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SOME ASPECTS ON THE METABOLIC EFFECT OF AMINO SUPPLEMENTATION OF PIG DIETS*)

By

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It is generally accepted that supplementation of grain with individual amino acids which are limited in the protein will improve the biological value. Evidence for this has been provided by experiments on laboratory animals (*Ericson et al.* 1961 a, b; *Ericson et al.* 1962 b; *Munck* 1964; and others), and e.g., pigs (*Clausen* 1962—1964; *Tollersrud* 1961; *Ericson et al.* 1962 a; *Berg et al.* 1962).

The effect of supplementation of a given amount of feed is seen not only as increased growth and higher weight gain but also as greater protein deposition at the expense of fat formation (*Ericson et al.* 1962 b; *Munck; Larsson & Nilsson* 1966; and *Larsson* 1966, laboratory animals; *Clausen*, pigs). The mechanisms underlying these effects should be sought at the intermediary metabolic level (*Larsson & Nilsson*). It is also known that the composition of the diet is of importance for the levels of enzyme activities (cf. *Knox et al.* 1956 and *Niemeyer* 1962).

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In order to increase the efficiency of swine production, a shorter feeding period (from birth to slaughter), increased feed efficiency, as well as maximal protein deposition is aimed at. Attempts to achieve this result have met with difficulties consisting, for instance, in an increased occurrence of dietary diseases. These may be due to metabolic disturbances caused by the diet. Optimal conditions for the enzymes involved in digestion and metabolism are desired (*Larsson & Nilsson*).

In the present study in pigs under normal conditions an attempt was made to analyze some of the changes occurring in liver and skeletal muscle when different feeds were supplemented with L-lysine.HCl and DL-methionine.

MATERIAL AND METHODS

Experiments 1 and 2

Experiment 1 was designed to study the effect of amino acid supplementation to commercial pig feed on growth, feed efficiency and protein deposition of pigs. The animals were divided into two groups and given the diets indicated by Table 1.

In experiment 2 the same composition and quality of groats as in experiment 1 was used. During a period of 43 days the only energy and protein source was barley and oats, supplemented with minerals and vitamines. The animals were divided into two groups with a mean weight of 14.7 and 15.4 kg in each group respectively. Both diets were supplemented with 0.35 % L-lysine and 0.12 % DL-methionine. The first group in this experiment (group 3) received L-lysine.HCl of pharmaceutical quality and the second group (group 4) lysine of feed grade quality (Table 2). At the end of the experiment the mean weight of the pigs (7 in each group) was 27.4 and 28.3 kg respectively.

From the 44th day onward the animals in group 3 received diet c (0.1 % L-lysine.HCl and 0.05 % DL-methionine) used for group 2 in experiment 1, and group 4 as well as the animals in group 1 in experiment 1 were given diet c (no amino acid supplementation; see Tables 1 and 2). When the animals of the two groups had reached a mean weight of 42 kg they were given diet d used in experiment 1 (Table 1). This meant that group 3 still received supplementation of the amino acids. The non-supplemented and supplemented diet d was given until slaughter.

Table 1. Basal feeding scheme used in experiment 1.

Diet	Weight of animals (kg)	Groats[1]) (kg)	Pig starter[2]) (kg)	Conc. feed no. I[3]) (kg)	Conc. feed no. II[3]) (kg)
a	20—25	100	7	8	
b	25—31	100	5	10	
c	31—42	100		15	
d	42—	100			15

[1]) The groats was composed of ⅔ barley and ⅓ oats.

[2]) The pig starter had the following composition:

Dried skim milk	15
Fish meal	21
Meat meal	10
Oil meal	10
Wheat bran	28
Sugar	14
Salt	1
Calcium carbonate	1
	100 kg

[3]) The concentrated feeds I and II had the following composition:

	I	II
Wheat and rye (85 % wheat)	30	30
Soya meal	20	30
Hay meal	13	12
Fish meal	16	
Meat meal	10	16
Calcium phosphate	5	6
Sodium chloride	0.9	2.5
Trace elements	0.6	
Dried yeast	2	2
Vitamines	2.5	1.5
	100 kg	100 kg

After slaughter the carcasses of the pigs of experiments 1 and 2 were graded according to the scheme used at the slaughter-house (Scan, Kävlinge).

Photographs of a transversal section just caudal to the last rib were taken. The negatives were magnified and projected on white paper, where the contures of meat and fat were drawn as indicated by Fig. 1. The meat and fat areas were cut out and weighed individually, the weights being proportional to the respective areas.

Table 2. Data from experiments 1 and 2 showing the number of pigs and the average of days in experiment, gain in weight per day and per kg of feed.

Experiment no.	1		2	
Group no.	1	2	3	4
Number of pigs	7	6	7	7
Supplements of L-lysine. HCl and DL-methionine, %	0	0.10 Ly, 0.05 Me	0.35 Ly*), 0.12 Me	0.35 Ly**), 0.12 Me
Supplements after 43 days			0.10 Ly, 0.05 Me	0
Weight at start of experiment (kg)	20.0±1.12	17.8±1.11	14.7±1.12	15.4±1.00
Weight after 43 days (kg)			27.4±1.81	28.3±2.02
Weight at end of experiment (kg)	93.2	92.6	94.7	92.3
Feeding period (days)	139	132	152	163
Weight gain/day (g)	526	566	526	471
Kg feed consumed/pig	284	277	285	300
Kg feed/kg weight gain ("feed efficiency")	3.88	3.70	3.56	3.90

*) pharmaceutical quality, **) feed grade quality.

Experiment 3

In this experiment 17 pigs of both sexes were used. When weaned they were divided into two groups each including 4 females. The animals were fed one week on a diet corresponding to the first diet given in group 1 (Table 3, A 1). After that the pigs were fed according to the scheme outlined in Table 3. The feeding periods and the amount of feed given are listed in Table 4.

Table 3. Feeding scheme used in experiment 3.

Feed ingredients	A Weaning - 40 kg Group 1	A Weaning - 40 kg Group 2	B 40 kg - slaughter Group 1	B 40 kg - slaughter Group 2
Groats[1]), kg	300	300	300	300
"Protein mix"[2]), kg	50	50	34	34
0.10 % L-lysine. HCl + 0.05 % DL-methionine	0	+	0	+
Mineral mixture[3]), kg	7	7	7	7

[1]) The groats was composed of ⅔ barley and ⅓ oats.

[2]) The "protein mix" had the following composition:

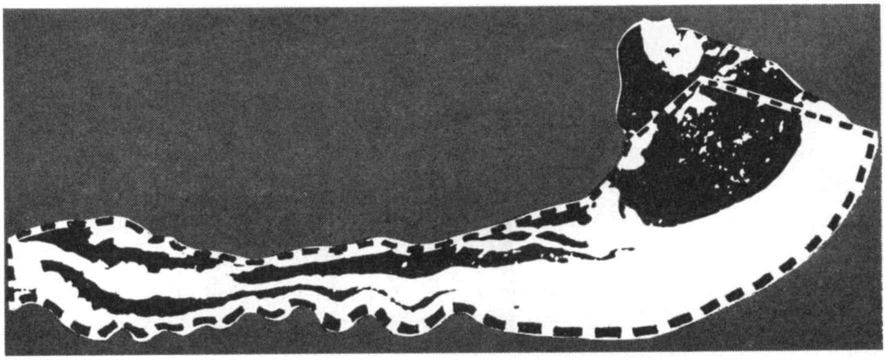
Arachnoid meal	70 g	Vegetable protein ⅔
Soya meal	50 g	
Rape meal	30 g	
Meat meal	75 g	Animal protein ⅓.

[3]) The mineral mixture had the following composition:

Dicalciumphosphate	1020 g
Sodium chloride	180 g

Table 4. Feeding schedule in experiment 3.

Mean wt. of pigs (kg)	Amount of feed per pig per day (kg)	Days on this quantity	Feed
20	0.9	about 14	A
25	1.0	" 14	"
30	1.2	" 14	"
35	1.4	" 14	"
40	1.6	" 20	"
50	2.0	" 14	B
60	2.3	" 14	"
70	2.7	" 14	"
80	3.0		"



F i g u r e 1. Transverse section of the carcass just caudal to the last rib. The broken line indicates the area within which meat and fat parts after projection on paper were cut out and weighed to obtain the meat-fat ratio. (The picture is taken from a pig belonging to experiment 2, group 4).

During the first week after weaning blood samples were taken from each pig in both groups by puncture of the anterior vena cava. The blood was analyzed with regard to the activities in serum of the enzymes listed in Table 5. The analytical methods used in this respect have been given previously (*Jacobsohn et al.* 1965). During the course of the experiment blood samples were taken regularly for subsequent serum enzyme analysis (Table 5).

When the mean weight of the pigs of the two groups was about 90 kg all the animals were brought to the slaughterhouse. About 20 minutes after the slaughter samples were taken from the liver and skeletal muscle. The tissues were rapidly frozen. Measurements of the pH of the longissimus dorsi were made electrometrically (Metrone) at 20, 50 and 200 minutes after slaughter (Fig. 2). The longissimus dorsi of all pigs was examined microscopically. The muscles were fixed in 10 % formaldehyde and embedded in paraffin wax. The sections were stained with hematoxylin-eosin.

The ovaries were kept at +4°C until the following day when they were analyzed with regard to the presence, number and size of follicles and corpora lutea (Fig. 3). The classification was made according to the grading of *Corner* (1921).

The meat of the pigs was graded using the general procedure of the slaughterhouse (Scan, Kävlinge). Determination of the refractory index of the abdominal fat was made by a routine procedure used at the slaughterhouse.

Table 5. Enzyme activities of blood serum of the pigs in experiment 3.

Time for blood sampling, days	0	43		57		112	
Group	1 + 2	1	2	1	2	1	2
Phosphohexose isomerase (PHI)	46±3	36±5	38±3	45±4	48±5	47±4	47±3
Aldolase (ALD)	27±2	31±4	39±5	23±4	35±3	21±2	23±3
Lactic dehydrogenase (LDH)	919±27	953±45	990±72	947±62	976±61	934±42	901±78
Iso-citric dehydrogenase (ICDH)				225±15	225±21	217±22	163±20
Glutamic oxalacetic transamin. (GOT)	38±3	47±5	51±4	30±4	34±4	38±4	24±4
Glutamic pyruvic transamin. (GPT)	39±2	38±4	40±4	35±3	35±4	23±3	20±2

Photographs of a transversal section just caudal to the last rib were taken and treated as outlined above under experiments 1 and 2 (Fig. 1).

The frozen liver and muscle samples were treated as described for rat and rabbit tissues (*Jacobsohn et al.*) and analyzed for DNA- and protein-contents as well as for activities of the enzymes listed in Table 6. The methods used for the analysis were the same as used by *Jacobsohn et al.* Protein determinations of the samples were made according to *Lowry et al.* (1951).

RESULTS

The results of experiments 1 and 2 are given in Table 2. It may be seen from this table that in experiment 1 the feed efficiency was slightly higher in group 2 and that the duration of the experiment (the number of feeding days) was seven days shorter than that of group 1. Table 7 gives the grading of the pigs with regard to quality of the meat. In group 2 all animals were graded as "extra prima" (the highest grade), while in group 1, 5 out of 7 received this high mark. Table 8 indicates that the protein/fat ratio of the pigs in group 2 was significantly higher than in those belonging to group 1.

In experiment 2 there was no difference in growth rate and feed efficiency between groups 3 and 4 up to the 43rd day when

Table 6. The effect of addition of L-lysine.HCl and DL-methionine to the feed of group 1, experiment 3, on the activities of certain enzymes in liver and skeletal muscle (longissimus dorsi).

Tissue	G-6-Pase	G-6-PDH	ALD	ICDH	LDH	GOT	GPT
Liver	+43[b])	+37[b])	0	+61[b])	—26[c])	+87[a])	0
Muscle			0	0	—40[c])	+56[a])	0

The values are calculated per unit tissue protein.
Activities of liver and muscle from pigs in group 1 are set to 100 per cent.
G-6-Pase = Glucose-6-phosphatase
G-6-PDH = Combined activities of glucose-6-phosphate dehydrogenase and 6-phosphoglyconic dehydrogenase.
For other abbreviations, see Table 5.
Differences in activity calculated according to Student's t-test,
a) $P < 0.001$, b) $P < 0.01$, c) $P < 0.05$.
group 1: $n = 8$, group 2: $n = 9$

Table 7. Grading of the meat of the pigs in experiments 1 and 2 (made by the slaughterhouse).

Exp. no.	Group	"Extra Prima"	Grade I	Grade III
1	1	5	2	
1	2	6		
2	3	4	3	
2	4	4	2	1

the feed was supplemented with the same amounts of lysine and methionine, which indicates that in this respect there is no difference between lysine of pharmaceutical and of feed grade quality (Table 2).

After the 43rd day when group 3 received a continued lysine-methionine supplementation while group 4 was fed the commercial diet only, a considerable difference in growth rate and feed efficiency was noted. This may be seen in Table 9 where a summary of the results of experiment 2 after the 43rd day is given. Group 3 had the highest feed efficiency as well as a higher protein/fat ratio than group 4 (Table 8). As may be seen from the table the area of longissimus dorsi of group 3 was larger than that of group 4.

Table 8. Data from measurements of the longissimus dorsi area, average thickness of back fat and meat/fat ratio from the section indicated by Fig. 1.

	Experiment 1		Experiment 2	
Group	1	2	3	4
Number of animals	7	6	7	7
Lysine + methionine	0	+	+	partially
Area of long. dorsi (cm^2)	25.9 ±3.35	28.4 ±2.89	30.6 ±2.91[c)]	25.5 ±2.12
Average thickness of back fat (mm)	33.7 ±3.82	32.3 ±3.98	35.0 ±4.20	35.9 ±4.00
Meat/fat	0.67±0.041	0.81±0.040[b)]	0.82±0.065[b)]	0.69±0.039

Differences calculated according to Student's t-test.
[b)] $P < 0.01$, [c)] $P < 0.05$

Table 9. Data from experiment 2 after 43 days showing the average of days in experiment, gain in weight per day and per kg of feed.

	Group 3	Group 4
Supplements of L-lysine. HCl and DL-methionine, %	0.10 Ly, 0.05 Me	0
Weight at start at experiment, kg	27.4±1.81	28.3±2.02
Weight at end of experiment, kg	94.7	92.3
Feeding period, days	109	120
Weight gain/day, g	617	533
Feed consumed/pig, kg	246	261
Kg feed/kg weight gain ("feed efficiency")	3.64	4.07

Experiment 3

From Table 10 it may be seen that the feed efficiency was slightly increased in group 2. The feeding periods were the same in both groups as the animals were brought to the slaughterhouse on the same day. Table 11 summarizes the results of measurements of the thickness of back fat, the area of a transversal section of the longissimus and the ratio of muscle to fat. The meat/fat

Table 10. Data from experiment 3 showing the number of pigs, gain in weight per day and per kg of feed.

Group	1	2
Number of animals	8	9
Supplements of L-lysine. HCl and DL-methionine, %	0	0.10 Ly, 0.05 Me
Weight at start of experiment, kg	23.9±0.91	22.7±1.08
Weight at end of experiment, kg	92.5	93.1
Number of days of experiment	126	126
Kg feed*) per pig	245	234
Kg feed/kg weight gain ("feed efficiency")	3.57	3.32
Kg feed/pig and day	1.89	1.85
Gain in weight, g/day	544	599
Total gain in weight, kg	68.6	70.5

*) The feed ingredients were consumed as follows:

Protein mixture	26.9	25.1
Mineral mixture	5.1	4.6
Groats	213.0	201.5

Table 11. Data from measurements of the longissimus dorsi area, average thickness of back fat and meat/fat ratio from the section indicated by Fig. 1.

Experiment 3	Group 1	Group 2
Number of animals	8	9
Area of long. dorsi, cm^2	28.6 ±152	31.2 ±2.62
Average thickness of back fat, mm	27.4 ±2.07	28.6 ±1.59
Meat/fat	0.80±0.040	1.06±0.038[a])

Differences calculated according to Student's t-test.
[a]) $P < 0.001$

ratio was calculated as previously mentioned (see Fig. 1). The ratio was significantly higher in group 2.

Fig. 2 shows the fall in pH of the longissimus dorsi after slaughter. Twenty and 50 minutes after slaughter the pH values of group 2 were significantly lower than those found in group 1. The ultimate pH (3 hrs. 20 min.) did not reveal any differences between the two groups.

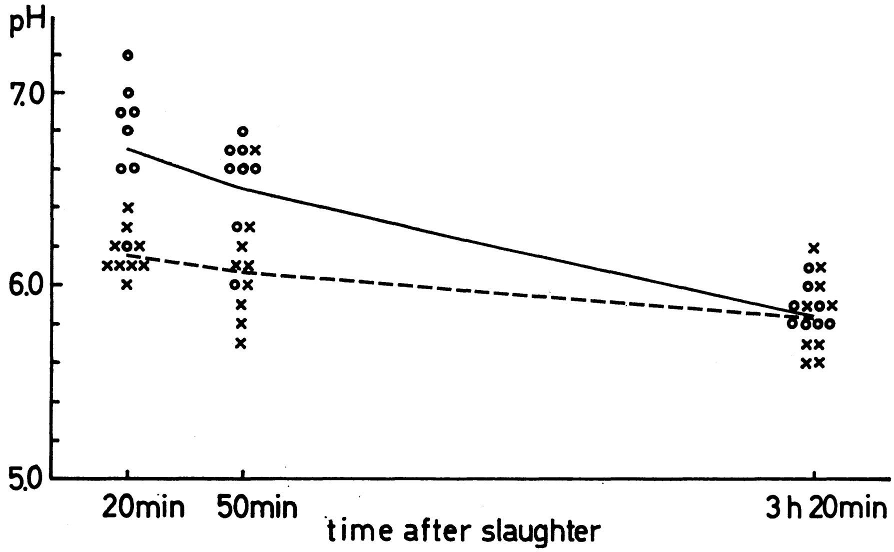


Figure 2. pH-measurements after slaughter of the longissimus dorsi of the pigs in experiment 3.
Circles group 1, crosses group 2.

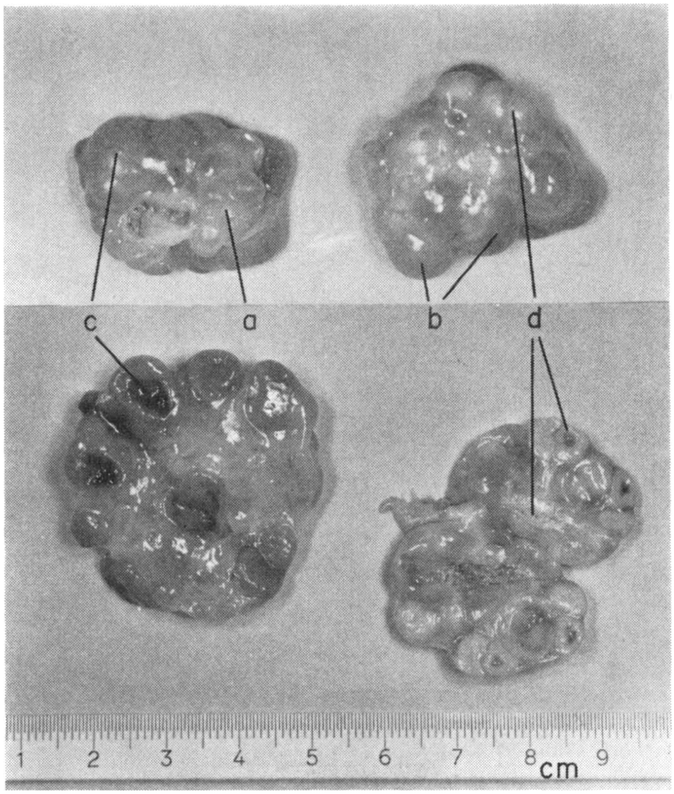
Histological examination of the muscle specimens did not indicate any differences between the two groups. The sections showed normal pictures without any signs of degenerative changes.

Evaluation of the carcass quality according to the ordinary grading procedure showed that all pigs except one in group 1 were judged "extra prima".

Measurements of the refractory index of the abdominal fat did not indicate any differences between the two groups.

Table 5 shows that significant changes in serum enzyme activities did not occur during the course of the experiment. There was a tendency ($P < 0.01$) for the GPT activity to decrease in both groups with increasing age.

The values for enzyme activities in liver and skeletal muscle are given in Table 6 as differences between the two groups. In liver the addition of L-lysine.HCl and DL-methionine resulted in a rise of the levels of G-6-Pase, G-6-PDH, ICDH and GOT, but a decrease of LDH. No significant changes were found in the activities of ALD and GPT between the two groups. In skeletal muscle (longissimus dorsi) the addition of these amino acids produced a significant decrease in the activity of LDH, but an increase in the activity of GOT.



F i g u r e 3. Ovaries from two pigs in experiment 3.

Group 1 — One ovulation.
Group 2 — Three ovulations.

a. Growing follicles.
b. Ripe follicles.
c. New corpora lutea.
d. Corpora lutea at different stages.

In the ovaries of the pigs of group 1 old corpora lutea were not found (Fig. 3). All four females of this group had corpora lutea of stage one (*Corner* 1921). In the ovaries obtained from the pigs of group 2 corpora lutea of different stages were found (Fig. 3). The examination of these ovaries revealed that in this group at least three ovulations had taken place.

DISCUSSION

It is well known that cereal proteins have a low biological value which is due to the relatively low level of certain essential amino acids, particularly lysine.

In experiments on laboratory animals it was found that the addition of L-lysine.HCl to cereal diets improved growth, protein efficiency ratio and protein deposition in rats and mice (*Ericson et al.* 1961 a, b, 1962 b; *Munck* 1964; *Larsson & Nilsson* 1966; and *Larsson* 1966). Experiments performed in Denmark on pigs have given similar results. Thus, in a large number of pigs, *Clausen* (1962—64) observed that the addition of L-lysine.HCl and DL-methionine to a cereal base diet improved not only body growth but also the quality of the meat of the pigs. *Clausen*'s findings have been confirmed in other countries (*Evans* 1958, 1961 and *McWard et al.* 1959, USA; *Tollersrud* 1961, Norway; *Ericson et al.* 1962 a and *Berg et al.* 1962, Sweden).

Also in the present study it was evident that the addition of L-lysine.HCl and DL-methionine had a marked effect on parameters such as growth rate, feed efficiency and meat/fat ratio even when feeds of accepted high quality were used. This supports the findings in rats (*Ericson et al.* 1961 a, 1962 b) and in pigs (*Clausen*) that supplementation with the limiting amino acids increased protein deposition irrespective of whether the feeds given were low or high in protein content.

The meat/fat ratio in *Clausen*'s experiments was determined by measurements of the areas of transversal sections of psoas major and longissimus dorsi at the level of the last rib and the area of the back fat at the same level. In the present study the areas of all muscles and fat at the same level were calculated according to the method described previously (also see Fig. 1). This method seems to give a more detailed indication of the relation between meat and fat of the whole carcass. In determinations of the meat/fat ratio in rats, it was found that the photographic recording used in this study supplied values that closely corresponded to the protein/fat ratio of the total carcass. It is therefore suggested that such measurements give a more reliable grading with regard to quality of the meat than the method used in Sweden at present.

As shown by Tables 2 and 9 the animals that were only given groats supplemented with the higher concentrations of lysine and methionine for 43 days (experiment 2, groups 3 and 4) showed a better feed efficiency and shorter feeding period when the high quality feed (given after 43 days) was supplemented with 0.1 % L-lysine.HCl and 0.05 % DL-methionine only (group 3). This finding seems surprising. The effect of supplementation of the feed should reasonably have the greatest influence on the growth rate of younger individuals (*Ericson et al.* 1962 a). It is possible that the metabolism of the animals was adapted to a certain level of the two amino acids — high compared to the total protein content of the groats. After the 43rd day the animals were given the feed high in total protein content but as discussed above responsive to amino acid supplementation.

The pH recordings indicated that the anaerobic glycolysis was faster in the longissimus dorsi of pigs belonging to the supplemented group (experiment 3). As early as 20 minutes after slaughter, the pH of the muscle in this group was 0.6 units ($P < 0.001$) lower than in the other group. Fifty minutes after slaughter the difference was 0.5 units ($P < 0.001$). After 3 hours and 20 minutes no difference was observed (pH 5.9). According to *Briskey* (1963) pale soft exudative muscle develops postmortem as a result of an extremely rapid rate of glycolysis. In the present study the 200 minutes value could not be regarded as excessively low. Further, the histological picture of the longissimus dorsi revealed no pathological changes. An explanation of the differences in the groups may probably be found in the values obtained for certain of the enzyme activities, particularly LDH (Table 6).

As may be seen from Table 11 the meat/fat ratio in experiment 3 of the non-supplemented group was 0.80 and in the supplemented 1.06 ($P < 0.001$). As pointed out by *Clausen* it is of fundamental importance to obtain objective measures of the meatyness of slaughtered pigs; weight gain values and measurements of protein efficiency ratio (PER) alone are not enough. In experiments on younger pigs, however, where the supplementation is ended before slaughter, such measurements are impossible to perform, chiefly because of economical reasons. The meat/fat ratio from the pigs belonging to experiments 1 and 2 (Table 8) indicates a lower protein deposition when compared to fat when compared to the animals of experiment 3 (Table 11). The supplementation of lysine-methionine increased the ratio in experiments 1 and 2 giving the same ratio as the controls of experiment 3, thus indicating that the addition of amino acids only is equivalent to protein supplementation.

The present results in pigs agree well with earlier work by *Clausen*, and with *Munck* in mice, *Larsson & Nilsson*, and *Larsson*. These workers have found that the supplementation of cereal proteins, which have a low biological value due to limitation of certain amino acids — with the limiting amino acids — improved not only the PER but also the deposition of proteins in the body. The basal feed in the present study, contained, in experiment 1 and 2 after the 43rd day and in experiment 3, according to standards, digestible protein in sufficient amounts. According to *Hellberg* (1963) amino acid supplementation is effective only when the base feed has a low protein level. The present results, however, indicate that under the experimental conditions reported, lysine-methionine supplementation to a high quality feed has a profound effect regarding in particular the meat/fat ratio. This is in accordance with findings by *Clausen* and *Larsson & Nilsson*.

There are reasons to believe that some of the differences discussed above depend upon adaptive changes in the intermediary metabolism. A possible means to study such changes is to measure the activities of certain enzyme systems involved in the carbohydrate and amino acid metabolism. As may be seen in Table 6 marked changes did occur in liver and muscle with regard to some enzyme systems. *Larsson & Nilsson* and *Larsson* found in rats that supplementation of small amounts of the limiting amino acids to a basal cereal feed caused adaptive changes in certain enzyme systems in liver and muscle. In the present study G-6-Pase, G-6-PDH and ICDH increased after the addition of small amounts of L-lysine.HCl and DL-methionine. The present experiments show that the supplementation with the amino acids in question exerts an influence not only on enzyme systems involved in the protein metabolism but also on enzyme systems concerned with carbohydrate metabolism.

It is known that e.g. fasting diminishes the level of G-PDH in liver of rats (*Niemeyer* 1962). On the other hand *Tepperman & Tepperman* (1958) considered an increased activity of this enzyme to be related with increased fat deposition. In the present study increased protein deposition was observed simultaneously with increased activity of G-6-PDH.

Srinivasan & Patwardhan (1955) found decreased transaminase activities of livers from protein defficient animals. The effect of fasting and of feeding low protein diets on the enzyme content of the liver has been regarded as a nonspecific reaction of defficiency in protein synthesis. *Wergedal & Harper* (1964) demonstrated that the adaptation of the rat to a high protein intake involves enzyme changes. Thus, under these circumstances GOT and GPT increase in the liver. The present results indicate that also the biological value of the protein is of importance. In experiments concerned with the effect of amino acid supplementation to different types of Swedish bread the transaminating capacity of the liver was found to increase with increasing biological value (*Larsson*).

Very few studies concerning the effect of diet on muscle metabolism have been published. Most of the studies have dealt with biochemical changes in muscular dystrophy. In the present experiments the skeletal muscle like the liver had an increased GOT activity of animals given lysine-methionine supplemented feed. The activity of LDH of the same animals decreased, however, which might partly explain the pH curve indicated in Fig. 2.

It is not surprising that the serum enzyme activities were the same in the two groups of experiment 3, since the basal composition of the feed is widely used in this country. In the literature no references have been found with regard to other serum enzyme activities in pigs than GOT, GPT and OCT. According to the knowledge of elevated serum activity of LDH in other species including man this should indicate muscle damage. It was therefore of value in the present study to find that even if significant changes of LDH took place in the muscle itself, these have been of physiological significance, since no coresponding differences were found in the blood.

It was of interest to note that lysine-methionine supplementation to the commercial feed used, advanced the time of ovulation. It is known that diets low in protein or energy content will modify or depress the oestrus cycle. The feed used in the present study was neither low in protein nor in energy content. The advancement of ovulation in the group on the supplemented feed was therefore probably due to the increased biological value of the protein. Lack of lysine has been noted to cause genital hypofunction (*Pearson* 1937).

In summarizing the results of the present study it is evident that in accordance with the previous findings (*Clausen*) supplementation of groats or commercial pig feed with lysine and methionine improves the growth rate, feed efficiency and protein deposition (increased meat/fat ratio). The last parameter is of great importance since a high meat and low fat content of the carcass is desired from the point of view of quality.

Another aspect of the present results is the further confirmation of findings in rats (*Larsson*) that for the etiology of obesity the protein value of the diet plays an important role.

REFERENCES

Berg, O., S. Larsson & T. Nilsson: Utfodringsförsök på svin med aminosyraberikad spannmäl. Medlemsbl. Sv. Vet.-förb. 1962, *14*, 606—607.

Briskey, E. J.: Recent advances in the study of pale, soft exudative porcine muscle tissue. IXth Conference of European Meat Research Workers, Budapest, Hungary, 1963, 12 p.

Clausen, Hj.: Landøkonomisk Forsøgslaboratoriums efterårsmøde, Copenhagen 1962, 1963 & 1964.

Corner, G. W.: Cyclic changes in the ovaries and uterus of the sow and their relation to the mechanism of implantation. Contr. Embryol. Carneg. Instn. 1921, *13*, 117—134.

Ericson, L.-E., S. Larsson & G. Lid: The loss of added lysine and threonine during the baking of wheat bread. Acta physiol. scand. 1961 a, *53*, 85—97.

Ericson, L.-E., S. Larsson & G. Lid: A comparison of the efficiencies of free lysine and of roller-dried skim milk, fish protein and soya bean protein for the supplementation of wheat bread. Acta physiol. scand. 1961 b, *53*, 366—375.

Ericson, L.-E., S. Larsson & C.-O. Östholm: Preliminary studies on the possibility of improving the protein value of cereals for swine by lysine supplementation. Acta agric. scand. 1962 a, *12*, 157—166.

Ericson, L.-E., S. Larsson & S. Rubarth: The effect of supplementation of wheat bread with amino acids and proteins on liver and muscle composition. Acta agric. scand. 1962 b, *12*, 234—250.

Evans, R. E.: Nutrition of the bacon pig. The requirement of the bacon pig for certain essential amino acids. J. agric. Sci. 1958, *50*, 230—242.

Evans, R. E.: The protein saving action of synthetic lysine and methionine. J. agric. Sci. 1961, *57*, 111—121.

Hellberg, A.: Foderdagen, Rosenön, Sweden, 1963.

Jacobsohn, D., S. Larsson & A. Norgren: Enzyme activities in various organs of hypophysectomized rats and rabbits. Acta physiol. scand. 1965, *63*, 271—284.

Knox, W. E., V. H. Auerbach & E. C. C. Lin: Enzymatic and metabolic adaptations in animals. Physiol. Rev. 1956, *36*, 164—254.

Larsson, S.: A comparison of the biological value of various types of Swedish bread and the effect of added lysine. Acta physiol. scand. 1966. In press.

Larsson, S. & T. Nilsson: Acta physiol. scand. 1966. In press.

Lowry, O. H., N. J. Rosebrough, A. L. Farr & R. J. Randall: Protein measuerment with the Folin phenol reagent. J. biol. Chem. 1951, *193*, 265—275.

McWard, G. W., D. E. Becker, H. W. Norton, S. W. Terril & A. H. Jensen: The lysine requirement of weanling swine at two levels of dietary protein. J. Animal Sci. 1959, *18*, 1059—1066.

Munck, L.: The variation of nutritional value in barley II. The CBA-mouse as test organism for large-scale evaluations of nutritional characteristics in programs of plant breeding. Hereditas (Lund) 1964, *52*, 49—58.

Niemeyer, H.: The influence of diet on the enzyme content of animal tissues. Acta physiol. lat.-amer. 1962, *12*, 173—187.

Pearson, P. B.: The effect of a lysine deficient diet on the estrous cycle. Amer. J. Physiol. 1937, *118*, 786—791.

Srinivasan, P. R. & V. N. Patwardhan: The effect of protein deficiency on (a) some liver constituents and (b) enzymes in liver, pancreas and blood plasma in albino rats. Indian J. med. Res. 1955, *43*, 1—13.

Tepperman, J. & H. M. Tepperman: Effects of antecedent food intake pattern on hepatic lipogenesis. Amer. J. Physiol. 1958, *193*, 55—64.

Tollersrud, S.: Försök med lysin-tillskudd till slaktegriser. Nord. Vet.-Med. 1961, *13*, 242—258.

Wergedal, J. E. & A. E. Harper: Metabolic adaptions in higher animals. 10. Glutamic dehydrogenase activity of rats consuming high protein diets. Proc. Soc. exp. Biol. (N.Y.) 1964, *116*, 600—604.

SUMMARY

Three series of feeding experiments in pigs are reported. It was found that supplementation of groats or commercial pig feed with L-lysine.HCL and DL-methionine improved growth rate, feed efficiency and meat/fat ratio. At the same time adaptive changes in some enzyme systems of liver and skeletal muscle occurred. The female animals ovulated earlier on the amino acid supplemented feed.

The results are discussed in relation to modern views in nutrition.

ZUSAMMENFASSUNG

Einige Aspekte auf den metabolischen Effekt aminosäurebereicherten Schweinefutters.

Drei Serien von Ausfütterungsversuchen an Schweinen werden beschrieben. Es konnte festgestellt werden, dass bei Bereicherung des Schrotes oder der kommersiellen Schweinefuttermischungen mit L-Lysin.HCL und DL-Methionin, der Zuwachs, die Futterausnutzung und die Fleisch/Fett Quote zunahm. Gleichzeitig konnten adaptive Veränderungen in gewissen Enzymsystemen in der Leber und in der Skelettmuskulatur beobachtet werden. Die weiblichen Tiere ovulierten bei der aminosäurebereicherten Diet zeitiger.

Die Resultate werden im Zusammenhang mit neueren Erfahrungen innerhalb der Nutrition diskutiert.

SAMMANFATTNING

Några synpunkter på de metabola effekterna av aminosyraberikat svinfoder.

Tre typer av utfodringsförsök på svin beskrivs. Det kunde konstateras att berikning av gröpe eller kommersiell svinfoderblandning med L-lysin.HCL och DL-metionin ökade tillväxten, foderutnyttjandet och kött/fett kvoten. Samtidigt kunde adaptiva förändringar i vissa enzymsystem i lever och skelettmuskulatur iakttagas. Hondjuren ovulerade tidigare på den aminosyraberikade dieten.

Resultaten diskuteras i anslutning till nyare rön inom nutrition.

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