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Environmental aspects of feed phosphates production

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The risks resulting from the selected feed phosphates application in animal nutrition were analyzed. The results of the analyses of the fodder phosphates obtained in laboratory conditions were presented, including the toxic and disadvantageous substances with regard to their impact upon the environment.

Keywords: feed phosphates, fluorine, heavy metals.

INTRODUCTION

The increasing pollution of the natural environment with compounds harmful to human and animal health as well as to the environment indicates a requirement for periodic tests and continuous supervision. The necessity is connected with the unintentional and (industry, transport, urbanization) also the intentional side of (agriculture) human activity and its impact upon the environment with food resources of animal and plant origin as its integral part.

Apart from the nutritional value, food safety is one of the most important factors that have influence on human health. Food monitoring and the methods of its production are the primary way of enabling health quality assessment with regard to population and environment. The requirement of tracking chemical compounds residues in food results from both its toxic effects and common use in agriculture[1, 2].

According to modern ideas enclosed in various ecological programs (HACCP, Sustainable Development, Good Agricultural and Veterinary Practices) and also related to management procedures (ISO 14000 standards), it is vital to determine the concentrations of toxic substances in the product. Additionally, the influence of the product on the environment, not necessarily associated with toxicity, should be estimated. Assessment of the product life cycle is significant and is the currently required parameter describing the influence on the environment. Monitoring of fodder additives composition and their assimilation by animals enables evaluation of health safety for future consumers[3 – 6].

Phosphorus is a compound most often considered to be deficient in natural doses applied in animal nutrition. Next to calcium, phosphorus is the body's second most abundant mineral; it is present in the cell nucleus, enzymes, hormones and other proteins. Phosphorus compounds are of great importance to the osseous system and teeth development processes, and also in acid-base equilibrium regulation in organisms. A deficiency of the phosphorus results in the inhibition of growth and body mass increase. Furthermore, it causes a significant reduction in fertility in animals[7].

Feed phosphates are the dominant compounds of mineral mixtures applied to enrich natural fodders with phosphorus and calcium and to enhance their nutrition value. Using feed phosphates additives, is one of the factors for the intensification of animal production[8].

Agriculture intensification, especially animal production, results in the loss of mineral balance in the environment in many parts of the world. Phosphorus excess displays disadvantages and can even cause degradation of the environment. It is an important biologically active compound of all living organisms. It is found in the soil, natural water and atmospheric precipitation. Increasing the concentration of phosphorus in municipal and farming sewage, especially in the dung was observed. It is connected with the assimilation of phosphorus into animals, thus a form in which this chemical compound occurs in fodders[9].

FEED PHOSPHATES

The requirement of improving pasture type industrial mixes with feed phosphates is a consequence of insufficient phosphorus contents, usually of low-uptake, in fodder raw materials. Feed phosphates enhance nutritional doses with essential nutrients i.e. calcium, magnesium and micronutrients being the source of well accessible phosphorus simultaneously.

World production supplies various kinds of phosphates and the following ones are the basic products on the list:

– MPC – monocalcium phosphate containing about 21 – 22 wt. % of phosphorus, with Ca:P ratio 0.8:1,

– DCP – dicalcium phosphate containing usually 17,5 – 18 wt. % of P with Ca:P ratio 1.3:1.5,

– tricalcium phosphate containing 16 – 18 wt. % of P and Ca:P ratio 1.9:1,

– DFP – defluorinated tricalcium phosphate containing about 18 wt. % of P, 5 – 7 wt. % of Na with Ca:P ratio 1.9:1.

From the environmental as well as the economical point of view the following criteria for feed phosphates evaluation should be taken into consideration:

– The extent of the utilization of phosphorus and other macro- and micronutrients from phosphates by animals,

– Appropriate purity i.e. the concentration of fluorine, heavy metals and other compounds harmful to human and animals,

– Proper Ca:P ratio that depends on the animal species.

Fodder type calcium phosphates present 30 to 70 wt. % concentration of mineral mixes and 0.5 to 1.5 mass % of the ready-made feed depending on the formula. The influence of phosphorus on the environment should be considered not only with regard to the total concentration in phosphates or the ready-made feed but also accessibility for animals[10, 11].

Phosphorus founded in natural minerals – phosphorites and apatites, isn't relatively well accessible for animals with respect to its structure. The increase of the accessibility of phosphates has been triggered by the smelting or calcination of the phosphorus material as well as the precipitation of phosphates. Chemically pure calcium orthophosphates – dihydrophosphate, hydrophosphate and orthophosphate, pasture type mono- and dicalcium phosphates characterize the highest (about 100%) accessibility. Anhydrous phosphates are less accessible than the hydrated forms[7].

Diverse phosphates solubility causes a different level of the phosphorus utilization by animals. The solubility in the 0.4 wt. % hydrochloric acid was assumed as a measure of feed phosphate accessibility by the organisms. The value of the applied hydrochloric acid concentration is similar to that presented in digestive juices of animals. Utilization of phosphorus from phosphates in animals is determined by many factors i.e. animal species, age, physiological condition, recently and previous nutrition level of an animal etc. Phosphorus accessibility in animals is evaluated on the basis of bioassays. Measurement of relative phosphorus accessibility is based on ash content in the bones of experimental animals fed with the low-phosphates diet, supplemented with analyzed phosphates. Assuming that the relative phosphorus accessibility value of monocalcium orthophosphate is 100, the value of: dicalcium orthophosphate is 96.2 – 98.6, defluorinated (0.19 wt. % of F) superphosphate is 91.6, defluorinated (0.34 wt. % of F) superphosphate is 89.4 and defluorinated (1.58 wt. % of F) superphosphate is only 41.3 [10 – 12].

Seeds, bran and green forages primarily of legumes origin are the natural source of phosphorus in animals' nutrition process. Vegetable fodders contain significant phosphorus concentrations; however it is the low-accessible form. Over two thirds of phosphorus enclosed in the feeds of vegetable origin is found in phytic acid form or its salts (phytates). Animals, especially the monogastric ones use this kind of phosphorus, to a low extent. Phosphorus remaining in fodders is bound to phospholipids and nucleic acids. It can be also found in the inorganic compounds. Ruminants utilize about 60 – 70% of phytic phosphorus due to the microbiological degradation of the feed organic matter in the paunch and decomposition of phytic acid salts with bacterial hydrolases. Phytates are the specific source of phosphorus. Their utilization depends on the presence and activity of the phytase – enzyme involved in the liberation of phosphorus. Phytic phosphorus is used by animals to a less degree than the inorganic form due to birds' low capability of phytic substances hydrolysis. Pigs can utilize phytic phosphorus better than birds. Phytic acid becomes completely hydrolyzed in ruminants (primarily in the paunch) by the bacterial phytase. Therefore, ruminant animals use both the organic and inorganic phosphorus compounds[12 – 15].

Feeding raw materials of animal origin contain large amounts of biologically essential proteins. The abovementioned protein consists of 20 aminoacids, a lot of minerals, especially calcium and phosphorus, compounds. A significant total protein content (45 – 70 wt. %) characterizes meat bone meals. The amino acid composition balancing in meal protein is thought to be advantageous, depending on the source used in processing (soft tissues, tendons, keratins and bones participation). Generally, the fish meal protein possesses higher nutritional value than the mammal meal protein. Food safety concerns prompted a complete prohibition of applying animal proteins in animal nutrition with regard to the crisis caused by BSE (Bovine Spongiform Encephalopathy). Both the animals with the disease symptoms and those without noticeable health disorders can the virus vectors. The epidemiological research confirmed the correlation between BSE and using meat bone meals in cattle nutrition. Majority of research workers emphasize that the "high-risk materials" should be eliminated from the food chain and destroyed. Therefore, the EU's (European Union) regulations (Council Decision 200/766/EC of 29 June 2000 and 2000/418/EC of 5 December 2000) regarding the utilization of the materials of animal origin for meals were sharpened and the prohibition of their application in animals' nutrition was introduced. These prohibitions are explained by the fact that the main cattle BSE disease inducing factor are the prions contained in meat bone meals that can cause human Creutzfeldt-Jakob disease within the framework of the food chain[16 – 18].

The fluorine and heavy metals content in the fodders can be the indirect problem for the natural environment and the direct problem for the health of animals fed simultaneously. They are penetrating the feed phosphates during the modification process. The concentration of fluorine and heavy metals in the feed phosphates depends on the applied phosphorus source as well as the methods for their production. Polish Standard PN-R-64803/97 Fodders – Feed phosphates regulates fluorine concentration levels below 0.2 wt. % of F, heavy metals concentration levels of arsenic below 0.001 wt. % of As, cadmium below 0.001 wt. % of Cd, lead below 0.003 wt. % of Pb, mercury below 0.00001 wt. % of Hg.

Recently much attention has been paid to the feed phosphates obtained from the phosphorus raw materials. It is caused both by removing the phosphates of animal origin from breading and the increase of the meat products demand. Such a situation is the impulse for the exploration of the new methods of production including the experience connected with health and ecological issue.

EXPERIMENTAL

Feed phosphates were obtained in laboratory conditions from extractive phosphoric acid applied in feed phosphates production. Phosphates were prepared by triturating assumed amounts of substrates. Phosphoric acid concentrations: 55, 56 and 57 wt. % of P_2O_5 were used. For further investigations acid concentration of about 56 wt. % of P_2O_5 was selected. The extractive phosphoric acid applied in the research was produced in Gdańskie Zakłady Fosforowe. The analysis of acid composition is shown in Table 1.

The experiments in producing calcium phosphates were carried out for the following assumed compositions:

1. $CaO + H_3PO_4$ in stoichiometric ratio,
2. $CaO + H_3PO_4$ in stoichiometric ratio + 5% stoichiometric excess of $CaCO_3$ with relation to CaO,
3. $CaO + H_3PO_4$ in stoichiometric ratio + 10% stoichiometric excess of CaCO3 with relation to CaO.

Table 1. Composition of the extractactive phosphoric acid

Sample	Name of compound	Unit	Concentration
1	P_2O_5	wt. %	56.4
2	F	wt. %	0.44
3	SO_4	wt. %	0.33
4	Ca	wt. %	0.05
5	Al	wt. %	0.42
6	Fe	wt. %	0.36
7	Mg	wt. %	0.37
8	Mn	ppm	416.00
9	Zn	ppm	15.835
10	Cu	ppm	14.297
11	Cr	ppm	8.979
12	B	ppm	2.420
13	Mo	ppm	0.824
14	As	ppm	1.710
15	Cd	ppm	1.446
16	Pb	ppm	0.004
17	Hg	ppm	0.004

A model mass balance of calcium phosphates production in laboratory conditions is shown in Table 2.

ology and its value doesn't exceed 2. The concentration of toxic compounds i.e. fluorine or heavy metals that are disadvantageous both for animal nutrition and with regard to its negative influence on the environment is significantly lower than the requirements defined in Polish Standards (PN) of feed phosphates. The P_2O_5/F factor value is more than 350. High concentration of accessible phosphorus, soluble in 0.4 wt. % HCl represents about 95% of the total phosphorus. This value indicates that the obtained phosphates can be applied in the nutrition of all animal species without the necessity of using additives improving their accessibility e.g. phytases or gonadotrophins. This feature is also beneficial for the environment because almost all of phosphorus will remain in the animal's organism, decreasing its level in excrement significantly. The method of the proposed production is energy-efficient, which is of great importance nowadays. Additionally, the given system meets the primary Sustainable Development assumptions with regard to its social aspect of the improvement of supplying people with food.

Table 2. Specification of substrates and product amounts in trials of a feed phosphates production

Sample	P_2O_5 concentration in acid	Mass of substrates			Mass of product	Efficiency
		Extractive phosphoric acid	CaO	$CaCO_3$		
	[wt. %]	[g]	[g]	[g]	[g]	[%]
1	56	100	55.56	0.00	134.43	86.40
2	56	100	55.56	4.96	132.44	82.51
3	56	100	55.56	9.92	141.86	85.73

Table 3. List of analyses of a different kind of phosphorus forms in calcium phosphates obtained on the basis of extractive phosphoric acid with 56 wt. % of P_2O_5 concentration

Sample	Total phosphorus		Dissolved phosphorus in 0.4 wt. % of HCl		Dissolved phosphorus in water		Calcium	Water	pH
	P_2O_5	P	P_2O_5	P	P_2O_5	P	Ca	H_2O	
	[wt. %]	[wt. %]	[wt. %]	[wt. %]	[wt. %]	[wt. %]	[wt. %]	[wt. %]	
1	45.34	19.80	42.75	18.66	4.95	2.17	28.26	2.17	5.34
2	43.75	19.10	41.50	18.12	4.99	2.18	29.60	2.07	5.37
3	41.96	18.32	40.19	17.55	2.74	1.20	29.60	1.24	5.34

Table 4. Heavy metals and fluorine concentration in feed phosphates samples

Sample	Ca:P ratio	Fluorine	Arsenic	Cadmium	Lead	Mercury
		[wt. %] F	ppm As	ppm Cd	ppm Pb	ppm Hg
1	1.43 : 1	0.078	0.012	0.012	0.008	0.00002
2	1.55 : 1	0.074	0.015	0.012	0.004	0.00001
3	1.62 : 1	0.076	0.014	0.012	0.006	0.00001

The results of the experiments carried out for the obtained calcium phosphates by analytical methods of PN-R-64803/97 and related standards are presented in Table 3.

The results of heavy metals and fluorine concentration for the obtained calcium phosphates samples were presented in Table 4.

SUMMARY AND CONCLUSIONS

A series of investigations has shown that the obtained feed phosphates are of a high quality and meet all the environmental and food production requirements. The given phosphates serve as a good source of phosphorus and calcium for animals. The Ca:P mass ratio in all the analyzed samples is favorable to animal nutrition physi-

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