. The results implicate that increasing dietary protein level had a consistent increase in ADG and a decrease in F/G of minks. Proteins are the major component in muscles. As previous study reported muscles and other tissues are primarily formed in the early growth phase of mink kits (Stryer, 1997).

Our research showed that the digestibility of DM, CP and CF were decreased with declining dietary protein level. The lower the dietary protein level, the lower was the digestibility of the DM, CP, CF and other nutrients in fox (Dahlman *et al.*, 2002). The influence of protein level on the apparent digestibility of protein has been studied more. Research on ileal-fistulated blue foxes by Szymeczko and Skrede (1991) showed a sight reduction in the apparent digestibility of CP at lower protein levels. Similar results were obtained by Skrede (1979), working with mink. The influence of protein level on the apparent digestibility of protein has been under intensive research in other animals, pigs in particular. A number of studies suggest that reductions in dietary protein lead to increases in relative amount of endogenous N secretion, which, in turn, reduce the apparent digestibility of protein (Low, 1980; Baker, 1989). In contrast, in studies by Li *et al.* (1993) the apparent digestibility of protein was not affected by the dietary level of protein. In the present investigations, the performances and digestibility of nutrient was not affected when the dietary protein level decreased from P36 to P32, which means 294.83 g kg^{-1} DM digestible protein of diet could meet the requirement of growing minks.

N intake, UN and N retention decreased with reducing dietary protein level. As pointed out by Glem-Hansen (1980) the growing mink fed low-protein diets were able to compensate for previous low nitrogen retention during the growing-furring period. From an environmental point of view, a substantial reduction in N emissions can be achieved by decreasing the dietary protein level. According to the present research, N excretion in urine declines significantly when the protein level in the diet is lowered from P36 to P32 and did not affected the performance of minks. The results are consistent with earlier findings that N excretion declined noticeably along with a reduction in dietary protein pigs (Jongbloed and Lenis, 1992; Valaja *et al.*, 1993). According to Valaja *et al.* (1993), a reduction in dietary protein from 180 to 120 (g kg^{-1}) resulted in a 38.3% decrease in urinary N excretion in growing pigs. Our research show that when the dietary protein level decreased from P36 to P32 resulted in a 6.06% decrease in urinary N excretion in growing minks.

BUN was affected by dietary protein levels. It was reduced linearly by declining CP level in the present study, which has also been found in plasma or serum in other reports (Kerr and Easter, 1995; Figueroa *et al.*, 2002; Nyachoti *et al.*, 2006; Yue and Qiao, 2008). No significant difference was found of serum total protein among all groups. The result are consistent with earlier findings, Blome *et al.* (2003) reported that TP concentration in plasma of dietary CP content was not significant in pig.

CONCLUSION

Based on the results from this experiment, we suggest that, in order to achieve normal growth and ensure low N emission, the level of dietary protein should be about 32% of DM (29.78% of ME) and the digestible protein about 29.4% of DM when the minks fed good protein resource. Furthermore, compare with the high protein level urinary N could decrease 6.06% in growing minks. BUN was affected by dietary protein levels. Serum total protein of minks was irrespective of dietary protein level.

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REFERENCES

AOAC, 2003. Official Methods of Analysis. 17th Edn., Association of Official Analytical Chemists, Arlington, VA.

Allen, M.R.P., E.V. Evans and I.R. Sibbald, 1964. Energy: Protein relationships in the diets of growing mink. Can. J. Physiol. Pharm., 42: 733-744.

Baker, D.H., 1989. Amino Acid Nutrition of Pigs and Poultry. In: Recent Advances in Animal Nutrition-1989, Haresign, W. and D.J.A. Cole (Ed.). Butterworth and Co., Borough Green, Sevenoaks, England.

Basset, C.F., J.K. Loosli and F. Wilke, 1948. The vitamin a requirement for growth of foxes and minks as influenced by ascorbic acid and potatoes. J. Nutr., 35: 629-638.

Basset, C.F., L.E. Harris and C.F. Wilke, 1951. Effect of various levels of calcium, phosphorus and vitamin d in take on bone growth. II. Minks. J. Nutr., 44: 433-442.

Blome, R.M., J.K. Drackley, F.K. McKeith, M.F. Hutjens and G.C. McCoy, 2003. Growth, nutrient utilization and body composition of dairy calves fed milk replaces containing different amounts of protein. J. Anim. Sci., 81: 1641-1655.

Bradford, M.M., 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Anal. Biochem., 72: 248-254.

Crampton, E.W., 1964. Nutrient-to-calorie ratios in applied nutrition. J. Nutr., 82: 353-365.

Dahlman, T., J. Valaja, P. Niemela and T. Jalava, 2002. Influence of protein level and supplementary L-methionine and lysine on growth performance and fur quality of blue fox (*Alopex lagopus*). Acta Agric. Scand. Sect. A: Anim. Sci., 52: 174-182.

Damgaard, B.M., 1997. Dietary Protein Supply to Mink (Mustela Vison): Effects on Physiological Parameters, Growth Performance and Health. Department of Animal Science and Animal Health, the Royal Veterinary and Agricultural University, USA., Pages: 106.

Figueroa, J.L., A.J. Lewis, P.S. Miller, R.L. Fishcher, R.S. Gomez and R.M. Diedrichsen, 2002. Nitrogen metabolism and growth performance of gilts fed standard corn-soybean meal diets or low-crude protein, amino acid supplemented diets. J. Anim. Sci., 80: 2911-2919.

Glem-Hansen, N., 1980. The protein requirements of mink during the growth period. Acta Agric. Scand., 30: 336-344.

Glem-Hansen, N., 1992. Review of protein and amino acid requirements for mink. Scientifur, 16: 122-142.

Hansen, N.E., 1978. The influence of sulfuric acid preserved herring on the passage time through the gastrointestinal tract in mink. Zeitschrifi fur Tierphysiologie, Tierernahrung und Futtermittelkunde, 32: 233-239.

Hansen, N.E., L. Finne, A. Skrede and A.H. Tauson, 1991. Energy supply for the mink and the fox. Nordic Association of Agricultural Scientists, NJF Report No. 63. DSR Forlag, Den Kgl. Veterinaer-og Landbohojskole, Copenhagen, Denmark

Harris, L.E., C.A. Cabell, C.A. Elvehjem, J.K. Loosli and H.C. Schaefer, 1953. Nutrient requirement for domestic animals, Number 7: Nutrient requirements for foxes and minks. Publication No. 296, Division of Biology and Agriculture, National Research Council, Washington, DC., USA.

Jongbloed, A.W. and N.P. Lenis, 1992. Alteration of nutrition as a means to reduce environmental pollution by pigs. Livestock Prod. Sci., 31: 75-94.

Jorgensen, G. and N. Glem-Hansen, 1973. A cage designed for metabolism and nitrogen balance trials with mink. Acta Agric. Sand., 23: 3-4.

Kainer, R.A., 1954. The gross anatomy of the digestive system of the mink. II. The midgut and the hindgut. Am. J. Vet. Res., 15: 91-97.

Kerminen-Hakkio, M., T. Dahlman, P. Niemela, T. Jalava, T. Rekila and Q.S. Syrjala, 2000. Effect of dietary protein level and quality on growth rate and fur parameters in mink. Proceedings of the 7th International Congress on Fur Animal Production, September 13-15, 2000, Kastoria, Macedonia, Greece.

Kerr, B.J. and R.A. Easter, 1995. Effect of feeding reduced protein, amino acid-supplemented diets on nitrogen and energy balance in grower pigs. J. Anim. Sci., 73: 3000-3008.

Li, S., W.C. Sauer and M.Z. Fan, 1993. The effect of dietary crude protein level on ideal and fecal amino acid digestibility in early weaned pigs. J. Anim. Physiol. Anim. Nutr., 70: 117-128.

Low, A.G., 1980. Nutrient absorption in pigs. J. Sci. Food Agric., 31: 1087-1130.

MacDonald, M.L., Q.R. Rogers and J.G. Morris, 1984. Nutrition of the domestic cat, a mammelian carnivore. Annu. Rev. Nutr., 4: 521-562.

Nyachoti, C.M., O. Omogbenigun, M. Rademacher and G. Blank, 2006. Performance responses and indicators of gastrointestinal health in early-weaned pigs fed low-protein amino acid-supplemented diets. J. Anim. Sci., 84: 125-134.

Rasmussen, P.V. and C.F. Borsting, 2000. Effects of variations in dietary protein levels on hair growth and pelt quality in mink (Mustela vison). Agric. Inst. Canada, 80: 633-642.

Rimeslatten, H., 1976. Experiments in feeding different levels of protein, fat and carbohydrates to blue foxes. Proceedings of the International Scientific Congress in Fur Animal Production, April 27, 1976, Helsinki, Finland, pp: 28-30.

SAS, 2002. SAS/STAT User's Guide. Version 8.2, SAS Institute Inc., Cary, NC., USA.

Sandbol, P., T.N. Clausen and C. Hejlesen, 2004. Ideal protein for mink Mustela vison in the growing and furring periods. Scientifur, 28: 120-128.

Sinclair, D.G., E.V. Evans and I.R. Sibbald, 1962. The influence of apparent digestible energy and apparent digestible nitrogen in the diet on weight gain, feed consumption and nitrogen retention of growing mink. Can. J. Biochem. Physiol., 40: 1375-1389.

Skrede, A. and O. Herstad, 1978. Micronized cereals and soybeans for mink and chickens. Scientific Reports of the Agricultural University of Norway, pp: 1-11.

Skrede, A., 1978. Utilization of fish and animal by-products in mink nutrition: Effect of source and level of protein on nitrogen balance, postweaning growth and characteristics of winter fur quality. Acta Agric. Scand., 28: 105-145.

Skrede, A., 1979. Utilization of fish and animal byproducts in mink nutrition: Fecal excretion and digestibility of nitrogen and amino acids by mink fed cod (*Gadus morrhua*) fillet or meat-and-bone meal. Acta Agric. Scand., 29: 241-257.

Stryer, L., 1997. Biochemistry. 4th Edn., Stanford University, USA.

Szymeczko, R. and A. Skrede, 1990. Protein digestion in mink. Acta Agric. Scand., 40: 189-200.

Szymeczko, R. and A. Skrede, 1991. Protein digestion in fistulated polar foxes. Scientifur, 15: 227-232.

Tyopponen, J., H. Berg and M. Valtonen, 1987. Effects of dietary supplement of methionine and lysine on blood parameters and fur quality in mink fed with low-protein diets. Acta Agric. Scand., 37: 487-494.

Valaja, J., T. Alaviuhkola and K. Suomi, 1993. Reducing crude protein content with supplementation of synthetic lysine and threonine in barley-rapeseed meal-pea diets for growing pigs. Agric. Sci. Finl, 2: 117-123.

Yue, L.Y. and S.Y. Qiao, 2008. Effects of low-protein diets supplemented with crystalline amino acids on performance and intestinal development in piglets over the first 2 weeks after weaning. Livest. Sci., 115: 144-152.