Minerals have a variety of functional characteristics with Ca and P mainly as mineral base in skeletal tissues and egg shell formation. Their requirements depend on many factors, such as their availability, the Ca/P-ratio and interactions with phytase and vitamin D3 and its metabolites. Phosphorus is either of vegetable, animal or mineral origin. In mineral feedstuffs, P is mainly present as a Ca-phosphate. Globally about 90% of the phosphate produced from phosphate rock is used as fertilizer being the major impact factor with only 5% for the animal feed industry. The production process of feed phosphates has an impact on their availability.

Before 2008, there was a large increase in the price in phosphate rock and feed phosphate. An overview is given of the driving macro-economic factors for the wide price fluctuation. Feed producers are looking more closely at alternative strategies to the current crisis through (1) the use of phytases, (2) limitations in dietary P-concentration and (3) the use of more effective vit. D3 metabolites. Finally, a description is given on feedstuff specification and alternative diet formulations.

**Nutritional factors**

All animal tissues and all feeds contain inorganic or mineral elements in widely varying amounts and proportions. Twenty two mineral elements are believed to be "essential" for the higher forms of animal life, comprising of 7 macronutrient minerals (e.g. Ca, P, …) and 15 trace mineral elements. Mineral elements exist in the cells and tissues of the animal body in a variety of functional, chemical combinations and in characteristic concentrations, within quite narrow limits (via homeostatic mechanisms) in order to safeguard the functional and structural integrity of the tissues. Phosphorus (P) is an essential nutrient for all life forms. The functions of P and Ca are quantitatively dominated by their requirements for the mineral base of the skeletal tissues. Furthermore, P also participates in a wide range of metabolic reactions involving energy transfer and nutrient metabolism as an integral part of the nucleic acids. The dietary P-content is an increasingly important issue from its nutritional as well as its environmental point of view. The 3 major players in mineral physiology are "P, Ca and vit.D3". Because of mutual interactions it is often difficult to have a general picture of each factorial effect on performance and bone metabolism (Huyghebaert et al., 2005).

**P-supply in poultry diets**

Phosphorus is either of vegetable, animal (depending on the country legislation!) or mineral origin. In animal and mineral feedstuffs, P is mainly present as a Ca-phosphate. But in "vegetable" feedstuffs, the situation is much more complicated because a major fraction (about 2/3 but with a wide variation) of plant P is present as phytate-P. Phytates are in fact salts of phytic acid, an inositol with 1 to 6 phosphate groups giving inositol-1-phosphate (IP-1) to inositol-6-phosphate (IP-6) (Eeckhout and De Paepe, 1994; Van Der Klis and Versteegh, 1996). Phytate is an important anti-nutritional factor because of its chelating capacity with minerals and other non-mineral nutrients and its adverse interference with endogenous AA flow at the terminal ileum in broilers in a dose-dependent manner (Cowieison & Ravindran, 2007). The mineral contribution from vegetable feedstuffs is much more important for P (>50% of total dietary P) than for Ca (<15% of total dietary Ca).

**Dietary supply of mineral P**

Phosphorus is generally found in mineral forms, as phosphates, and is mainly insoluble. Phosphate rock is the term given to a range of P-bearing minerals (belonging to the apatite group) that are commercially exploited. Phosphate rock has widely differing mineral, textural, and chemical characteristics depending primarily on the origin of the rock, its formational or post-depositional history, and the type and degree of near-surface processes to which the rock has been subjected to (pressure, shearing forces, heat, …). Phosphate rock deposits are widespread throughout the world, occurring almost on all continents. There are two main types of phosphate rock deposits: (1) Sedimentary phosphate deposits that provide more than 85% of the total world production of phosphate rock, mainly mined in Morocco, USA, Brazil and China and (2) Igneous phosphate deposits, mainly mined in Russia, the republic of South Africa, Finland and Brazil. Sedimentary ores are often high in grade with 30% P2O5 and heavy minerals. Igneous ores are often low in grade with 10% P2O5 but can provide phosphate rock with 30% P2O5 through beneficiation processes. The currently mined deposits have also been mined in the past or are potentially economically viable.
Phosphate rock production & reserves
Commercial production of phosphate rock began in the mid-19th with a production of 500 tonnes. The world production of phosphate rock increased to more than 10 million tons in 1928, 100 million tons in 1974, 125 million tons in 2002 and over 175 million tons in 2007. More than 90% of the phosphate rock produced is used to fabricate mineral fertilizers, essentially, diammonium phosphate (DAP), monoammonium phosphate (MAP), triple superphosphate (TSP), single superphosphate (SSP) and phosphoric acid (about 5% for animal feed). Four countries, USA, China, Morocco and Russia, collectively produce 70 to 75% of the world's total phosphate rock. Since 1995, 60% of new animal feed phosphates production capacity has been added in China. Of the four major producers, Moroccan reserves account for around 50% of the world total. According to the World Phosphate Institute (Strategic Plan of Action 2001-2010), depletion of the most economically exploitable and viable reserves might be estimated to occur within a period of 100 years. Meanwhile, it is worth mentioning that high grade and economic reserves are being depleted, which could result in mining slightly more costly resources and/or lower grade phosphate rocks.

Phosphate production schedules & phosphate quality
The flow chart for the production of the 4 main feed phosphates is given in figure 1 (Bleux and Ruyseveldt, 2008). In the process fluorine is removed and that is what distinguishes feed grade phosphates from fertilizer grade. There are three types of mineral feed phosphates—dicalcium phosphate (DCP), monocalcium phosphate (MCP) and defluorinated phosphate (DFP). DCP contains typically 18.5% P and 22% Ca. MCP has a higher concentration of P to Ca namely 21% P and 17% Ca. DFP is typically 18% P and 32% Ca and 5% Na. However, these values depend on the degree of hydration. Hereby, it might not be overlooked that the “wide” variation in P-digestibility of inorganic feed phosphate is caused by chemical form (e.g. MCP, DCP, DFP, ...) as well as the production technology and the raw materials used. The hydrated DCP is characterized by a regular crystal structure with a low variability in composition. Moreover, MCP is more useful than DCP in mash diets because of its granular structure. Most availability-studies are based on sensitive “bone” response criteria and, more recently, also on true P-absorption and apparent P-retention (Huyghebaert et al., 1980; Ketels and De Groote, 1988, Van Der Klis and Blok, 1997; Van Der Klis and Kwakernaak, 2008). The first category provide only relative values of bioavailability related to a reference source (e.g. Na-phosphate), while the second category generates absolute values of P-retention or P-absorption, which afterwards are in fact partly related with each other. MCP and DCP.2H₂O have the highest relative bioavailability values for P between 90 and 100%. DCP.0H₂O has an intermediary bioavailability, with relative values between 80 and 85%. Finally, the P in DFP is less available with values between 70 and 75%. The retainable P-values are different with 55, 77 and 84% for DCP.2H₂O, DCP.0H₂O and MCP, respectively.

There are animal species and geographic differences in the application of the feed phosphates. DCP/MCP and MCP account for about 80% and 20% of the total global feed phosphate usage, respectively MCP and hydrated DCP become more important mainly because of their higher biological value (digestibility). North America is the world’s largest consumer of feed phosphates, followed by Western Europe, Asia and then Latin America. Due to its large livestock and poultry industry, North America is the largest consumer of all three feed phosphates: DCP, MCP and DFP. DFP is used in Russia but no longer in the EU. P-digestibility in DFP is only 55% in poultry; this low value is due to its chemical composition (TCP) as well as the defluorination “thermo” processing (possible formation of meta- and pyrophosphates, which are biologically unavailable). This processing is not environmental friendly and it is energetically expensive. In the EU, dietary specifications and limits (feed constraint for place, Ca vs P, ...) may have an impact on the use of the feed phosphates : MCP (pigs), hydrated DCP (poultry), mixtures of MCP/DCP, Mg-phosphates (cattle and pigs). MAP is used in some dairy and beef formulations because of its protein replacing nitrogen equivalency. MAP is also preferred in aquaculture because of its high digestibility (85% vs 60% for MCP) and as partial replacer for the P in feed grade fish meal.

As a conclusion, high quality feed phosphates are characterised by stable and accurate physical-chemical properties, good phosphorus solubilities and a low amount of undesirable substances. These phosphates are certainly characterised by a high phosphorus digestibility minimising the phosphorus output in the environment without endangering the performance and well-being of the animals. High-quality feed phosphates require a quality assurance and an implemented traceability system to ensure feed safety. In this way, high-quality feed phosphates contribute to bringing quality “from the stable to the table”.

Phosphate price and macro-economic factors
About 96% of the world’s total phosphate rock production are used in agriculture through fertilizers and animal feeds to providing enough food to the world population. This important share of phosphate used in agricultural production indicates that the development of agriculture is the driving force of phosphate rock production. Globally about 90% of the phosphate produced from phosphate rock is used as fertilizer being the major impact factor. A huge increase in demand for fertilizers is at the root of the phosphate shortage problem for the animal feed industry in 2008. The large amount and high quality of food obtained today worldwide, and in particular in developing countries, are largely due to the use of phosphate.
There was an enormous leap in the price of both phosphate rock (over the past year 2008) and sulphur (over the past 2nd semester 2007 & year 2008) as well as overall production costs (including energy, as well as ammonia for downstream product production), most likely due to strong demand and tight supply. On the Moroccan market, the prices have soared with a price rise from 50 to 190 US$/ton. There was a 9-fold price increase for fertilizer phosphate (from 50 to 450 US$/ton), a 20-fold price increase for sulphur (from 50 to more than 1000 US$/ton) and a 5-fold price increase for $H_3PO_4$ (from 500 to 2500 US$/ton). As a consequence, there were also large increases in the price for feed phosphates ($figure$ 2) (Bleukx and Ruyseveldt, 2008). On the other hand, phytase followed a different price profile (figure3)

What are the driving forces to understand the present situation - both in the short and medium term? The animal feed industry is an integral and growing segment of the food supply chain. It supplies the feed ingredients needed to produce healthy animals that provide essential human food protein and energy. The current scarcity of feed phosphates seems to find its roots in several factors.

1. Animal products are a vital and important food source for the world’s 6.3 billion people who are multiplying at a rate of an additional 72 million per year or a global net population growth of 200,000 people per day (+1.14% increase/year). The world population has doubled during the last 40 years. By the year 2020, there will be some 800 million additional people to feed on the planet. Countries with large population bases and high growth rates are : Indonesia - 240 m, 1.5%, India - 1,065 m, 1.4%, Pakistan - 161 m, 2.0%, Bangladesh -143 m, 2.1% and Brazil - 185 m 1.1%

2. Economic prosperity in developing countries (increase of the GDP/capita) is increasing the demand for food and changing the eating patterns. In many countries, especially in China and India, per capita income levels have more than doubled over the past two decades. Rising per capita income drives demand for complex protein (meat). Patterns of household spending on food differ dramatically between high and low income countries. Bread and cereals account for around 12% of food expenditure in high-income countries while they are 27% in low-income countries. High-income consumers spend more on meat and dairy products than do low income consumers. High income human population is moving from vegetarian towards animal protein based food. Chinese meat consumption has tripled in past 7 years. At the same time, there is a relative shift from poultry to porc to beef. For the latter animal species feed (grain) conversion is worse. An increase of the poultry meat consumption of 3-4%/year requires an additional arable land of 30 mil. Ha.

3. Industrial feed production growth in annum in mills producing more than 2,500 mt per year is currently at 625 mmt. Although total feed production including expanded premixes and backyard production is much higher, growth rates globally are around 2% per year. If future demand increases at this rate, the supply of raw materials is expected to cover demand for the next 10 years. Shortage in the supply of nutrients to feed ever more animals is a concern. Arable land per capita is declining as population increases. So, more “new” arable land and/or higher crop yield per hectare must increase to meet increased demand for feed and food. Increased fertiliser consumption will support increased yields. Large increases in production of grain and oilseeds are already taking place in Brazil and Argentina, and increased production efficiency is being made possible in the U.S., Argentina and other countries through the use of transgenic herbicide and insect resistant soy and corn. But over the past ten years, China has gone from being a net exporter of oilseeds to the world’s largest importer of soybeans. Corn imports to that country are expected to exceed corn exports in the next few years as demand increases and more cropland is converted to higher value horticulture and vegetable production.

4. Recent dislocation in nutrient demand has been driven by biofuel. The latest forecast for 2008/09 points to further increases in the use of cereals for production of biofuels. Total cereal utilization for production of biofuels is forecast at 104 million tonnes, up 22 percent from the 2007/08 estimated level, representing 4.6 percent of world cereal production. In the United States, total use is forecast to increase to roughly 93 million tonnes (91 million tonnes maize), up 19 percent from the 2007/08 level. Earlier forecasts expected an even faster growth in maize utilization in the United States for production of biofuels but the steep decline in oil prices and the economic slowdown have lowered those expectations in recent months. Increased use of corn for production of ethanol and soy oil for diesel fuel is placing even higher demand on these important crops and will change the scope and pricing of nutrients available for animal feed production. The world will likely experience more tightness and price spikes in coarse grains as ethanol production increases and as China becomes a net importer of corn.

5. The higher feedstuff and phosphate prices might also be driven on the supply side due to tight availability with limited new capacity built in 2007 and 2008, as well as on the demand side. The price increase has occurred on the back of the strength of demand and tightness in the market. Cereal stocks and ending stock-to-use ratio (Q4 2008) were at record lows, equivalent to just 10 weeks’ production. China has introduced (2008) a new export tax for some phosphates (135%), thereby inhibiting the phosphate export. Furthermore, global cost curve has moved up in line with phosphate costs and the limited planned new capacity additions to Phosphate Rock capacity whereby a 4-year lead-time is needed for new capacity in an increasing capital cost environment.
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6. Sulphur is essential for the production of $\text{H}_2\text{SO}_4$ (figure 1: flow chart for feed phosphates). There are 3 sources for sulphur: refining industry of petroleum, pyrite (iron sulphide $\text{FeS}_2$) and solid sulphur. Natural gas and petroleum are key determinants of cost, price and margin. Globally, there are step changes in global energy costs, increasing demands (from e.g. China, India), supply interruptions and lack of new capacity in the near-term as possible reasons for the large scale of the price increase. Global demand for sulphur increased steadily between 1999 and 2006 by between 500,000 tons and 1.5 million tons, year on year but with a strong growth in 2007 & 2008 (International Fertilizer Industry Association). Pyrite is used commercially for the production of sulfuric acid, for use in such applications as the paper industry, and in the manufacture of sulfuric acid.

7. Sustainability of financial system. With the global economic crisis in Q4 of 2008 attacking the fundamentals of not only the financial system but also the commodities markets and other industries have followed suit, as grain prices, shipping rates and sulphur costs are all on a steep decline. At the same time, there was a decline in the trade activity of fertilizers and as a consequence a decrease in the price for fertilizer and feed phosphates. The fundamentals of the phosphate rock market might take advantage of the lower market prices by a recovery in the P-demand and the shutdown of some P-production units. As the recent dramatic plunge in world markets has shown, predicting economic events and trends (downturns in major economies of the world during Q4 in 2008 and 2009) is becoming more and more difficult since the economic forces, including commodity price fluctuations, are beyond our control.

**Dietary adaptations for P**
The huge increase in demand for fertilizers was at the root of the phosphate shortage problem for the animal feed industry. The scarcity of feed phosphate seemed to appear since 2008, leaving many feed producers perplexed and concerned. Given the dramatic rise in phosphate prices, feed producers are looking more closely at alternative options. A partial solution or strategy for poultry producers to the current crisis can be found through (1) the use of "new generation" phytases, (2) limitations in dietary P-concentration and (3) the use of more effective vit. D$_3$ metabolites. Furthermore, land application of poultry litter is limited by its phosphorus (P) content in areas of intensive poultry production.

1. Phytase

There are numerous studies demonstrating the favourable effect of phytase on the phytate-P availability. In other words, phytase releases phosphorus from the phytate, making it available for monogastric animals thereby reducing environmental P-excretion. The use of microbial phytases in monogastric feed is an attractive option to supply more digestible phosphorous to livestock and to overcome the shortage in mineral phosphates without imposing an additional risk to the environment and the food chain (as an effective and sustainable approach). However, only since the mid 80-90-ies microbial phytases are used in commercial poultry diets. There are currently two primary classes of phytase. The 3-phytase (Aspergillus sp) initiates the dephosphorylation of phytin at the 3-position on the inositol ring, the 6-phytase (Peniophora lycii & E. coli) at the 6-position. The early biotechnology of phytase focused on screening for novel phytase genes. That effort resulted in the isolation and characterization of several new phytase genes from bacteria (E. coli; Bacillus sp.) and fungi (Aspergillus fumigatus; Peniophora lycii). These novel phytases offer a wide range of enzymatic properties for developing effective phytases targeting different species or feed processing conditions. Most recent molecular research of phytase has been shifted to developing efficient enzyme production systems and optimizing catalytic efficiency and peptin-resistance & thermostability of phytase. An alternative economic efficient way to supplement the diet with phytase is the use of phytase-containing transgenic seeds; e.g. corn-based phytase is a genetically modified corn containing a phytase product expressed in the endosperm of the corn kernel that is identical to an Escherichia coli derived phytase. Thereby, corn has a unique advantage as the expression vehicle for phytase in that unlike soybeans, it does not require the high temperature associated with processing soybean meal.

Phytase activity is expressed in activity units (FTU) where 1 FTU is defined as the quantity of enzyme that liberates 1 µmol inorganic P per min from sodium phytate at pH=2.2 & T=37 °C (for EU-registration). This in-vitro technique do not give information on the kind of phytase & in-vivo efficacy. The conditions in some labo’s are, however, not always in line with the EU-recommendation.
Phosphorus (P) and calcium sparing values for phytases have been estimated from digestibility, growth, and bone ash studies where comparisons with an inorganic source yield an equivalency value. In practice there is a great deal of variation in the responses observed in vivo, due to variations in the composition of the basal diet (including the presence of intrinsic phytase and the phytate P content), the physiological status of the animal (classes of animals, age,…) and the processing of the feed. In common with all enzymes, the relationship between the amount of phytase and the amount of digestible P released is according to an asymptotic curve. However, for the purposes of feed formulation, it is not easy to work with such a relationship (figure 4; resp. 625, 284 & 177 P-release by 3 successive dosages of 250 U phytase). For reasons of simplicity, formulators using phytase are advised to use one phytase equivalence value for all inclusion rates, assuming that between 0 - 500/750 FTU there is a “linear dose-response relationship. I may not be overlooked that the efficacy of an additional 2nd dosage (as an attractive option!) is only 50% of the 1st dosage, being in general the recommended “standard” dosage; thereby phytase can introduced in LP diet formulation as 2 feedstuffs with a different substitution value for inorganic phosphates. In feed production, specific dietary inclusion rates of phytases for different species have been recommended to provide equivalence for the replacement of 1 g of inorganic P. In literature, there is some disagreement in their efficacy with quite wide ranges in P-equivalency values. Numerous experiments have shown that supplemental microbial phytases at between 300 and 1,000 units/kg of feed improve bioavailability of dietary P by between 10 and 40%, and reduce manure P excretion (et al., 1999; 2005; Driver et al., 2005). For direct comparison, use of phytase for phosphorus and digestible or available (relative) P, equivalency values must be adjusted by the estimated digestibility or bioavailability (relative) of the inorganic P-sources that phytase replaces. The responses are further complicated by the effect of phytase on the utilisation of other elements as minerals (cations), amino acids, metabolisable energy,… (the so-called non-mineral value). Dietary phytate enhances and phytase reduces endogenous losses in what appears to be a dose dependant manner, thus phytase will favour partitioning of MEn to NE of gain rather than NE of maintenance. (Bedford, 2008). Recently, Cowieson & Ravindran (2007) have demonstrated that phytate is an antinutrient capable of increasing endogenous amino acid flow at the terminal ileum in broilers in a dose-dependent manner. Therefore, the beneficial effect of phytase on amino acid digestibility may be mediated through the route of reduced endogenous loss. Furthermore, their results suggest that variation in the response to phytase may be partially explained by the dietary phytate-P concentration.

2. Impact Ca & P as sparing method

Several feeding strategies have been developed to limit P overfeeding (diet composition more closely to the animal's P-requirement) and P excretion by e.g. phase feeding and lower safety margins. Phase feeding is used in broiler chickens (decreasing dietary Ca and P concentrations with advancing age) and in laying hens (widening the Ca/P-ratio by enhancing the dietary Ca concentration and lowering the dietary P concentration with advancing production stage). A safety margin was normally included, since there is always a variation in the nutrient content of the diet as a result of natural variations in raw materials. When a critical nutrient requirement or a low safety margin is used, a low variation in the nutrient content (e.g. for digestible/ available P content) of the raw materials becomes very important. This phenomenon is more important for laying hens than for broilers because of the obvious difference in duration of the production cycle.

In the past, dietary calcium (Ca) and P recommendations (INRA, 1989; NRC, 1994) were based on maximum bone mineralisation. For chickens up to 21 d of age, diets containing 10.0 g Ca and 4.2 g available P (INRA, 1989) or 4.5 g non-phytate P (NPP) per kg (NRC, 1994), fulfil these requirements. Over the last decade, the requirement values for digestible or available P for poultry diet formulations have been decreased markedly. Driver et al. (2005) showed that reduction in dietary P can be achieved without deleterious effects on performance and bone mineralisation if Ca is reduced concomitantly (Ca and P interaction). From a literature review including 158 treatments from 14 references, Létourneau-Montminy et al. (2007) estimated that diets containing 6.0 g Ca/kg and 3.1 g NPP/kg allowed similar performance and bone mineralisation to currently recommended levels. In low P diets, reduction in dietary Ca would improve P availability by avoiding formation of insoluble calcium-phytate complexes (Wise, 1983) and calcium phosphate precipitates. Microbial and plant phytases, which release phosphate from phytates, are also used in practical diets to improve P availability in monogastric animals. Several authors concluded that decreasing the Ca:P ratio in diets for monogastric animals improves the efficiency of microbial phytase (Sebastian et al., 1996; Qian et al., 1997; Driver et al., 2005). More recent research has demonstrated that broiler chickens exposed to an early moderate Ca and P deficiency at early stage of growth, were able to adapt and compensate for growth and bone mineralisation when provided later with an adequate diet (Yan et al., 2005). This adaptation could be used in order to achieve a global reduction in P excretion through a dietary restriction repletion protocol, possibly with metabolic changes thereby modulating the response of chicks to phytase at different Ca:P ratios during the repletion period. Also the study of Létourneau-Montminy et al. (2008) confirms the feasibility of stimulating dietary Ca and P utilisation capacity of chicks after a moderate P and Ca deficiency. However, reduced dietary Ca had contradictory effects on growth rate and on bone mineralisation: the diet with phytase and a Ca:P ratio of 1.5 maximised bone ash weight, while the diet with phytase and a Ca:P ratio of 0:9 elicited the highest growth rate. These results emphasise the requirement for further work to fine-tune Ca and P balance in diets for broiler chickens.
3. Vitamin D₃ metabolites

The interaction between P and Ca is clearly affected by vitamin D₃ & analogues. Vitamin D refers to a group of closely related compounds that poses antirachitic activity, such as: ergocalciferol (vit. D₂) and cholecalciferol (vit. D₃). The absorption of dietary vit. D₃ depends greatly on intestinal conditions. Vit. D₃ is converted to 25-OH-D₃ (in the liver), which in turn is converted (1) at low blood Ca- & P-levels to 1,25-(OH)₂-D₃ (stimulated by parathyroid hormone "PTH" vs calcitonin) or (2) at normal blood Ca- & P-levels into one of two other metabolites 24,25-(OH)₂-D₃ or 1,24,25-(OH)₃-D₃ (in the kidney). Vitamin D₃ (1,25-(OH)₂-D₃) controls the levels of blood Ca & P through specific mechanisms in the intestine, kidney (secretion/reabsorption) and bone (deposition/mobilisation) (DeLuca, 1979). In comparison with vit. D₂ (as reference=100%), the relative biological effectiveness varied from 100-400 for 25-OH-D₃ and from 200-1500 for 1,25-(OH)₂-D₃ (Applegate and Angel, 2002 & 2004; Soares et al., 1978; Soares et al., 1995; Huyghebaert et al., 2008). There are indications that vitamin D analogues have a favourable "sparring" effect on the availability of P and phytate P (Edwards, 1993; Biehl et al., 1995; Qian, et al., 1997; Snow et al., 2004).

Economical "P" considerations in poultry

The global poultry meat production was about 86 million metric tons in 2007 with a share of 36, 28, 16 & 16% for Asia, N-America, S-America and Europe, respectively Broiler meat accounts for about 85% of total poultry meat worldwide. There was an asymptotic growth in poultry meat production from 70 million metric tons in 2000. For 2008, China and Brazil had the faster growth while the USA-production was decreasing for the first time since 1973 due to relatively high levels of feed and energy costs. Production in China and Brazil increased with 8 and 5%, respectively. Chinese production has been accelerating since 2006 due mainly to a sharp decline in pork supplies. Brazil’s production is expected to grow with increased foreign demand. The USA for 2009 will continue to be the world’s largest broiler producer with 22% of global output, followed by China with an 18% share, Brazil with a 15% share and EU-27 with a 12% world share. Brazil is expected to continue to be the top broiler exporter in 2009 with a forecasted 3.660,000 tons, 44% of total world broiler exports. USA broiler exports are expected to slip 6% in 2009 compared with 2008. The EU will continue in 2009 to be a net importer of broilers by 70,000 tons. The number of laying hens in the world is estimated at 5,690 million in 2006 producing just over 66 millionmetric tons of eggs. Asia, the largest egg producing region, produced 42.4 million tons in 2006 with China, the Worlds largest egg producer, produced just under 30 million tons (44.9% of the global egg production). Europe produced around 10.1 million tons (about 15% of the global egg production) while North America produced just over 8.2 million tons (FAO Database, 2006). Global egg production has been exploding in recent decades, tripling since 1970. "Within a few years the production volume will be higher than that of beef and veal if the growth rates remain fairly constant. China and India, the world’s No. 1 and 3 egg producers have boosted their output with 66% over the past decade. USA, the world’s No. 2 egg producing nation, was up 21% over this period. This growth illustrates how rapidly the developing world is gaining egg production market share over the developed world. For the EU-27 there are extra rules and regulations for feed composition, animal welfare (housing, density, beaktrimming), environment, disease control and food safety.

World feed volumes have grown from just over 610 million metric tons in 2000 to pass 700 million metric tons for the first time in 2008 (FAO) (Figure 5). About 32% is used for feeding the poultry stock (vs 35% for pigs and 26% for cattle). The %-share of poultry feed is quite variable with values of 33, 50 and 60% for USA, China and Brazil, respectively. The world feed industry struggled against a series of difficulties ranging from huge ingredient price rises, serious animal disease outbreaks, thin margins between costs and prices to the crisis affecting financial markets internationally. The depth of the crisis and the first signs of a recession in the national economies of a number of leading countries did not become clear until mid 2009. The big players are USA, EU-27 (3.4% growth in 2007), China and Brazil; the latter 2 countries with a large expansion in feed production in 2008. In European Union countries (EFFAC), the evolution of compound feed volumes relates more closely to the development of poultry meat and egg production than to pork, because industrially made compounds enjoy a much higher market share against on-farm mixing in the poultry sector than in pig feeds. The combined output of the top 10 countries amounts to approximately 556 million metric tons, which is still over 79% of the world total feed production. Animal feed is the most important cost factor and represents up to 75% of the production cost for chicken. This explains why the dramatic increase in feed materials prices on the global market in 2007, exacerbated in the EU by the 0-tolerance policy on non-EU approved GMOS, impacted seriously the EU livestock sector. The future of the feed industry will be primarily marked by challenges and difficulties instead of opportunities.

The world wide feed production is about 700 million metric tons with 32% for poultry.

LP diet simulations will depend on:
1. The relative prices for MCP, DCP.H₂O & exogenous phytase. The present prices for MCP, DCP.H₂O and Ronozyme P 5000 are 500 €/ton, 450 €/ton and 4.80 € / kg, respectively.
2. The differences in biological value and product structure (e.g. MCP vs DCP.H₂O).
4. Difference in safety margins between laying hens, broiler chickens during the starter or grower/finisher period. In general, a 2nd dosage of phytase is not advised for laying hens as well as for broiler chickens during the starter phase chickens.

5. Difference in time-duration between laying hens and broiler chickens.

6. The maximal allowable P-content: e.g. in laying hens 0.5% Pt and in broiler chickens 0.60 Pt (1-14 days) and 0.55% Pt (15 days to slaughter age).

7. The recommended dosages for Ronozyme P 5000 are 750 and 500 U/kg for broiler chickens and laying hens, respectively.
   a. For laying hens, a dosage of 500 U (100 g Ronozyme P 5000/ton) represents 0.09% Pret. which corresponds with 0.106 MCP-P or 0.115 DCP.H2O-P or a sparing impact of 4.8 kg MCP or 6.3 kg DCP.H2O/ton complete feed.
   b. For broiler chickens, the 1st dosage of 750 U (150 g Ronozyme P 5000/ton) represents 0.08% Pret. which corresponds with 0.09 MCP-P or 0.103 DCP.H2O-P or a sparing impact of 4.1 kg MCP or 5.7 kg DCP.H2O/ton complete feed.
   c. For broiler chickens, the 2nd dosage of 750 U represents 0.04% Pret. which corresponds with 0.045 MCP-P or 0.051 DCP.H2O-P or a sparing impact of 2.0 kg MCP or 2.8 kg DCP.H2O/ton complete feed.

In laying hen diets, the 1st dosage of phytase decreases from 100 to 90 g/ton at a MCP-price of 75 €/ton.

In broiler chicken starter diets, the 1st dosage of phytase decreases from 750 to 522 U at a MCP-price of 120 €/ton and from 522 to 202 U/ton at a MCP-price of 110 €/ton. In broiler chicken grower/finisher diets, the 1st dosage of phytase decreases from 750 to 126 U at a MCP-price of 55 €/ton. In boiler grower/finisher diets, the 2nd dosage of phytase disappears at a MCP-price of 220 €/ton.

It might be concluded that (1) only a part of the mineral P can be replaced by phytase and (2) such low prices for mineral phosphates are not expected for the coming years.

Table 1: Mineral composition for some main feedstuffs, 2 kinds of phytase and mineral phosphates.

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>Ca, %</th>
<th>Ptot.,%</th>
<th>Pinositol,%</th>
<th>Pavailable, %</th>
<th>Pretainable, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
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<td>0.33</td>
<td>0.22</td>
<td>0.12</td>
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<td>0.25</td>
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<td>0.07</td>
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<td>FF soybean</td>
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<td>0.48</td>
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<tr>
<td>Soybean meal 46% CP</td>
<td>0.27</td>
<td>0.66</td>
<td>0.43</td>
<td>0.20</td>
<td>0.28</td>
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<tr>
<td>Ronozyme P 5000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• broilers</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>• 0-750 U</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>666</td>
</tr>
<tr>
<td>• &gt;750 U</td>
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<td></td>
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<td></td>
<td>333</td>
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<tr>
<td>• layers 0-500 U</td>
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<td></td>
<td></td>
<td>1110</td>
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<td>Natuphos</td>
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</tr>
<tr>
<td>• Broilers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1000</td>
</tr>
<tr>
<td>• 0-500 U</td>
<td></td>
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<td></td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>• &gt;500 U</td>
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<td></td>
<td>1665</td>
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<tr>
<td>MCP</td>
<td>17.5</td>
<td>22.2</td>
<td>-</td>
<td>22.2</td>
<td>18.9</td>
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<tr>
<td>DCP.H2O</td>
<td>24.0</td>
<td>18.1</td>
<td>-</td>
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Figure 1: Production technology schedule for hydrated & anhydrous DCP, hydrated MCP and DFP (Bleukx and Ruyseveldt, 2008)
**Invited Speakers**

**Figure 2:** Price evolution for 2 types of feed phosphates: DCP and MCP (Bleukx and Ruyseveldt, 2008)

![Graph showing price evolution for DCP and MCP](image_url)

**Figure 3:** Price evolution for phytase Ronozyme P-5000 CT (ref. DSM)

![Graph showing price evolution for Ronozyme P-5000 CT](image_url)
**Invited Speakers**

**Figure 4:** The response in metabolisable P-% on dietary phytase dosage (U/kg)

![Graph showing P-equivalency of exogenous phytase](image)

\[ y = 47.4 + 20.0 \left( 1 - e^{-0.0027x} \right) \]

\[ R^2 = 0.98 \text{ and } MSE = 1.6 \]

**Figure 5:** The global compound feed production

![Pie chart showing global compound feed production in 2007 (mio. t)](image)

Source: FEFAC - Feed International


International Fertilizer Industry Association (IFA), *Phosphate rock statistics*.


