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REPORT S-01

Effectiveness of Calcium Phosphates as Mineral Supplement During Pig Fattening

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Calcium phosphates play a special role as nutrient phosphates. Many mineral supplements are based on mono or dicalcium phosphate, while such a phosphate source provides not only phosphorus but also calcium, which must be regularly supplemented during pig fattening.

Since the introduction 25 years ago of the Göettingen transposition test, it is well known that the various calcium phosphates (mono, di, and tricalcium phosphate) are associated with different nutritional physiological effectiveness. Several investigations carried out internationally have confirmed this. While the transposition test was first of all performed on young rats, it has in the course of time been extended to chicks, young pigs, lambs and calves.

All tests undertaken in these young animals fully support the idea that monocalcium phosphate (MCP) is superior to dicalcium phosphate (DCP) and this in turn to tricalcium phosphate (TCP) as an effective supplement for calcium as well as phosphate.

In additional investigations it was concluded that the results of the transposition tests in young animals could be directly applied to the agriculturally useful species, broilers, fattened pigs, lambs and also fattened calves.

Effect of different calcium phosphates on productivity

The recognition that calcium phosphates possess a differential effectiveness in the feeding of agricultural animals has had a decisive influence on the formulation of the types of mineral feed and mineral mixtures. This has lead to the development of new types of phosphate feed, for example calcium phosphate, which is partly MCP and partly DCP.

In the classic transposition test it was shown that the mono-di-calcium-phosphates from MCP and DCP are nutritionally and physiologically effective, according to their proportion of MCP or DCP. In view of this it is to be expected that for a mixture of MCP and DCP, in proportions of 50%, and efficiency grading for calcium and for phosphorous lies approximately between MCP= 125 and DCP = 80, that is 102.

Results from several species of young animals are in complete agreement with this value. The nutritional physiological evaluation of calcium phosphates in the realm of ration supplementation by mineral feed or mineral mixtures, which consist partly of MCP and DCP, is of practical relevance to pig fattening, as long as the basic evaluation by the transposition test is directly applicable to the feeding conditions in practice. In this connection it is particularly important for practical animal nutrition, that it can be experimentally clarified to what extent a mono dicalcium phosphate given during pig fattening can influence productivity, that is gain in body weight, feed expenditure and bodily condition for slaughter, as well as the mineral evaluation, that is the calcium and phosphorous deposition from the feed ration in the animal body, particularly in the skeletal system.

Experimental design and criteria

In order to answer this question we carried out experimental investigations in fattening pigs under defined conditions with two feed phosphates based on calcium phosphate. One consisted of MCP (CEFKAPHOS, Firma Chemische Fabrik, Cologne) and the other mono dicalcium phosphate containing 50% MCP and 50% DCP. They will hitherto be referred to as "MCP" and MDCP" respectively.

Their chemical analytical composition was as follows:

	% MCP	% MDCP
Calcium	16.20	19.50
Phosphorus	22.70	20.00
Sodium	0.20	0.22
Magnesium	0.84	0.64
Fluorine	0.12	0.22

They were found to have similar productivity and mineral utilization. The experimental pigs were largely genetically homogeneous and taken at the age of 10 weeks old from the experimental farm of the University of Göettingen.

Table 1 shows the composition and nutrient content of the food used in the nutritional physiological experiments. The total phosphorus content of 2.9g per pound feed originated from 1.35g per pound of the feed phosphate to be tested. Total calcium content of 4.1g per pound feed was provided as 3.2g per pound by the mineral supplement, that is from the test phosphate with the addition of calcium carbonate.

Table 1. Composition of experimental feed mixture

A. Constituents	**in %**
Barley wholemeal	45.00
Wheat wholemeal	26.00
Soya wholemeal	20.00
Mineral mixture	3.00
CaCO3	1.00
Hormone mixture	3.00
Feed fat	2.00
B. Nutrient content of air dried substance	**in %**
Crude protein	16.95
Crude fat	4.60
Starch	40.10
Sugar	4.00
Crude fibre	4.35
MJME	1.34
Ca	0.90
P	0.65
Na	0.17

The experimental animals were maintained without straw in a common sty, whereby they could be housed in pairs in separate bays. The sty was ventilated and temperature regulated during the experimental period. Feed was administered twice daily by hand and drinking water was available in automatic containers. Each experimental group consisted of 30 animals in equal numbers of both sex and the males were castrated. The following experimental criteria were checked:

1. Development of body weight and thereby live weight gain in individual animals throughout the experimental period.
2. Feed consumption for each pair, allowing calculation of the average feed requirement per lb. body weight growth arid also the average energy requirement for body weight gain.
3. Condition of the body for slaughter in the case of the individual animals.
4. Mineral deposition in the distal extremity bones of the hind leg.
5. Calculation of the mineral deposition in the whole skeleton of the individual animals.
6. Behavior of the experimental animals throughout the experimental period.

Table 2. Average growth eficiency of the experimental animals

	Group I MCP, n=30	Group II MDCP, n=30
Initial weight, lb.	58.85 ± 5.39	59.62 ± 5.79
Final weight, lb.	228 ± 15.7	223 ± 17.5
Weight increase, lb.	169.5	163.8
Daily increase, lb.	1.84	1.78
Relative increase, %	100.00	96.63

Table 3. Average feed consumption and utilization of food and energy

	Group I MCP, n=30	Group II MDCP, n=30
Initial feed consumption, lb.	475.3	506.2
Feed consumption per animal per day, lb.	5.17	5.26
Feed expenditure per lb. gain, lb.	2.804	2.957
Relative expenditure, %	100.00	105.46
Energy expenditure per lb. increase, MJME	17.09	18.0

Table 4. Condition of the carcasses of the experimental animals

	Group I MCP, n=30	Group II MDCP, n=30
Classification		
E	8	7
I	17	17
II	5	6
III	0	0
Carcass weight	182.9	177.5
Slaughter yield, %	80.08	79.46
Thickness of dorsal fat, mm	21.74	21.91
Thickness of lateral fat, mm	27.44	27.67
pH value, cold	5.42	5.48
pH value, warm	5.77	5.81
Color value	66.79	66.21

Daily weight gain and feed analysis

The experiments yielded the following results. As shown in Table 2, the average body weight development of the pigs reveals that during the fattening period of 92 days there was a body weight range of 57.2- 226 lb. The body weight gain in the MCP group was on average 169.5 lb. and in the MDCP group 163.8 lb. This represents an average daily weight increment of 1.84 lb or 1.78 lb with the mineral supplement based on MCP or MDCP respectively. The average difference in the increase amounted to 5.70 lb. which corresponds to 3.40% as related to the fattening period. This difference is weakly statistically significant.

Table 3 shows that there is no significant difference between treatments in the average feed consumption by the animals. The average feed consumption per lb body weight growth amounted to 2.804 lb. in the experimental group fed MCP and 2.957 lb. in that fed MDCP. The feed consumption is thus relatively low. Likewise the energy consumption for 1 lb. growth was 17.09 or 18.0 MJME units for the MCP and MDCP groups respectively. The difference in energy as well as feed consumption for the same efficiency amounted to 5.50% in favor of the MCP group. Thus, for each fattening pig between 57 lb. and 226 lb. a total of 26.0 lb. of a commercial air dried feed with 88% dry matter can be saved in the course of the production period.

The carcass weights exhibit similar differences between both treatments as the live body weights, so that the average values for MCP treatment are about 3.01% higher than those for MDCP treatment. The classification of the carcasses agreed as expected in both experimental groups for all pigs, and similarly the slaughter yield is the same for both treatments. Furthermore, as seen in Table 4, other criteria of the carcass examination are also in agreement.

Differences in mineral deposition

The average mineral deposition in the bones of the extremities of the experimental pigs examined during the 92-day fattening period exhibited statistically significant differences between both groups for calcium as well as phosphorus. The deposition values for both added elements were about 7.0% higher in the MCP group than in the MDCP group, even though the same amount of mineral was taken up in both treatments. However, when considering these results, It should be pointed out the supply of phosphorus in a quantity of 1.6g per lb. feed arose from the untreated preparation and therefore was the same in both experimental groups. The only differences were in the 1.35g phosphorus per lb feed, supplied by the mineral supplement When the differences in the utilization of the total phosphorus in the feed ration was reduced to the phosphorus supplement alone, a difference in utilization of about 15% in favor of the feed phosphate MCP was obtained. Individual values for the mineral deposition in the bone extremities of the pigs examined are presented in Table 5.

When the deposition values for calcium as well as phosphorus are calculated in terms of the whole skeleton, a mean difference of 4.5% is obtained for the total content of the feed due to calcium or phosphorus, or 10% for the supplement contribution by calcium and phosphorus in the feed ration. The average phosphorus deposition in the whole skeleton of an experimental animal was 439g in the MCP group and 419g in the MDCP group. The corresponding values for calcium deposition in the whole skeleton were 879g and 839g (Table 6).

The difference of about 10% in utilization of the mineral elements calcium and phosphorus from both feed phosphates MCP and MDCP, which exerts a uniform effect of the utilization rate for the deposition in soft tissue and in the skeletal system, influences the utilization rate of total phosphorus (that is, native phosphorus in addition to supplement phosphorus) of the feed throughout the fattening period by 36.60% in the MDCP group and 39.10% in the MCP group.

During the fattening period both groups received an average of 650g phosphorus as supplement. In the MCP group it was found that for each animal an average of 10% more of this supplement was deposited compared with the MDCP group. When a phosphorus supply of about 0.65% in the air dried matter is provided, defined changes in the phosphorus concentration resulted in linear changes in utilization. This means that the same phosphorus deposition in the body of the pig is achieved by MCP using 10% less phosphorus as supplement (that is, 585g phosphorus as MCP) as with 650g as MDCP. Of course, it is doubtful whether the same deposition effect can be obtained by 10% more phosphorus as MDCP, that is by 715g as MDCP, compared with 650g phosphorus as MCP, since the increase in phosphorus concentration in the total feed would lower the rate of utilization.

Table 5. Average mineral deposition in bones of the extremities

	Group I MCP, n=30			Group II MDCP, n=30		
	Ash	Ca	P	Ash	Ca	P
Initial content, g	22.00	8.15	4.05	22.00	8.15	4.05
Final content, g	145.10	54.66	27.27	137.65	51.40	25.65
Deposition during experiment, g	123.10	46.51	23.22	115.65	43.25	21.60
Relative deposition, g	100.00	100.00	100.00	93.95	92.99	93.02
Average deposition per day, g	1.34	0.51	0.25	1.26	0.47	0.23

Table 6. Calculated mineral deposition in the whole skeleton

	Group I MCP, n=30			Group II MDCP, n=30		
	Ash	Ca	P	Ash	Ca	P
Initial content, g	566.0	211.99	105.0	566.0	211.0	105.0
Final content, g	2906.0	1090.0	544.0	2815.0	1050.0	524.0
Deposition during experiment, g	2340.0	879.0	439.0	2249.0	839.0	419.0
Relative deposition, g	100.00	100.00	100.00	96.11	95.45	95.44

Conclusion

1. These results in fattened pigs confirm that calcium phosphates, widely used as feed phosphates, exhibit differences in their nutritional physiological effectiveness. This is also apparent when pure MCP is compared to MDCP, consisting of approximately 50% MCP and DCP. Thus the results obtained by the classical transposition test are applicable to rats as well as suckling pigs and fattened pigs. The influence of a difference of about 20 to 25 degrees of efficiency for both calcium and phosphorus on the production and mineral utilization can be seen from Table 7. A difference in the degree of efficiency produced a positive effect in production data of 3.5-5.5% (body weight gain, feed consumption and carcass weight) as well as 4.5-7.0% in terms of the rate of mineral utilization.

2. The influence of mineral supplements on production data may at first seem surprising. This effect of feed phosphates, as reported here for calcium phosphates, on body weight gain, feed consumption and carcass weight can be explained for calcium and phosphorus in terms of the different rates of utilization. In the case of an essential supply of added elements, this can become a limiting factor for production at a high efficiency level. Every mineral source, which leads via the intermediary metabolism to the same quantitative uptake of minerals from the food, and to intermediary metabolism of more calcium and phosphate, stimulates simultaneously the efficiency and thereby the anabolic body growth and,

Table 7. Average food consumption and utilization of food and energy

	Group I MCP, n=30	**Group II** MDCP, n=30
Body weight gain	100.00	96.63
Feed consumption	100.00	105.46
Carcass weight	100.00	97.08
Phosphorus deposition		
Bone of extremities	100.00	93.02
Whole skeleton	100.00	95.44
Phosphorus utilization, %	39.10	36.60

secondarily, the food requirement for the same food expenditure. For this reason feed phosphates cannot be considered as “efficiency promoters” in the conventional sense. However, they can improve the supply of calcium and phosphorus for effective intermediary metabolism, and thereby the provision of the “net requirement of these elements for growth”. In this way they exercise a positive influence on growth processes, provided that the other essential nutrient factors such as energy and crude protein are available.

3. The higher utilization rates for calcium and phosphorus in supplements of MCP instead of MDCP lead to an increased mineral deposition in the bones of the extremities, as well as in the whole skeleton. This results in an improvement in the stability of the skeletal system together with an enhancement of the overall capacity. Although weakness of the legs and other disturbances in mobility cannot be eliminated, they can however be significantly reduced.

The answer to the question to what extent an increased utilization rate for calcium and phosphorus can influence the quantitative use of the mineral supplement is of practical importance in nutrition. Thus a nutritional physiological mineral source, such as MCP, through a quantitatively lower deposition, which corresponds to the higher utilization rate, leads to the same mineral deposition in the pig body as mineral source with lower utilization, such as MDCP, which can be employed quantitatively in unlimited amount. This applies only when the animal producer is satisfied with a low deposition rate of mineral feed in the animal body, and thus a low overall capacity of the skeletal system (increased risk).

The opposite case, namely the augmented deposition of the poorly utilizable mineral sources, e.g. from MCDP, at a percentage rate corresponding to the lower utilization rate usually does not result in the same minerals deposition in the animal bodies as with the higher utilizable mineral source. This is due to the fact that the calcium or phosphorus concentration in the food necessarily decreases

the utilization of these elements. Thus it cannot be expected that the same effect can be achieved quantitatively by the demand for a higher deposition, as compared with a higher utilizable mineral source in the required dosage.

Economic aspects

The immediate effects of body weight gain and feed consumption are naturally of primary concern for the pig producers. The production of about 5.7 lb. higher weight gain for about 5.3 lb. more carcass weight, from 26 lb. less expenditure of air dried feed per slaughter pig means that for a series of 400 fattened pigs one ton more living or carcass mass is achieved with 5.3 tons of less feed. When this is calculated for our production level, on the basis of three series per calendar year, the above values have to be tripled.

The economic consequences for trade of achieving a three ton higher production of livestock or carcasses, despite 15.9 tons less feed per year, may be individually estimated according to the various regional prices. Furthermore, when the possible indirect effect of a different mineral supplement on skeletal capacity and health is also considered, and these indirect consequences are calculated for only two pigs per stock of 400 animals, the estimated weight gain would be additionally augmented.

The weight gain corresponds to an expenditure of 6.3 lbs. of MCP, instead of 7.15 lbs. of MDCP per fattened pig. This can be supplied in the form of mineral feed or mineral mixture, as 18.7 lbs. mineral supplement I containing MCP and 21.6 lbs. mineral supplement II containing MDCP. When calculated on a yearly basis, an expenditure of 11.2 tons of mineral supplement I and 13 tons mineral supplement II is required for each series of 400 fattened pigs. Each animal producer can estimate the cost difference as applicable to his regional conditions.

The results and calculations of our investigations have shown the effects on the productivity and economy of pig fattening by supplementing the feed ration with two different feed phosphates based on MCP or MDCP. It should therefore be brought to the attention of the animal producer that “fine tuning” of the fattening feed ration can be really profitable.

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