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„THESES OF THE DOCTORAL (PHD) DISSERTATION"

INFLUENCES OF CERTAIN ENVIRONMENTAL FACTORS ON THE RESULTS OF PIG FATTENING

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I. THE BACKGROUND TO THE RESEARCH

The ways of production and the economy of the production of pork – traditionally one of the most important staples – is an outstandingly important issue. Increasing the productivity of pigs is also important, which is the most important task for practising professionals and researchers.

In the 1970's, under the so-called industrial animal keeping project, pig production experienced an improvement never seen before. There were almost 300 so-called industrial pig farms constructed using the latest knowledge, some of which later proved to be wrong. New breeds and crosses were developed and hybrids (Hungahib, Kahyb, Pannonhibrid) also appeared. Among others, artificial insemination and early weaning of pigs became general. The genetic potential of the stocks, however, could not be exploited. The lag in weight gain and specific nutrition were 30-40 % and 20-30 %, respectively, which is equally due to difficulties in animal hygiene, keeping technology and misunderstandings.

Unfavourable stock density (a higher number of animals per one square metre, saying this ensures a more efficient utilisation of the building) together with all its consequences (insufficient ventilation, ethologically unfavourable crowdedness, etc.), some practical-looking feed distribution method (less labour requirement, floor feeding)) that later proved to be unable to stand the test are the most serious difficulties in the area of keeping technology. The biggest concern for nutrition was the inevitably economy on the use of proteins, which was the consequence of the foreign exchange controls of the era.

As a result the insufficient feed intake was the reason for the inadequate production as the former is closely related to body weight gains and feed conversion, which have decisive effects on the shaping of the efficiency of farms.

Certainly, the feeds fed to the animals also played their part in the smaller feed intake and unfavourable feed conversion ratio. We did not know well enough the importance of particle size and we did not know how to make granules. It was found out only in practice that, among others, very finely pulverised feeds (which is produced even in the case of granules as a result of friction in the feed distribution system) cause massive occurrences of oesophageal/stomach diseases in pig populations. Also we had uncertain knowledge as regards the effects of various degrees of moistening on the production in these new management practices.

Among other things, it is the considerations outlined above that led me to present in this thesis the research dealing with the effects of feed particle size and consistency out of the investigations I conducted over the past 10-15 years. This area refers to three significant issues: the relationship between particle size and the digestibility of the feed, the occurrence of gastric ulcer and the performance of piglets and fattening pigs.

2. OBJECTIVES OF THE EXPERIMENTS

Feeding grain or ground compoundfeed to pigs has been a research topic for about five decades. It has been justified that appropriate grinding will favourably influence digestibility, body weight gain and feed conversion. Even today the optimum particle size of feed is widely researched. It is supposed that it is necessary to have adequate particle size in order to achieve optimal feed conversion ratio.

As regards digestion small particle size seems to be more favourable but from the point of view of consumption finely powdered feed appears to be expressly disadvantageous.

Coarser particle sizes are more favourable because these particles irritate the digestion tract they enhance the peristal of intestins and the movement of villi. They are also advantageous because – depending on age – 3, 5, 7 or perhaps 10% fibre is indispensable for the normal functioning of the digestive system of the pig and for adequate feed conversion. It is a fact, however, that in practice it is the ground meal prepared from raw materials higher in fibre that have the bigger particle size.

This study analysed the effects of the particle sizes in feedstuffs on production taking consistency and the interaction between the two into consideration. That is why pigs were fed feedstuffs of different particle sizes as dry grinded, moistened grinded and in granulated form.

On the basis of the reasons outlined above I thought it was well-founded to study the following issues under large-scale farm conditions:

- the ratio of particle size after grinding applying screens with different hole sizes,
- what particle size feed is the most favourable for piglets and pigs of various ages and body weights, i.e., what is the particle size they like eating most,
- feeding of what particle size of compound feeds results in the highest weight gain and the most favourable feed conversion,
- what is the extent of the oesophagus gastric ulcer decreasing effect of decreased fibrous feed due to its particle size,
- What is the interaction between the particle size and the consistency of the feedstuff like in relation to body weight gain, feed conversion and health changes,
- whether there are differences in the digestibility of different feedstuffs, the degree of nitrogen retention per body weight categories depending on particle sizes and consistency.

3. MATERIALS AND METHODS

3.1. Conditions of the experiments

The large-scale farm experiments were conducted at Biharkeresztesi Állami Gazdaság and Fehérgyarmati Sertéstenyésztő Közös Vállalat. Both farms can house one thousand sows and apply Mezőpanel system.

In Biharkeresztes the Mezőpanel plant is complemented with a traditional sow house, KA-HYB piglet battery system and fattening house for 600 pigs. In Fehérgyarmat the farm is made complete with ISV fattening system. Both pig farms keep and fatten KA-HYB hybrid pigs. Their yearly fattening pig production is almost identical: sixteen thousand pigs per year.

The rearing of piglets was conducted in similar ways at both farm and took place in battery-type rearing houses following weaning at the age of thirty days. The weaned piglets were put into one-floor batteries for ten piglets from 30-35 to 91-100 days of age. The piglets were granulated starter piglet feed and later ground piglet feed from self-feeders. Drink water was supplied by nipple-drinkers.

The piglets were transferred to the fattening houses at the age of 90-100 days. They were put there in groups of 10-15 at both locations. The dry feed was given to them from self-feeders, while the wet feed was eaten from troughs. Drink water was supplied by nipple-drinkers.

3.2. Experimental design

The eight experimental designs that were carried out during the research are shown in table 1.

3.2.1. Experiments with weaned piglets

The experiments were conducted in two experiments with 600 and 1800 pigs from weaning till fattening. Both were conducted at the pig farm of Biharkeresztesi Állami Gazdaság. In the first experiment there were three treatments formed according to the particle sizes of the feeds (factor “a”), which were made by hammer mill, using screen with 3, 4 or 5 mm holes.

The effects of dry meal and granulated feed were analysed according to consistency (factor “b”). There was also an opportunity to make comparisons according to sexes (factor “c”) as the barrows and gilts piglets were kept separated.

In accordance with the method described above altogether 600 weaned piglets were included in the first experiment alltogether in 12 treatments (3 x 2 x 2), each in five repetitions, and ten pigs per group.

In the second experiment 5 groups were formed according to the particle sizes of the feed-stuffs, which were made by hammermill using screen with 2, 3, 4, 5 or 6 mm holes diameters (factor “a”). As regards consistency, dry and moistened meal and granulated feed were in-cluded (factor “b”). The third (factor ”c”) factor was the sex of the animals.

Table 1.

Experimental design

Experiments	Number of experiments	Effects			Experimental periods		Gastric ulcer studies		
		Screen holes mm	Consistency	Number of animals	Age days	Live weight kg	Slaughtered pigs	Compulsive slaughter	Died animals
Experiments with weaned piglets	**1.**	3, 4, 5	d.m. - gr.	600	30–104	8–30	126	-	101
	2.	2, 3, 4, 5, 6	d.m. m.m. gr.	1800	30–104	7–30		-	
Experiments with fatenning pigs	**1.**	3, 4, 5	d.m. - gr.	360	104–215				
	2.	3, 4, 5	d.m. m.m. gr.	450	120–219				
	3.	2, 3, 4, 5, 6	d.m. m.m. -	600	100–156–219	30–105	2 654	93	65
	4.	2, 3, 4, 5, 6	d.m. m.m. gr.	1800	100–140–212				
	5.				100–170	30–75	90		
Digestibility experiments	(1.)	2, 3, 4, 5, 6	d.m. m.m. gr.	270	100–	30			
	(2.)					40			
	(3.) **6.**					50			
	(4.)					60			
	(5.)					70			
	(6.)				– 160	80			
TOTAL:	**8**			**5.880**	**30–219**	**7–105**	**2.870**	**93**	**166**

d. m. = dry meal m.m. = moistened meal gr. = granulated

Altogether 1800 weaned piglets were involved in the second experiment in a total of 30 treatments (5 x 3 x 2) and six repetitions in groups of 10.

At identical keeping technology the piglets were fed prestarter and starter feed of identical composition and nutrient in both experiment. Moistened meal was mixed with water in 1:1 proportion and fed from troughs. Individual body weights were weighed at the beginning of the experiment at 30 days of age and at the end of the experiment at 100 days of age. The piglets could be identified by their ear-markings.

3.2.2. Experiments with fattening pigs

There were six experiment conducted with fattening pigs.

3.2.2.1. The effects of feed processing on performance of growing-finishing pigs

This research project included four experiments.

In the first experiment the effects of compound feed, in it grinded grain as dry meal and in granulated form were studied, which were prepared by using screen with holes of 3, 4 and 5 mm diameters. Including the three particle sizes, two consistencies and two sexes (3 x 2 x 2) in the experiment there were 12 treatments with three repetitions, including 10 pigs in each totalled to 360 pigs.

In the second experiment the feed with the particle sizes described above were fed as dry and moistened meal and in granulated form. Thus this experiment of 18 treatments with 25 porklings per treatment included 450 pigs.

In addition to the three screen hole diameters applied earlier, the third experiment involved hole 2 and 6 mm diameters too. The resulting five different particle sized feed mixes were fed to the pigs as dry and moistened meal. This experiment involved a total of 600 pigs in 20 treatments (5 x 2 x 2) in three repetitions with 10 pigs per group. This experiment was conducted in Fehérgyarmat.

The fourth and the most populous experiment was conducted in Biharkeresztes. Screen with hole diameters from 2 to 6 mm, i.e. the five already familiar particle sizes were used and the fattening in a total of 30 treatments (5 x 3 x 2) used dry and, moistened meal and granulated form that is a total of three consistencies and also the pigs were separated according to the two sexes. Altogether 1800 pigs were involved in the experiment in three repetitions with ten pigs per group.

In addition to weighing the pigs at setting up the experiment and at 100 kg weight, the third and the fourth experiments included individual weighings at the finishing of feeding growing I. feed at the age of 140 and 156 days.

3.2.2.2. Digestibility experiments with growing-finishing pigs

Side by side with piglet rearing and pig fattening experiments digestibility experiments were also conducted involving growing-finishing pigs by feeding them growing feeds marked I. and II.

In this case too, the primary experimental considerations were the five hole sizes of screen and the three consistencies. It was deemed reasonable to conduct the experiment with each kind of feeds in three different weights.

Growing feed I was fed to pig of 30, 40 and 50 kg of body weight while growing feed II was given to ones of 60, 70 and 80 kg body weight. In each cases the experiment was conducted with three pigs, involving a total of 270 animals (5x3x6x3), which were of the same breed and body weight. When setting up the experiment a difference of ± 1 kg was allowed in the three lower weight and in the three higher weight groups this was ± 2 kg.

The feed ratios adequate to the body weight categories were always allocated at the same time twice daily.

Urine and faeces were collected and samples were taken at the same time once per day following the morning feeding. The samples were analysed in the Central Laboratory of DE ATC.

3.3. Research methods

3.3.1. Analysis of the particle size of the feed

A set of sieves was used to determine the proportions of the particle fractions of the feeds prepared by grinding and the use of screen with holes of 2, 3, 4, 5 and 6 mm diameter, and also to determine the mean of particle size.

3.3.2. Feed analyses

The feed samples reaching the laboratory were very finely ground. Nutrient analyses were conducted from these samples on the basis of Hungarian Standard series (MSZ 6830.) in the Central Laboratory of DE ATC.

In analysing moisture content the samples were dried at 103±2 ^{o}C according to Hungarian Standard MSZ 6830/3 and the values were expressed in percent by weight.

The amount of crude protein was determined with Kjel-Foss Automatic Nitrogen Analisator equipment. The ether extract content was determined by Soxleth extraction on the basis of Hungarian Standard MSZ 6830/6. The crude fibre content was determined on the basis of Hungarian Standard MSZ 6830/7. The amount of crude ashes was determined after cremation at 550 ^{o}C according to Hungarian Standard MSZ 6830/8 and it was expressed in percent by weight.

3.3.3. Body weight studies

In order to determine body weights and body weight gains individual weighing was conducted on 30, 100, 120 and 156 days of age and also at slaughtering. Up to 100 days of age the precision of weighing was 0.1 kg while later it was 1 kg and the weighing was always done in the same part of the day.

3.3.4. Analysis of slaughtering value

The slaughtering value of the pigs involved in the experiment was determined at the slaughterhouses in Debrecen, Nyíregyháza and Bakonszeg on the basis of back fat depth and carcass weight with a calculation method.

On the basis of the carcass and the back fat depth on the top of shoulder and the lumbar area, the proportion of fat ratio was calculated with a function worked out in the Meat Research Institute (LENCSEPETI, 1973).

The determination of lean meat percentage, lumbar area bacon 1, lumbar area bacon 2 and chop thickness was done by using a licensed ultrasonic device. Fat depth 1 (sz1) was measured 8 cm to the side from the vertebra line between lumbar vertebrae 3 and 4 on the left-hand side of the pig while fat depth 2 (sz2) and chop diameter (k2) were measured 6 cm to the side from the vertebra line between ribs 3 and 4. Fat depth and chop diameter were defined in mm. The calculation of the lean meat percentage was done according to the following formula:

$$h = 56{,}333381 – 0{,}122854 \times sz1 – 0{,}78612 \times sz2 + 0{,}006160 \times (sz2)^2 + 0{,}237677 \times k2$$

3.3.5. Gastric ulcer examinations

101 piglets and 65 fattening pigs died during the experiments. 93 pigs were compulsorily slaughtered. On my request, during the post mortem examination oesophageal ulcer examination was carried out on each animal. On days 100 and 104 at the end of the piglets rearing period 126 while on day 170 at the end of fattening 90 (4^{th} fattening experiment) and at the end of the fattening period 2654, a total of 3129 pig stomachs, the stomachs of 55.77 % of the pigs involved in the experiment, were examined. The diagnosis was always done by the same person, the chief veterinary surgeon of the Animal Health Institute in Debrecen

In the examination of oesophageal ulcer pathological keratinisation (+), surface ulcer, i.e. deficient mucosa (++) and serious profound ulcer (developed gastric ulcer) (+++) were separated. In some cases scarry healed ulcer also occurred.

3.3.6. Digestibility experiments

The experiments were conducted on fattening pigs of 30, 40, 50, 60, 70 and 80 kg individual body weight each in 15 treatments (5 particle sizes x 3 different consistencies) on 3 barrows per treatment in individual metabolism-cages. In the course of experiments 7 day preliminary

and 5 day collection periods were set. In each period feed amounts matching the body weight were fed. The faeces and the urine were collected from each animal daily. 10 and 5 % samples were taken from the weighed and homogenised faeces and the urine and after preservation with 0.5 % formic acid they were stored in a refrigerator. The faeces and urine samples collected over 5 days were again homogenised and samples were taken from them for laboratory analyses.

3.3.7. Faeces and urine analyses

The raw composition analysis of the faeces was done according to Hungarian Standard MSZ 6830 in a similar way to the one followed in determining the nutrient compositions of feedstuffs. Crude protein contents were determined from fresh samples while the other components were determined after drying them at 80±2 ^{o}C. The determination of ether extact contents differed from the method employed in analysing feedstuffs that the sample was boiled in 3 n HCl before extraction.

The N-content of the urine in the course of N-analyses was determined with Kjeldahl digestion and than Parnass-Wagner distillation process.

3.3.8. Statistical Analysis

Means, standard deviations and CV % were calculated for the group means of the traits studied.
Analysis of variance were applied to compare the effects of :

– particle size (effect „a"),
– feed consistency (effect „b") and
– sex (effect „c").

The traits analysed in the three-way analysis were:

– body weight at the beginning of the experiment,
– daily gain,
– slaughter loss,
– fat ratio,
– lean content,
– digestibility of feed stuffs.

The significant difference between treatment means were calculated by

$SzD_{5\%} = t_{5\%} * \sqrt{\frac{2 * HibaMQ}{r}}$ (SVÁB, 1981).

4. MAJOR CONCLUSIONS OF THE THESIS

4.1. Results of the experiment with weaned piglets

– In the two experiments with piglets, feeding 0,80±0,1 mm average particle sized meal-made in screen with 3 mm diameter hole-resulted in 2.2-10.8 % higher body weight gains than the other feeds with differing particle sizes, on the average of the dry, moistened meal and granulated consistencies. As a result pigs fed this feed had 1.5-8.3 % higher body weights on day 100 than pigs fed with particle sizes smaller or larger than 0.80±0.1 mm. In my experience small and big particle sized feeds meal and grinded with holes in screen of 2 and 6 mm (0.53±0.06 and 1.41±0.17 mm), respectively, are equally disadvantageous for the animals, which is in agreement with PROKOPENKO and NOVIKOV (1977).

  When feeding dry meals feeds to the animals it is the one of 1.19±0.13 mm particle size, prepared with a hole size of 5 mm that is the most favourable. WU and FULLER's (1974) and later ZABUTKO and CSALÜJ (1977) found that for suckling pigs 0.48-0.78 mm and for weaned pigs 0.86 mm particle sizes were more favourable than 1.2- and 1.43 mm particle sizes. ROYER (1999) recommends a finer particle size on the average, 0.3 mm. MORIMOTO and HOSHINO (1967) and FEKETE et al. (1980, 1983a), however, claim that particle sizes of 1.0-1.4 mm are the optimal ones for weaned pigs, which coincides with my own results.

  When feeding granulated feeds to the animals I found that it is the one of 0.80±0.1 mm particle size, prepared with hole size of 3 mm that results in the highest (426-434 g) average daily gains. The pigs eating the finest (0.53 ± 0.06 mm) particle sized feed took the second place. In the case of feeds fed as dry meal the 0.53±0.06 mm particle size refers to a fine powder and this size brought about the weakest results, which conformed by the studies conducted by NIELSEN and INGVARTSEN (1999). Feeding granulated feeds brought about 13.0 % and 15.9 %. i.e. significantly higher, weight gains in pigs than dry meal and moistened meal did, respectively. My conclusion are also confirmed by QUEMERE et al. (1979), ERICKSON et al. (1980), and MIYAWAKI et al. (1996, 1998). I did not find a link between particle size and daily consumption, but there was a connection between particle size and feed-waste (dispersion, removal) to the disadvantage of finely grinded feed. Pigs consumed 4.7 % more granulated feed than dry meal, which is the result of popularity, savouriness and easier intake. According to the opinions of HEROLD (1977), as well as KAKUK and SCHMIDT (1988) piglets prefer granulated feeds.

  In the experiments on daily feed consumption 0.77 kg is 4.7 % of the body weight, which coincides with the 0.8 kg as 4.2 % of the body weight indicated by BEREK and HOLL (1978). By giving the animals moistened feed SKIBA et al. (2002) increased the feed in-

take of piglets, body weight gain, however, was unfavourable and feed conversion remained unchanged. BROOKS et al. (1996) however reported higher feed intakes and better body weight gains as a result of feeding animals moistened feed.

– Feed conversion in the two experiments was 1.88 and 2.26 kg, respectively, and the experimental average was 2.17 kg. BEREK and HOLL (1978) report a practically identical figure of 2.14 kg for piglets of similar age and according to BEREK (1978) this value can further be reduced by rationed feeding.

  Feed conversion was the best (2.09 kg) when medium-fine (1.00±0.10 mm) particle-sized feed, which was grinded through a hole of 4 mm diameter, was fed to the animals. Feeding 0.80±0.10 and 1.19±0.13 mm particle sized feed, which was grinded through holes of 3 and 5 mm diameters, respectively, deteriorated this result by 1.09 and 0.5%. PROKOPENKO and NOVIKOV (1977) found the best feed conversion when feeding 1.0-1.44 mm particle-sized feed, which was grinded through a screen with holes of 3.5-4.4 mm diameters, thus reducing the optimal particle size to 0.3-0.4 mm.

  Using screen with either small or large hole diameters (2 and 6 mm), that is the corresponding feeds of 0.53±0.06 and 1.41±0.17 mm particle sizes deteriorated feed conversion by about the same values of 9.5 and 8.7 %. Correspondingly, in the piglet experiments this feed increased costs of feed/kg gain in comparison to the medium particle sized (1.00±0.10 mm) one, which was grinded using screen with hole of 4 mm diameter.

  The consistency of the feedstuffs had an even more significant effect on feed conversion ratio than particle size did. F/G of 2.02 kg experienced with the granulated feed was by 7.8 and 13.7 % better than in the cases of dry meals and moistened meals, respectively. QUEMERE et al. (1979), and ERICKSON et al. (1980) also found that feeding granulate feeds to weaned piglets was more favourable than feeding dry meals form.

4.2. Results of the experiment with growing-finishing pigs

– The results of the experiments indicate that grinding and the consistency of the feed had an effect on the efficiency of fattening. Namely, depending on the particle size the highest weigh gain was obtained throughout the whole fattening period when medium (1.00±0.10 mm) particle-sized feed, which was grinded using screen with holes of 4 mm diameter, was fed to the animals. Using a screen with 2 mm hole diameter deteriorated feed conversion ratio by 7.2 %, while 3, 5 and 6 mm diameters decreased body weight gains ratio by 2.8-3-3 %. Granulated feed was superior to dry meal and moistened meal by 3.7 and 3.35% respectively. Barrows surpassed the body weight gain of sows by 4.8 %.

  As regards the total period from weaning till slaughtering it was also the feeding of medium (1.00±0.10 mm) particle-sized feed that brought about the highest weight gain. The

smallest (0.53±0.06 mm) and the biggest (1.41±0.17 mm) particle sizes resulted in 3.8 and 3.35 % weaker productions. According to THOMSON and HALE (1985) and FANTUZ et al. (1997) too small particle sizes are unfavourable for fattening pigs, which claim fully corresponds to my conclusion. In LAWRENCE et al.'s (1980), and FIEDLER's (1981) experiments, however, it was the smaller particle sized feeds, grinded, using screen with hole of 2 and 3 mm that gave the best fattening performances. Similarly, ROYER (1999) recommended feed mixtures of 0.5 and 0.7 mm particle sizes for fattening pigs and breeding animals, respectively. KRACHT and SCHRÖDER (1973) claim that 2, 3, 4 and 5 mm, while LUCE (1970), POLIMANN et al. and MUIRHEAD (1986) say that small, medium and crushed particle sized feeds fed to pigs did not bring about dissimilar body weight gains. EVSZTAF'EVA and PAHNO (1979) indicate that the particle size range favourable for pigs is between 0.2 and 1.0 mm, which – in my opinion – is a wider than optimal range. In my experiments – breaking down the whole period into stages. Between 30 and 100 days of age it was the smaller (0.80±0.1 mm), between 100 and 150 days it was the medium (1.00±0.1 mm) and between 150 and 220 days it was the bigger (1.19±0.13 mm and 1.41±0.17 mm) as well as average particle sizes that I found to be the best. As a consequence optimal particle sizes, considered to be the best grow with age and body weight growth.

In my experiments granulated feed brought about 4.8 and 1.74 % better results than dry and moistened meal, respectively. Most of the authors such as CASTEELS et al. (1970), PIEPER (1971), KENDALL (1977), also say that feeding granulated feeds results in significantly, - 6.6 %, 7-7.5 %, 8-10 %, respectively – higher body weight gains than feeding dry meal does, which claim is also supported by DARSSON (1981). CASTAING and LEUILLET (1977) and GROSJEAN et al. (1989) consider feeding granulated feeds and dry meal more favourable than feeding dry meal, which as illustrated above is also supported by my experiments.

HARTROG and HUTTEN (1987) found that feeding granulated feeds brought about equally better results than feeding either dry or moistened meal, which finding corresponds to my experimental results. It is only BENNEWITZ et al (1975) that claim that feeding granulated feeds result in an approximately 2 % smaller body weight increase in comparison to feeding dry meal.

THOMKE (1980), GROSJEAN et al. (1989), and MATON and DAELEMANS (1992) unanimously claim that feeding moistened feeds results in 4.3-10.0 % higher body weight gains than feeding dry meal does. At the same time STEINER et al. (1978), CSÓKA (1976) and KORNEGAY et al. (1981) did not find feeding moistened feeds more advanta-

geous in comparison to feeding dry meal or granulated feeds, which confirm my claims relating to the whole of the experimental period.

– Higher daily weight gains shorten growing-finishing time, production cycle becomes shorter, decreases production costs and makes the return of the expenses more favourable. When feeding medium (1.00±0.10 mm) particle sized feeds grinded using screen with hole of 4 mm diameter throughout the whole fattening period pigs reached the body weight of 100 kg on 212.6 day of life, which period is 6-8 day shorter than in the case of the ones fattened on the finest (0.53±0.06 mm) particle sized feed. When the pigs were fed granulated feeds they reached the slaughtering weight 6-8 and 5-7 day earlier when they were fed dry or moistened meal, respectively. BEST (1972) as well as NAGY and NÉMET (1985) found that feeding moistened feeds resulted in a shorter (by 0.5 day) fattening period in comparison to when they were fattened on dry meal. Gilts reached 100 kg of body weight in fattening than barrows did.

– When there is a same genotype and under the same environmental conditions the daily body weight gain primarily depends on the amount of daily feed intake. In agreement with the observations made by JIH-FANG et al. (1986) in my experiments the increase in the size of the particle - although to varying extents - increased (by 2.06-8.69 %) the daily feed intake. On the average of the four experiments I conducted, pigs consumed 2.22 kg of the dry and the moistened feeds while they consumed 3.6% more i.e. 2.3 kg of the granulated feed. Feeding granulated feeds also increased feed consumption by 3.2 % in KENDALL's (1977) experiments whereas in BENNEWITZ et al.'s (1975) studies they decreased it by 3.2 % in comparison with feeding dry meal. PIEPER (1971) found higher eating speed when feeding granulated feeds while WITTMANN (1983) experienced that speed was higher when moistened feed was given.

  In my experiments sows consumed 2.23 kg feed daily, while barrows ate 4.48 % more i.e. 2.33 kg a day. WITTMANN and PAPP (1983) also highlight the more intensive activity and 20 % faster feed consumption of barrows. This is why keeping and feeding separately by sexes is justified in pig keeping.

– Feed conversion ratio was the most favourable in my experiments when holes in screen 3 or 4 mm diameters were used. The smallest and the bigger than medium particle size improve feed conversion by 4.0 and 2.2-2.7 % respectively. The opinions of researchers differ on this issue as well. In the experiments of THOMPSON and HALE (1985), and MUIRHEAD (1986) feeding big particle sized feeds worsen feed conversion by 7 %, whereas in the experiments of JIH-FANG et al. (1986) conversely, it was the small particle size that was the more favourable one.

As regards consistency the experiments with granulated feeds and moistened meal resulted in 2.3 and 1.0 % better feed conversion ratio, respectively, than dry meal. When feeding pigs granulated feeds BENNEWITZ et al. (1975), and KENDALL (1977) found that feed conversion was 3.6-9.4 % better than in the case of feeding dry meal. THOMKE (1980) and CHAE (2000) found 2-8 % better results when feeding moistened feeds.

- In the experiments I found that the particle size of the feed did not influence slaughtering losses while in comparison to feeding dry meal and granulated feeds feeding moistened feeds increased losses by 4.0-4.6 %. WITTMANN (1977) and THOMKE (1980) also came to similar conclusions. It is true that WITTMANN came to this conclusion when using moistening of 1:3, 1:4 and even 1:5 ratios and the 1:1 ratio moistening did not entail the same losses. The slaughtering losses of barrows were found to exceed those of gilts by 3.2 %.

- The value of the slaughtered pig is indicated, among other things, by the fat layer on the pig. In my experiments increasing the particle size from 0.80±0.10 mm to 1.41±0.10 mm decreased the fat ratio by 3.93 %. The feeding of dry and moistened feed resulted in identical fat ratios, increased by 2.1 relative percentage points when granulated feeds were fed. In my opinion increasing the particle size of the feed will decrease digestion and feed conversion ratio while granulating increases them, as a result of which the fat ratio in the pig's body will decrease or increase. STEIWE (1979) also reported weaker slaughtering values when pigs were fed granulated feeds. On the other hand, WITTMANN (1977) and THOOMKE (1980) obtained thinner fat layers and more favourable fat ratios when the pigs were fed moistened feeds, which I did not find in my experiments. Dry meal and granulated feed ratios adjusted to voluntary feed intake and 1:1 ratio moistening, similarly to higher ratio moistening, did not limit feed intake and consequently the fat ratio either. The increased fattening of barrows is indicated by their 5.18 relative percentage point fat ratio. BOS (1986) also found 9.9 % more fat in barrows than in gilts.
- Lean meat contents in pig carcasses represent inverse proportions to fat ratios. In all four experiments, disregarding the absolute value of lean meat percentage, increasing the particle size of the feedstuff entails an increase in the lean meat contents too. As regards consistency it was the feeding of dry meal that resulted in the highest lean meat ratio while the lowest ratio was brought about by feeding a granulated feed. The differences between the treatments are significant in a number of cases. Considering the two sexes, on the average of the four experiments, the carcasses of barrows contain by an absolute value of 1.9 % and a relative value of 3.5 % (1.5 kg) less lean meat than those of gilts. In the first experiment the value of the relative difference was 5 % i.e. 2.16 kg lean meat.

4.3. Results of gastric ulcer studies

- The animal health effects of feed processing can be identified in weaned piglets as early as 100 days of age. In my experiments there was an inverse relationship between the particle size of the feed and the occurrence of traumatic stomachs. Ulcer or lesions indicating ulcer occurred in 77.8 % of the pigs consuming the smallest particle sized 0.53±0.06 mm feed, which was grinden using screen with hole of the smallest diameter (2 mm). At the same time when feed was grinded using screen with a 6 mm hole the ratio of traumatic stomachs was only 27.8 %.

  Among the traumatic stomachs abnormal keratinisations decreased to 1/3, surface ulcer, went down to 1/2 and developed ulcer reduced to 1/4 when 1.41±0.17 mm average particle sized feed was fed instead of 0.53±0.06 mm particle size. PROKOPENKO and NOVIKOV (1977) and FEKETE et al. (1983a) also found when the smaller particle sized feed was fed the more serious stomach problems occurred. 47.6 % of the total pig population involved in the experiments and 45.5 % of the ones that died showed some kind of ulcer-like stomach problem.

  In my experiments on piglets the feeding of dry meal or in granulated form hardly had any influence on the frequency of oesophageal ulcers (50.0 and 52.1 %). GAMLE and CHAMBERLAIN (1967) however, found more numerous and more serious ulcers in pigs when feeding them granulated feeds than when they were fed the same feed in the form of dry meal.

  In my experiments the feeding of moistened meal did not confirm SZABÓ's (1984) unfavourable conclusions as in this case I also found 26.6 % fewer traumatic stomachs than in the case of feeding dry meal.

- In the experiment with growing-fattening pigs increasing the particle size from 0.53±0.06 mm to 1.41±0.17 mm decreased the occurrences of stomach damage by 28.3 %. Increasing the particle size from 0.53±0.06 mm to 1.41±0.17 mm decreased the frequency of surface ulcers and developed ulcers by 65.3 % and 123.7 relative percentage points, respectively, while it did not decrease the frequency of abnormal keratinisation. The unanimous opinion of PETTERSSON and BJÖRKLUND (1976), as well as KOVÁCS (1984) is that the development of stomach ulcer is in inverse proportion to the particle size of the feedstuff. MUIRHEAD (1984) considers too finely ground maize meal to be expressly ulcerogenic. Others, such as LAWRENCE et al. (1980) found 1.98 and 4.1 mm particle sizes and FIEDLER (1981) found feedstuffs grinden using screen with hole of 3 or 6 mm diameters to have identical effects on the development of ulcer.

In my experiments feeding moistened or granulated feeds decreased the frequency of gastric ulcer in growing-fattening pigs by 13.3 and 11.3 % respectively, in comparison to dry feeds. My conclusions are in harmony with the conclusions of KOVÁCS (1974) and WONDRA et al. (1995). In the experiments done by BENNEWITZ et al. (1973) however, granulation did not influence the health status of the stomach.

Side by side with several other factors SZABÓ (1984) considers moistening a factor that causes gastric ulcer as the liquid stomach content makes the animal prone to the disease. KAKUK and SCHMIDT (1988) consider the feeding of finely grinded dry meal or granulated feeds, the lack of crude fibres, a factor that makes the animal prone to the disease due to the fact that starch will break down in the stomach more quickly, whereas moistening creates a more homogeneous stomach content and the hydrochloric acid in the stomach impedes the microbial breaking up of carbohydrates decreases the danger of ulcer development.

In my experiments the fewest number of diseases occurred at a 1:1 ratio moistening. The same amount of moisture as that of the dry matter, which at the maximum contains 2.7-3.0 kg water, deemed necessary for 1 kg dry matter by HEROLD (1977) together with the drinking water cannot create a too watery consistency in the stomach and at the same time it impedes the microbial breaking up of carbohydrates.

The extent grain is crushed, the ratio of average and finely powdered parts, the fibre content of the feed, the consistency of the feed mix and other disturbing environmental factors, the so called stress factors also play their parts in the development of gastric ulcer. Over the past decade a number of *Helicobacter* strains have been isolated in the pig stomach and 99.5 % of the isolated types are identical to the ones also found in the human stomach. According to the studies by SZEREDI et al (2005) *Helicobacter* infections do not play an important part in the development of gastric ulcer but they may be a factor that contributes to the pathological changes in the stomach of the pig.

56.9 % of the pigs that died and 80.6 % of the ones that were slaughtered compulsorily demonstrated some degree of gastric ulcer. KOVÁCS (1974) found gastric ulcer in 75 and 56 % of the animals that died or were slaughtered compulsorily, respectively. BOKORI and TAMÁS (1981) found healthy mycoderms in only 7.2 % of the pig stomachs they examined and found a serious form of the disease in 49.1 %. According to FEKETE (1978) also, 80-90 % of certain pig stocks suffer from the damage of digestive mycoderm and 20-30 % of the latter suffer from developed gastric ulcer too. At this level of morbidity KOVÁCS (1974) recommends mixing 3-5 mg/kg thiamine in the feedstuff, while TAMÁS (1984) proposes the application of 0.1-0.2 g/kg vitamin U. Let me note here that in my experiments the pigs were given feeds complemented with vitamin U from 2-3 weeks of age

till slaughtering. Despite this medication symptoms of ulcer were found in 66.2 % of the pig stomachs out of which 31.57 % was pathological keratinisation in the oesophagus, 23.51% was surface ulcer and 11 % fully developed ulcer. In these experiments the body weight gain of the pigs that developed ulcer was 16.2 % weaker and their fattening periods were 19.4 % longer than those of their healthy peers. Considering the whole stock a decrease of 7-8 % in body weight gains increases the fattening period by 8-10 %. The feed conversion ratio of pigs with traumatic stomachs is 19.3 % worse and that of the whole stock becomes 10 % worse through gastric ulcer. This factor alone greatly decreases the profitability of the industry.

4.4. Results of the digestibility experiments

– On the basis of the digestibility experiments I concluded that the digestion of crude protein, nitrogen-free extractable material, organic matter and dry matter do not differ significantly when pigs are given growing I and II concentrates, i.e. in the case of smaller (30-50 kg) and heavier (60-80 kg) pigs there is no significant difference. The digestibility of ether extract and crude fibre concentrates was almost identically favourable at 9.37 and 9.69 % respectively.

  In their experiment BABINSZKY and GUNDEL (1978) found that with pigs of smaller body weight the digestion coefficient of crude protein and ether extract while with those of heavier body weight that of crude fibre, nitrogen-free extractable matter and total dry matter was higher.

  Increasing the particle size of the feed from 0.53±0.06 mm 1.41±0.17 mm the digestibility coefficients of crude protein, ether extract, nitrogen-free extractable matter, organic matter and dry matter systematically and in a number of cases significantly decreased when feeding either growing I or II concentrates. My results coincide with the references found in the technical literature and so e.g. in the experiments of WONDRA et al. (1995), and LEE et al. (2001) the utilisation of nutrients increased proportionately to the fineness of grinding while in LAWRENCE's (1978) investigations it was the best in the case of finely grinded feeds.

  ROTH and KIRCHGESSNER (1984) also found the digestibility of fine particle-sized meal 5 % better than that of either the medium or coarse particle sized one. According to NIELSEN–INGVARTSEN (2000) increasing the particle size of the feed by 0.1 mm will decrease the digestibility energy and protein by 0.6-0.8 unit. With the exception of wheat and rye, which become starchy-gummy easily HEROLD (1977) also recommends the fine grinding of grain as this will increase digestibility by 8-12 % in comparison with coarse meal. At the same time he mentions that too fine particle size will not result in improved

digestibility in comparison to the medium-fine (1-2 mm) meal, which is confirmed by KAKUK and SCHMIDT (1988) too. For this reason PROKOPENKO and NOVIKOV (1977) find it important to define the particle sizes of feed mixes for animals of different breeds and ages from both a biological and a technological point of view.

The consistency of the feed also has an effect on the digestibility of the feedstuff. The digestibility of crude protein was more favourable in pigs when the feed was granulated while older pigs digested it more favourably in the form of moistened meal. As regards ether extract it was the granulation that ensured the most favourable digestibility in the case of both concentrate. The digestibility of crude fibre was found better in younger pigs when feeding them moistened feed while in the older ones it was dry meal that brought better results and granulation proved to be the least advantageous. In the experiments of ANGELOVA and DZSAROVA (1973) granulation decreased the digestibility of crude fibre by 6.05 and 10.43 %. In the case of growing I and II concentrates the digestibility of nitrogen-free extractable matter, organic matter and dry matter was the best when fed as dry groats and granulation brought the weakest result.

QUEMERE et al. (1979) and AVRAMENKO et al (1984) mention a better utilisation of granulated feed mixes than that of meal feeds. My experiments confirm this claiming the cases of ether extract and crude protein. In his experiments SCHULZ (1967) compared the digestibility of finely grinded, granulated and crumby feedstuffs and concluded that the "repeated treatments" improved the digestibility of protein, fat and organic matter significantly. PALIEV et al. (1972) reported that with the exception of fat the digestibility of trients decreased under the influence of granulation. AUMAITRE et al. (1977) and SKOCH et al. (1983) also mention the decrease of the digestibility of granulated concentrate.

KOVÁCS (1964) found that when feeding dry feed and 1:1 diluted moistened feed from self-feeders all the organic matters were digested to the same extent. BABINSZKY and GUNDEL (1978) did not find any decreases in the digestion of nutrients up to a dilution ratio of 1:3. According to ROTH and KIRCHGESSNER (1984), however, the feeding of wetfeeds decreases digestibility by 1.5%.

When feeding growing I concentrate in my experiments only the digestibility of crude protein decreased with the growth of the body weight to 30-50 kg and that of the other nutrients improved. When feeding growing II concentrate the digestibility of ether extract and nitrogen free extractable matter improved with the growth of the body weight between 60 and 80 kg, the digestibility of crude fibre remained unchanged and the utilisation of crude protein, organic matter and dry matter became worse.

– The nitrogen retention, utilization of crude protein and digestible crude protein was significantly better when feeding medium particle sized (1.00±0.11 mm) feeds than in the cases of feeding either the smallest (0.53±0.06 mm) or the largest (1.41±0.17 mm) particle sized growing I and II concentrates.

  What concerns consistency, in my experiments I found that the highest nitrogen retention and the best utilization of crude protein and digestible crude protein occurred when the animals were given granulated feeds. With the increase of body weight nitrogen retention increased in the case of either concentrate. In the experiments conducted by BABINSZKY and GUNDEL (1978) when feeding dry feeds the body weight gain increased nitrogen retention and the same was found in pigs of 25-60 kg live weight when the feed was moistened up to the ratio of 1:3.

5. NEW SCIENTIFIC RESULTS

- The extent of crushing, the consistency (preparation) and particle size of concentrates has an effect on the production and health status of pigs of different ages and body weights. It is the feedstuffs of different particle sizes that enable pigs of different ages to reach higher performances. The optimal utilisation is defined by the appropriate particle size.

- It is smaller than medium particle sized granulated feed (0.80±0.10 mm) that enables weaned pigs to reach the highest body weight gains and the most favourable feed conversion.

- Too finely (053±0.06 mm) pulverised feeds can be fed only in a granulated form whereas coarser particle sized (1.19±0.13 mm) ones can be fed in a gritty form. When feeding moistened feeds to the animals the particle size has a smaller effect on the body weight gain. Due to the less favourable specific indicators weaned piglets should not be fed moistened feeds. Granulating the feed will moderate but will not wholly offset the unfavourable effects of either too big or too small particle sizes on the feed conversion ratio.

- The gastric ulcer producing effect of feed preparation can be displayed in pigs of 100 days of age already. The total number of gastric ulcers can be decreased to ¼ if pigs are fed coarser (1.41±0.17 mm) particle sized feeds instead of finely (0.53±0.06 mm) crushed ones.

- The particle size and consistency found to be the most favourable will change with time. In the first stage of fattening it is the feeding of medium particle sized (1.00±0.11 mm) granules while in the finishing stage it is the coarser particle sized (1.19±0.13 and 1.41±0.17 mm) granules concentrate that enables pigs to reach the highest performance. With the increases of the age and the body weight the particle size considered to be optimal also increases.

- As regards the ratio of fat and meat the feeding of the coarser (1.41±0.17 mm) particle sized feed is recommended as it decreases the incorporation of fat and increases the meat ratio as well as improves the slaughtering value of the pig

- The occurrence of oesophageal ulcer in fattening pigs is greatly influenced by the particle size and the consistency of feeds. When increasing the average particle size of the feed from 0.53±0.06 mm to 1.00±0.11 or 1.41±0.17 mm the frequency of the occurrence of gastric ulcer decreases from 81.31 % to 62.74 and 58.33 %. Feeding a feed-

stuff diluted to 1:1 ratio decreases and feeding a granulated feed increases to the same extent the frequency of gastric ulcers in comparison to the situation when dry granules are fed. Gastric ulcer could be diagnosed in two thirds of pigs.

- The body weight gain of pigs with traumatic stomachs lags behind healthy ones by 16.2 % and their specific feed utilisation and fattening period is also worse than those of the healthy one by almost 20 %, which alone can decide the profitability of the industry.

- The conversion ratio of the nutrients in feedstuffs is most favourable with the small particle sized (0.53±0.06 mm) feed mixes. With the increase (to 1.41±0.17 mm) of the particle size the feed conversion ratio will decrease. At younger ages the digestibility coefficients, with the exception of protein, will increase together with the increase in the body weight.

- Nitrogen retention and protein conversion improve with the increase in the particle size of the feed and is the most favourable when feeding medium particle sized granulated feeds.

- The utility of fat decreased by 8.6 % in growing pigs (60-80 kg) given growing feed II., the utility of fiber increased by 9.7% compared to pigs (30-50 kg) fed with growing feed II.

- The N-retention, the digestibility of crude protein and the digestible crude protein increased with the increase of particle size till the medium size (1.00±0.11 mm) then remained stable in both growing feed and age groups.

- The growing pigs fed with growing feed II. increased their N-retention (by 25.6%9, and decreased their protein digestibility (by 13%) compared to pigs fed with growing feed II.

- With increasing body weight (betwen 30 and 80 kg), the N-retention significantly ($P<0.05$) decreased, while the digestibility of crude protein decreased.

- The highest N-retention and the favourable crude and digestible protein digestibility occured in both smaller (30-50 kg) and larger (50-80 kg) groups fed with granulated feeding.

6. RESULTS THAT MAY BE USED IN PRACTICE

1. The cost and performance-wise most favourable feed processing in pig nutrition can only be choosen by considering the optimal particle size and consistency as well as body weight simultaneously.

2. It is expedient to using screen with 3 mm diameter and then granulate to a hard consistency the grain components of feeds for suckling pigs and weaned pigs. This can ensure the highest body weight gains, pre-fattening body weight, the most favourable feed conversion and the smallest specific feed cost. If it is impossible to granulate the feed, medium sized meal concentrates, grinded using screen with holes of 5 mm diameter are to be fed. Moistened feeds are not recommended for feeding weaned pigs.

3. From about 100 days to about 140-150 days of age it is expedient to feed concentrates made from moderately fine particle sized components, grinded using screen with holes of 4 mm diameter. This will ensure the highest body weight gain and at the same time effectively reduces the risk of oesophageal ulcer.

4. In the finishing phase of the fattening period it is the feeding of coarser particle sized concentrates, grinded using screen with holes of 6 mm diameter that ensures the highest body weight gains, the best fat ratio and the necessarily healthy status of the digestive tract. As regards feed conversion and feed costs, however, it is the somewhat finer particle sized concentrate, grinded using screen with holes of 4 mm diameter that can be considered more favourable.

5. In pigs of between 30 and 80 kg body weight the utilisation of the nutrients is the best when they are given small (0.53 ±0.06 mm) particle sized feeds. For reasons of more favourable production indicators, higher nitrogen retention and better protein conversion it is expedient to give fattening pigs medium (1.00 ± 0.11 mm) or even coarser (1.19 ± 0.13 and 1.41 ± 0.17 mm) particle sized feeds.

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