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Phosphate sources in pelleting

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Pelleting can be described as a process during which individual ingredients or mixed feeds are agglomerated using heat, moisture and pressure. The purpose of pelleting is to transform a finely-divided, sometimes dusty and difficult-to-handle feed material and form it into larger particles—usually resulting in improved feeding properties and animal performance compared with non-pelleted product. Thus, pelleting has long been recognized as a means of maximizing feed utilization and profitability for both producer and feed manufacturer.

This chapter does not elaborate on the merits of pelleting, for that has been proven, but rather provides insights and a greater understanding of typical feed ingredients that optimize the pelleting process. Of particular interest to the feed industry and poultry and swine integrators, and subject to much debate over the last 15 years, has been the effect of minerals on hardware, pellet quality and rate of production.

We will focus this discussion, in particular, on inorganic feed phosphates (**Table 17-1**) and their effect on the pelleting process. The importance of highlighting inorganic feed phosphates is self evident in the dietary levels added to our formulations and the dynamic impact they continue to have on the pelleting process.

Source comparisons

Much of the early pelleting work with minerals involved assessing the effect of defluorinated phosphate (DFP) and dicalcium phosphate (DCP) on pellet mill performance. Pellet mill performance can be significantly affected by the physical and chemical forms of the inorganic feed phosphate sources used in the formulation (McEllhiney, 1986). Sutton (1979) investigated the effect of DFP and DCP on pellet mill performance with a broiler grower formula. He found the production rate for the diet containing regular and fine-grind DFP to be 60% greater than for the diet containing an equal amount of DCP.

Table 17-1. Chemical properties of commonly-used inorganic feed phosphates.

Ingredient	P, %	Ca, %	Na, %
Monosodium P	26	-	20
Monoammonium P	24	-	-
Dicalcium P	18.5	20	-
Monocalcium P	21	15	-
Defluorinated P	18	30	5

Behnke (1981) also studied the effect of mineral sources on pellet mill performance and pellet quality. Defluorinated phosphate was compared with DCP and monocalcium phosphate (MCP). He concluded that DFP improved production rate 23% and 33% compared with DCP and MCP, respectively (**Table 17-2**). Verner (1988) and others have suggested that DFP either coats or polishes the holes of the die with most plants reporting extended die life.

Table 17-2. Effect of inorganic feed phosphate sources on pellet production rate.

Ingredient	Production rate, kg/hr
Defluorinated P	1,877
Dicalcium P	1,528
Monocalcium P	1,411

Verner (1988) conducted a year-long research project in commercial feed plants over a broad geographical area, using many different feed rations to determine the effect of inorganic feed phosphate sources on pellet mill performance (**Table 17-3**).

The tests showed pelleting rate increases using DFP in the range of 5-50%, depending on the degree of pelleting difficulty of the original formula. The greatest improvement (25-50%) appeared in beef and dairy feeds using high levels of corn gluten, urea and minerals. The next greatest improvement was found in heat-sensitive feeds (high milk/high sugar). Poultry and swine feeds showed increased throughputs of 5-25%, depending on the amount of fat added in the pellet.

Table 17-3. Effects of replacing dicalcium P (DCP) with defluorinated P (DFP) in select pelleted diets.

Diet	Feeder Rate, %	Production Rate, metric ton/hr	Pellet Mill Load, %
Poultry diet			
DCP	98.0	22.5	95.0
DFP	98.0	25.0	87.0
Calf supplement			
DCP	37.4	3.0	75.0
DFP	47.1	5.0	88.0
38% cattle supplement			
DCP	53.5	6.0	59.7
DFP	75.7	9.4	62.8

Starting with a blend of DCP and DFP, an improvement of 20% was observed when the ration was re-formulated with 100% DFP. An increase of 10% was achieved with the replacement of 50% DFP. Pelleting rate improvements were noted using amounts varying from 6.5-30 kilograms per metric tonne. Also, the pellet mill size (45-224 kW), die size (3.2-9.5 mm) or die composition (standard alloy or stainless steel) had no effect on the percentage improvements, and the pellet durability was not significantly different.

Dietz (1989a, 1989b), in two pellet studies using broiler type diets, compared DFP with DCP, MCP and monosodium phosphate (MSP). He found that DFP was 7.9%, 14.9% and 13.8% higher in throughput than DCP, MCP and MSP, respectively.

Particle size

The particle size of common inorganic feed phosphates has had a variable impact on the pelleting process. Sutton (1979) found that the production rate for a diet containing a regular-grind DFP was 68.9% greater than for a diet containing an equal amount of DCP. Comparatively, the finely-ground DFP produced only a 52.2% advantage over DCP. Similarly, Behnke (1981) evaluated a fine- and regular-grind DFP compared with DCP. In Trial 1 of his evaluation, he found that a finely-ground DFP resulted in an increase in production rate over the more coarsely-ground DFP. However, in Trial 2 the regular-grind promoted a faster throughput than the fine-grind DFP (**Table 17-4**).
Dietz (1989a) investigated the effect of particle size of inorganic feed phosphate sources on pellet throughput. The study conducted at Kansas State University compared a finely-ground form of DFP, DCP and MCP with a typical feed-grade size product. In all three inorganic phosphate sources the finer-grade material resulted in a 6-10% lower throughput.

Table 17-4. Effect of particle size on pellet mill performance.

Particle Size	Production Rate, kg/hr
Regular	1,921
Fine	1.833

Pellet durability

Behnke (1981) compared the pellet durability index (PDI) of inorganic feed phosphates, which is a measure of the feed pellets to withstand mechanical handling (**Table 17-5**). The DCP and MCP products produced a more durable pellet compared with DFP. Work by Dietz (1989a, 1989b) and Axe (1996) supports these findings. On average, MCP was 6% and DCP was 3% higher in pellet durability compared with DFP.

Table 17-5. Effects of feed phosphate source on pellet durability index (PDI).

Ingredient	PDI
Defluorinated P	88.5
Dicalcium P	89.7
Monocalcium P	92.9

Energy efficiency

The DFP used significantly less energy per unit of feed than either DCP or MCP (Behnke, 1981). Differences follow the same trend as found in the production rate data. **Table 17-6** shows that DCP and MCP increased energy used per unit of feed 20.3% and 29.2%, respectively, over DFP.

Table 17-6. Effect of feed phosphate source on pellet mill energy use.

Ingredient	Energy use, kWh/ton
Defluorinated P	9.84
Dicalcium P	11.84
Monocalcium P	12.71

Winowiski (1996) compared DFP to MCP, DCP and monoammonium phosphate (MAP). This study found that the load amperage increased in a linear fashion from DFP to MAP (**Table 17-7**). Similarly, Axe (1996) found a 4% increase in energy consumption with MCP over DFP.

Table 17-7. Effect of feed phosphate source on pellet mill load amperage.

Ingredient	Load amperage, %
Defluorinated P	65.6
Dicalcium P	67.5
Monocalcium P	68.8
Monoammonium P	72.5

Fat addition to inorganic feed phosphates

Dietz (1989b) and Axe (1996) added 1% fat or soybean oil to diets containing different sources of feed phosphates to determine if adding lubrication can reduce observed throughput differences between feed phosphates. Diets with added fat or soybean oil gave higher throughputs and reduced energy consumption. In respect to reducing the throughput differences between feed phosphates, there was only minimal effect. All feed phosphates with added fat produced a similar additive response in production rate.

No inorganic feed phosphates added

We have generally overlooked the value of inorganic feed phosphates to the pelleting process. This information becomes increasingly important as we consider substituting feed phosphates with phytase and/or alternative ingredients.

Some of the early work showing a pelleting benefit in adding granular feed phosphates to the diet was generated by Ranne and Richardson (1979). They evaluated pelleting efficiency and pellet quality of diets containing DCP or a liquid ammonium phosphate source. They found that diets containing ammonium polyphosphate required significantly more electrical energy than corresponding diets containing DCP.

Two studies by Dietz (1989a, 1989b) reported on the effects of pelleting a broiler type diet with different inorganic feed phosphates compared to a no-feed-phosphate-added diet (control). Both studies demonstrated an increased throughput for feed phosphate sources compared with the control diet (**Table 17-8**).

Similarly, a pilot study by Winowiski (1996) found that a control diet (no added inorganic feed phosphate) dramatically reduced pellet mill performance compared with diets containing inorganic feed phosphates. These findings are also supported by a recent study at Kansas State University (Axe and Behnke, 1997).

Table 17-8. Pellet mill throughput comparison between inorganic vs. non-inorganic feed phosphate sources.

Ingredient	Improvement, %
Defluorinated P	39.5
Dicalcium P	28.5
Monocalcium P	18.7
Monosodium P	20.3

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