KRMIVA

AVAILABILITY OF PHOSPHORUS IN FEEDSTUFFS FOR PIGS

RASPOLOŽIVOST FOSFORA U KRMIVIMA ZA SVINJE

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SUMMARY

The paper is a review of current research on phosphorus availability from different P sources. Feedstuffs of plant origin are stressed. It can be stated that the availability of P in various feedstuffs of plant origin varies from 10 to 60%. This is due, to the proportion of phytate P and the presence of intrinsic phytase. Proportion of phytate P in total P varies widely (40-90%) in cereals, by-products and high-protein feeds. Also activity of intrinsic phytase varies, widely range (0-5000 PTU/kg). Microbial phytase supplementation improves the P availability. It is already visible at a dose of up to 500 PTU/kg. The higher dose increases, P availability, but less distinctly. In a mixture of feeds with low and high activity of intrinsic phytase and/or supplemented by commercial phytase the P availability are additives. However, in the light of current results it seems that exceeding the P availability equaling 60-70% is unrealizable even at large microbial phytase doses.

INTRODUCTION

Availability of phosphorus in feedstutfs and feed phosphates used in pig nutrition ranges very widely. The differences among phosphorus sources should be taken into account in formulation of diets providing optimal phosphorus utilization. Excessive amounts of dietary phosphorus are excreted by the animals leading, to environmental pollution, whereas a deficiency of P diminishes pig production.

The main objectives of current nutritional studies on phosphorus are as follows: to determine precisely animal requirements of phosphorus (I), to identify the main factors influencing phosphorus bioavailability (II), to develop better methods of determining phosphorus bioavailability (III), and to use the enzyme phytase to enhance phosphorus utilization from feeds of plant origin (IV).

Phosphorus is an essential component of animal body, which plays an important role in the development and maturation of the skeletal system, as well as in numerous other metabolic pathways. However, the requirements phosphorus in pigs are still not sufficiently recognized. Two basic methods are used to determine phosphorus requirements (R): the empirical method, and the factorial method. In the empirical method the requirement of P is determined on the basis of one or a few easily measured and important production traits, e.g. daily body gains, feed utilization. The factorial method is more reliable since it is based on biology and it requires measuring the retention (G) of the element

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in the body (or fetus and milk), its obligatory losses (OL), and its availability (A) as follows:

$$R = (G + OL)/A \quad (1)$$

NET REQUIREMENT

Recent studies on the chemical composition of pigs body have provided new data on net P requirements (eg. Jongbloed et al.,1991; Ketaren et al.,1993). It has been found that in the body weight range from 20 to 100 kg, over 5 g of P is deposited per kilogram weight gain (Jongbloed, 1987), and it depends on the proportion of lean body mass in the daily gain. Phosphorus deposition, expressed in more modern terms, e.g. in relation to protein deposition, is about 3.4 g per 0.1 kg protein deposited in the body (Rymarz et al., 1982), and it can differ depending on sex (Fandrejewski and Rymarz, 1986), but not on breed, as shown in Table 1.

Table 1. P and Ca content in the bodies of pigs of three breeds as a function of protein content (PROT, kg) (63 gilts from 12 to 30 weeks of age, r = 0.99, any differences are significant, data of Rymarz et al., 1982)
Tablica 1 - Sadržaj P i Ca u tijelima svinja triju pasmina kao funkcija sadržaja bjelančevina (Prot.kg) (63 nazimice od 12 do 30 tjedana starosti, r = 0.99, sve su razlike značajne, (podaci Rymarz i sur., 1982.)

Breeds - Pasmine			Within the breeds Unutar pasmina
Landrace - Landras	Large White - Velika bijela	Hampshire - Hempšir	
$P = 34.5PROT^{1.000}$	$P = 34.9PROT^{0.989}$	$P = 34.5PROT^{0.987}$	$P = 34.8PROT^{0.991}$
$Ca = 51.5PROT^{1.053}$	$Ca = 54.0PROT^{1.028}$	$Ca = 51.6PROT^{1.040}$	$Ca = 52.5PROT^{1.040}$

Phosphorus deposition declines markedly from the age of 7 months. The rate of P deposition in the body of meat pigs is somewhat slower than that of Ca (Rymarz, 1986).

OBLIGATORY LOSSES

Phosphorus digestion starts in the stomach (Lantzsch et al., 1988). Inorganic phosphates are liberated by alkaline phosphatase by hydrolysis of phospho-compounds, or by phytase from phytin complexes. Phosphorus is absorbed mainly in the small intestine (Partridge et al., 1986) but certain amount of P is absorbed in the large intestine (Drochner, 1984). It seems, however, that the proportion of P absorbed in the large intestine is little in comparison with the small intestine. At a high dietary calcium level part of the phosphate binds with Ca forming insoluble polycalcium salts which are excreted with the faces.

Endogenous phosphorus from which the alimentary tract is mostly reabsorbed. It seems, however, that about 10% of phosphorus in faces is of endogenous origin. According to Jongbloed (1987) it is about 8-10 mg (together with a small amount of metabolic P) per kilogram of body weight. However, this value is variable, since the dietary level of P varies considerably, as do feeding intensity, fibre concentration and interactions among mineral components, particularly P and Ca. Some mineral components are P antagonists, which is already evident in the digestive and absorption processes (Peo Jr: 1991). This makes the objective evaluation of P availability from particular feedstuffs or feed mixtures more difficult and complicated, since not all antagonisms between minerals are foreseeable and possible to prevent.

AVAILABILITY

The definition of phosphorus availability is generally accepted as the part of the P content in the feed that can be absorbed and fully utilized by an animal. Currently three terms describing the availability of phosphorus are used: the traditional term - apparent digestibility, and the newer terms - intestinal digestibility and availability. As can be expected, these terms are not fully equivalent. Moreover, there is controversy about the qualitative interpretation of differences and similarities between them. These difficulties result primarily from the specificity in determining the nutritional value of phosphorus, which in contrast to major organic elements, is not easy to do. Although phosphorus plays a very important role in the body, it should be emphasized that it is not the major nutrient, since major mineral elements are of secondary importance, following energy and amino acids, in the feeding of pigs. Moreover, phosphorus is an example of nutrient that is subject to mechanisms ensuring homeostasis.

Methods of determining phosphorus availability

The apparent digestibility of phosphorus is measured as the difference between the intake with feed and excretion in faces. This is the relatively easiest measurement to make, but the results may be burdened with errors, e.g. not strictly adhering be methodological rigors, especially of the depressive effects of large doses of calcium are ignored (Jongbloed, 1987). The result of measuring phytate hydrolysis may also depend on the selection of the indicator used in th indirect method (Lantzsch et al., 1988).

True digestibility of phosphorus is estimated from the difference between the P intake with feed and voided in faces with the correction for the endogenous P excretion. Apparent digestibility is lower than true digestibility because the endogenous excretion of P into faces is not accounted for. In some pig feeding systems (e.g. the German, DLG, 1992) the P availability is expressed as intestinal digestibility. According to DLG system, when calculating P availability in the small intestine, the coefficients 09, 0.6 or 0.4 are used when P is from a mineral source, a non-phytate component or a phytate component. When the digestibility of phosphorus from an unknown source is measured by the difference method, basic feedstuffs devoid of native phytin should be used, e.g. maize (Jongbloed, 1987; Jongbloed and Kemme, 1990).

The availability of P can be measured by the slope ratio method. In this method, the pigs receive a semisynthetic diet with gradually increasing P content coming from the studied feed, or from a source that provides complete assimilation of phosphorus in the body. Monosodium phosphate is usually used as the reference since l00% of it is digested, absorbed and deposited in the body. The procedure requires using diets with phosphorus contents in amounts smaller than the total P requirement at the animals, so that linear reaction to increasing the mineral component content in the diet occurs. Evaluation is conducted on young animals, which are sacrificed after about a 5-6 week test period. Specific bones are then taken from the carcass (e.g. the femur) and subjected to chemical and physical analysis, which usually includes breaking point and ash content (Cromwell, 1992). Other criteria of P available value such as level of P in serum, serum alkaline phosphatase, growth and feed utilization are, according to the opinion of many authors (Dellaert et al., 1990), less sensitive indicators. After determining partial regression coefficients, the phosphorus availability coefficient is computed, which is the quotient of the regression of two equations calculated for the experimental and control diets.

Availability of phosphorus in feedstuffs of plain origin

In feed compounds for pigs phosphorus is derived from three sources of different bio-availabilities: high (phosphates), high-medium (feedstuffs of animal origin) and low (feedstuffs of plant origin). Information on P demands of pigs from phosphates and feeds of animal origin are available in other papers presented that this conference (by Byme and by Boehme and Schultz). This paper devoted to the utilization of P from feeds of plant origin is based on the results of current research on pigs (data from over 50 published works were taken).

In feedstuffs of plant origin P occurs in association with phytates, and the variation in P availability may be partly ascribed to the presence of native enzyme phytase which cleaves to phytates and affects P availability (Jongbloed and Kemme, 1990).

Forms of phosphorus in feedstuffs of plant origin

In feeds of plant origin phosphorus occurs in two forms: in phytate - less available and nonphytate-more available form.

Phytates are organic compounds of phosphoric acid and inositol. Each molecule of phytic acid contains six atoms of phosphorus and is a typical chelating agent that makes it difficult to digest complexes when it binds divalent cations of metals or protein. Breaking up these complexes liberates the elements, particularly the P.

Phytates occur in the generative parts of plants; they are almost never found in the vegetative parts. High amounts of phytates occur in the aleurone layer of wheat, barley and oat grain, as well as in maize and pea germ. The role of phytates in both seeds and grains to store phosphorus and calcium, magnesium, zinc, iron and manganese cations.

A review of published studies on P availability in feeds of plant origin for pigs (Table 2) shows that phytate P accounts for at least one half of total P. Among cereals, the highest amount is found in triticale and maize (72-75%), while the lowest in rye and oat grain (60%). In the remaining feeds, the phytate P contents are usually more variable and lower in the seeds of legumes than in oil-plants. The nonphytate P content in cereal grain is about half that in other feeds. Therefore, when composing a diet for pigs based exclusively on feeds of plant origin, it is possible to fully satisfy their requirements for amino acids and metabolic energy, but it will always have a available phosphorus deficit, even assuming that nonphytate P utilization is complete. An exception is rapeseed meal, in which total and nonphytin P content is high (1.24 and 0.51%, respectively).

Table 2. Phosphorus content in feeds of plant origin (adapted from review of Weremko, 1997)
Tablica 2 - Sadržaj fosfora u krmivima biljnog podrijetla (prilagodjeno iz izvještaja Weremko, 1997.)

Feedstufft – Krmiva	Phosphorus (%) - Fosfor (%)		Phytate P. % of P-total Fitinski fosfor, % okupnog fosfora
	Nonphytate - Nefitinski	Phytate - Fitinski	
Maize – Kukuruz	0.08	0.23	75
Sorghum – Sirak	0.08	0.19	70
Wheat – Pšenica	0.11	0.26	70
Triticale – Tritikale	0.11	0.30	72
Barley – Ječam	0.14	0.25	63
Rye – Raž	0.14	0.21	60
Oats-zob	0.15	0.22	59
Wheatmiddlings - Pšenično stočno brašno	0.24	0.60	70
Wheat bran – Pšenične posije	0.27	0.87	76
Maize gluten – Kukuruzni gluten	0.33	0.48	59
Rice bran – Rižine posije	0.34	1.31	79
Peas - Grašak	0.23	0.24	51
Field beans – Poljski grašak	0.23	0.38	61
Lupins – Lupina	0.26	0.24	39
Cottonseed meal – Pamukova sačma	0.27	0.65	71
Peanut meal – Graškova sačma	0.27	0.37	59
Soybean meal – Sojina sačma	0.28	0.38	58
Sunflower meal – Suncokretova sačma	0.36	0.77	68
Rapeseed meal - Repičina sačma	0.51	0.73	58

Phytase

For many years it has been accepted that only the nonphytate form of phosphorus in plant feedstuffs is fully available to pigs, while phytate P is not utilized at all (NAS-NRX, 1960). Studies carried out in the last two decades, however, show that the availability of P from feeds of plant origin to monogastric animals is not directly proportional to the ratio of phytate to nonphytate P, and that there are considerable differences among feeds (Cromwell 1992). It thus becomes evident that total P digestibility in feedstuffs of plant origin depends to a considerable extent on the activity of phytase, which, among others, was shown by Pointillart et al. (1987).

The digestive tract of monogastric animals does not contain sufficient amounts of phytase, an enzyme that hydrolyses the unavailable phytate complexes to available, inorganic orthophosphates. Although phytase can be isolated from the mucosal layer of pig intestine, these are only trace amounts. Phytase is, in fact, a plant enzyme. Its activity depends on the temperature and pH (Scheuermann et al., 1988). Most phytases occurring naturally have an optimum pH between 5 and 5.6 (Reddy et al., 1982).

Phytase occurs naturally in many feeds, but in various amounts (Table 3). Among cereals, the highest phytase contents are found in rye grain (over 5000 PTU/kg), triticale (up to 2040 PTU/kg) and wheat (up to 2000 PTU/kg). Maize kernels, oats and sorghum contain little phytase (no more than 110 PTU/kg). More phytase than in cereal grains is found in wheat bran (even in excess of 5000 PTU/kg). High protein feeds, even those that are not subjected to such technological processing as are peas, contain no more than 200 PTU per kilogram. It should be stressed here that the intrinsic phytase level depends not only on the kind of feedstuff, but also on the conditions in which the feed is produced and processed.

Table 3. Phytase activity in feeds of plant origin (adapted from review of Weremko, 1997)
Tablica 3 - Aktivnost fitaze u krmivu biljnog podrijetla (prilagodjeno iz izvještaja Weremko, 1997)

Feedstuff - Krmiva		Number of trials Broj pokusa	Phytase activity (PTU/kg) Aktivnosti fitaze
Cereals - Žitarice	Maize - Kukuruz	15	≤100
	Barley - Ječam	13	200-882
	Wheat – Pšenica	74	300-2000
	Triticale – Tritikale	11	840-2039
	Rye – Raž	4	1782-5130
	Oats – Zob	6	0-108
	Sorghum – Sirak	5	0-76
By products Nuzproizvodi	Maize feed gluten – Kukuruzni gluten	9	0-177
	Wheat bran – Pšenične posije	7	600-5208
	Wheat middling – Pšenično stočno brašno	5	2825-5042
High-protein Visoke bjelančevinaste	Peas – Grašak	11	36-183
	Soybean meal – Sojina sačma	17	0-120
	Rapeseed meal – Repičina sačma	10	trace - tragovi
	Sunfiower meal – Suncokretova sačma	12	0-185
	Peanut meal – Oraškova sačma	4	trace - tragovi

Phytase is inactivated during thermal processing, such as drying, granulating or extracting at temperatures exceeding 80^0 C (Nair et al., 1991). A good example of this are the results of Jongbloed and Kemme's experiments (1990), in which the high temperatures used considerably reduced P digestibility in the studied feeds, e.g. in wheat from 50 to 27% (Table 4). Conversely, the addition of microbial phytase doses of 750-1000 PTU/kg of feed devoid of native phytase (or with only trace amounts) restored phosphorus digestibility.

Table 4. Effect of intrinsic and microbial phytase on the digestibility of phosphorus (%) in some feeds
Tablica 4. Učinak prirodne i mikrobne fitaze na probavljivost fosfora (%) u nekim krmivima

Feed - Krmiva	Without intrinsic phytase Bez prirodne fitaze	With intrinsic phytase S prirodnom fitazom	With supplemented by microbial phytase S dodanom mikrobnom fitazom
Wheat mildlings - Pšenično stočno brašno	19	33	-
Wheat – Pšenica	27	50	-
Wheat – Pšenica	-	62	74 (750)
Maize – Kukuruz	18 (100)	-	56 (750)
Maize + SBM - Kukuruz +sojina sačma	13 (50)	-	43 (750)
	29	-	64 (1000)

Phytase activity is shown in brackets (PTU/kg) - U zagradama označena aktivnost fitaze (PTU/kg)
Source - Izvor: Jongbloed and Kemme (1990), Pallauf et al. (1992), Simons et al. (1990)

The advantageous effect of phytase on phosphorus digestibility in feeds of plant origin was recognized some time ago. This gave rise to the idea of adding exogenous phytase to feeds for monogastric animals, especially to feeds that do not have a naturally occurring enzyme.

Nelson et al., (1968) were the first to use microbial phytase obtained from Aspergillus ficuum. From that time it has been intensively studied, especially in recent years. Phytase is currently readily available commercially; the best known preparations are made by BASF, Degusa, Alltech, Novo-Nordisk and Alko Ltd., Rajamäki. It is used in various doses depending on the feed.

The effectiveness of phytase rises along a dose-dependent curve, as can be seen from the data presented in Table 5. A distinct improvement in P digestibility (from 10 to 20%) is already visible a dose of up to 500 PTU/kg. Increasing the dose increases P digestibility further (to 1000 PTU/kg), but less distinctly. In our own studies (Weremko, 1997), exceeding the 1000 PTU//kg in a mixture composed of rapeseed meal and cereals did not further improve digestibility. In light of the current results it can be said that even large phytase doses, exceeding P availability equals to 60-70% is highly unlikely. It should be added that digesting phytate by phytase, as any other enzymatic process, requires certain conditions, mainly time. Thus soaking the feed in warm water before feeding is a way to increase P availability by 5-10%, and has been demonstrated experimentally (Näsi et al., 1995). It is difficult to assume, however, that this way of preparing feeds will become prevalent in practice.

Moreover, it has been reported that microbial phytase enhances the availability of other macro-elements (eg., Pallauf et al., 1992) as well as of protein (Ketaren et al., 1993; Mroz et al., 1993). Thus, diet supplementation with phytase allows for a decrease in supplementary, inorganic P, and it leads to better performance of animals.

Table 5. Effect of microbial phytase addition to feeds on the apparent digestibility of phosphorus (%)
Tablica 5 - Učinak dodatka mikrobne fitaze u krmiva na stvarnu probavljivost fosfora (%)

Feedstuff - Krmiva	PTU/kg	Apparent digestibility of P Stvarna probavljivost fosfora	Author's - Autori
Tapioca + maize + barley + SBM +sunflower meal	0	33	
Tapioka + kukuruz + ječam + sojina sačma +	300	47	Mroz et al. (1993)
suncokretova sačma	600	54	
Field beans + wheat + peas + barley	0	48	
Grah + pšenica + grašak + ječam	350	67	Pallauf et al .(1993)
	700	71	
Wheat + barley + SBM + wheat bran	0	54	
Pšenica + ječam + sojina sačma + pšenične posije	350	66	Pallauf et al. (1994)
	700	71	
	0	15	
Maize + dehulled SBM	250	20	Cromwell et al. (1993)
Kukuruz + oljuštena sojina sačma	500	27	
	1000	40	
	0	29	
Maize- + SBM - Kukuruz + sojina sačma	500	55	Pallauf et al. (1992)
	1000	64	
	0	33	
Cereals + RSM	1000	47	Weremko (1997)
Žitarice + repičina sačma	1250	46	
	1500	48	

Availability of P as a common effect of several factors

The presented review of the literature shows that there are several ways in which the digestibility of plant P can be improved. The most important are (1) mixing appropriate combinations of feedstuffs, in which one or more of the components is characterized by high native phytase activity (Helander et al., 1994), (2) supplement feeds with a microbial phytase additive (Simons et al., 1990) or (3), use both of these methods simultaneously. The availability of P in feeds of plant origin also depends on the composition of P compounds. In effect, it depends on at least several factors, and the importance of each of them individually is not known well enough.

An attempt to rank them by importance was undertaken in this review. Table 6 presents a compilation of the results of 9 experiments in which both forms of P (phytate and nonphytate), as well as intrinsic phytase activity were evaluated in plant feeds. Exogenous phytase at doses of 500-1500 PTU/kg was added to some feeds.

Table 6. Apparent digestibility of phosphorus in relation to the phytate and phytase activity
Tablica 6 - Stvarna probavljivost fosfora u odnosu na aktivnost fitata i fitaze

Feedstuff Krmiva	P-total Ukupni	P-phytate Fitinski	Phytase activity Aktivnost fitaze PTU/kg		Digestibility Probavljivost (%)	Author's Autori
			native prirodne	added dodane		
Maize – Kukuruz	2.8	2.3	<100	-	18	Düngelhoef et al. (1994)
	2.8	2.3	<100	750	56	Pointillart (1984)
	2.8	2.2	20	-	29	Weremko (1997)
	3.3	2.5	56	-	16	
Wheat – Pšenica	4.2	3.1	440	-	62	Düngelhoef et al. (1994)
	4.2	3.1	440	750	74	Düngelhoef et al. (1994)
	3.2	1.6	664	-	40	Barrier et al. (1996)
	3.0	1.9	438	-	40	Barrier et al. (1996)
	1.9	0.9	520	-	42	Pointillart (1984)
	2.7	2.0	470	-	39	Pointillart (1984)
	3.6	2.4	160	-	46	Weremko (1997)
	3.6	2.3	936	-	38	
Barley – Ječam	4.4	2.8	550	-	45	Rodhutscord et al (1996)
	4.4	2.8	550	750	66	Rodhutscord et al (1996)
	4.1	2.6	310	-	38	Berk and Schulz (1993)
	4.2	2.6	750	-	37	Weremko (1997)
Triticale – Tritikale	4.2	3.2	540	-	52	Düngelhoef et al. (1994)
	4.2	3.2	540	750	67	Düngelhoef et al. (1994)
	5.40	3.66	1475	-	55	Berk and Schulz (1993)
	3.60	2.50	1395	-	40	Weremko (1997)
SBM – Sojina sačma	7.2	4.7	-	-	31	Rodhutscord et al. (1996)
	7.2	4.7	-	750	73	Rodhutscord et al. (1996)
	6.8	4.7	-	-	26	Berk and Schulz (1993)
Maize + SBM Kukuruz + sojina sačma	3.3	2.6	<50	-	13	Jongbloed et al. (1992)
	3.3	2.6	<50	1500	43	Jongbloed et al. (1992)
	3.3	2.7	-	-	20	Simons et al. (1990)
	3.3	2.7	-	1000	46	Simons et al. (1990)
	4.4	3.5	-	-	16	Näsi (1990)
	4.4	3.5	-	500	40	

The average count of total P was 4.1 g/kg feed, of which 71% was phytate P. Apparent digestibility was 45 ± 19%. A preliminary analysis of the data in Table 8 already shows that P digestibility is influenced by several factors. This was confirmed by multiple regression analysis, which had the following form:

$$Y = 0.10 * X_1 + 0.90 * X_2 + 0.76 * X_3 + 1.08 * x_4, R = 0.92 \quad (2)$$

where:

Y - digestible P, g/kg - probavljivi P g/kg

X_1 - phitate P content, g/kg
- sadržaj fitinskog P., g/kg

X_2 - nonphytate P content, g/kg
- sadržaj nefitinskog P., g/kg

X_3 - native phytase activity (in thousands of units)
- prirodna aktivnost fitaze (u tisućama jedinica)

X_4 - added microbial phytase (in thousands of units)
- dodana mikrobijelna fitaza (u tisućama jedinica)

This equation (2) shows that the digestibility of phytate P is about 10%, which is in agreement with the studies by Cromwell (1990) on the availability of isolated phytate P, while the coefficient 0.89 for the nonphytate P indicates its high digestibility (89%), which remains in agreement with other authors (Vipermann et al., 1974). These calculations are also corroborated by the advantageous effect of phytase on P digestibility: it is slightly higher in the case of microbial phytase than the native form of the enzyme. In the analyzed material, it was possible to attribute 30% of the digested nutrient in the diet to the microbial phytase (at an average level of 620 PTU/kg). Windisch et al. (1994) also reported that when phytase was added to the diet in amounts of 1000 PTU/kg, the amount of added mineral phosphorus could be reduced by 1 g/kg of feed.

The Polish studies

Although numerous works on P utilization in pig nutrition have been done in Poland (Minerals, 1994), only a few concerned the phytase supplementation to diet. Except for additives made by Novo-Nordisk, phytase is currently not available commercially. However, other preparations as of the BASF and Alltech were also used in the study. It was found in digestive trials, that above phytases increased the digestibility at a similar rate, but differed in respect to a response in digestibility of other nutrients. Recently investigations have been focused on improvement in availability of P from rapeseed oil meal (RSM), which is a valuable source of protein for pig nutrition in Poland. In contrast to other high-protein feeds of plant origin, the RSM contains large amounts of P (twice more than soybean meal). It seems, that diets composed of rapeseed meal as the only source of high-protein do not require any inorganic P supplementation, as long as microbial phytase is added to the diet. In one from a series of experiments performed by the Kielanowski Institute, pigs from 25 to 70 kg LW were fed isoenergetic and isoprotein P-, P+ or C diets composed of rapeseed meal (25%) and cereals (barley + wheat) and premix without P content (Table 7). The P- diet (basal) was a P-digestible deficient (0.21%). The P+ diet was supplemented with 1000 PTU phytase/kg (Natuphos 500 L), while the C diet was completed with 0.7% dicalcium phosphate according to requirements for growing pigs. The pigs were slaughtered at 70 kg and their chemical body composition was estimated. Digestibility (apparent) of P in the P- diet was 34.7%. Phytase supplementation improved the digestibility to 48.7% (P<0.01) and increased the P-digestible content to 0.29%. Inorganic supplementation also increased P- digestible content to 0.29%, but with less extension in digestibility rate (up to 41.2%). All animals used in the study were healthy and no pig showed signs of leg weakness or other locomotory disease. Treatments had no significant influence on the growth performance and chemical body components, except ash and P for content. Pigs fed P-deficient diet had significantly less ash and P in the body. It can be concluded that it is not necessary to include inorganic P into phytate-rich diets for fatteners, when they are supplemented with microbial phytase.

Table 7. Effects of supplemental P or phytase on performance and chemical body composition of growing pigs (n = 30, cereals +RSM (25%). Data of the Kielanowski Institute

Tablica 7 - Učinak dodatka P ili fitaze na proizvodna svojstva i kemijski sastav tijela svinja u rastu (n = 30, žitarice + Repičina sačma (25%). Podaci iz instituta Kielanowski

P of plant origin, % - P u biljci	85	100	100	
Phytase added, PTU/kg – Dodana fitaza	-	-	+	
P digestibility., % - Probavljivost	41	35	49	SEM
Content of P-dig., % - Sadržaj probavljivog fosfora	2.9	2.1	2.9	
Group – Skupina	C	P-	P+	
Performance – Proizvodna svojstva				
ADG (25-70 kg), g – Prosječni dnevni prirasti	753	757	772	11.1
FCR, kg/kg – Konverzija hrane	2.77	2.80	2.70	0.03
Chemical composition g/kg – Kemijski sastav				
Empty body weight – Težina tijela	65.5	65.1	65.6	0.21
Protein – Bjelančevine	158	156	157	1.12
Ash – Pepeo	28.6[a]	26.9[b]	29.0[a]	0.28
Phosphorus – Fosfor	5.3[a]	5.0[b]	5.3[a]	0.06
Water/protein ratio – Odnos voda/bjelančevine	4.12	4.06	4.09	0.02
Fat/protein ratio – Odnos mast/bjelančevine	1.02	1.18	1.07	0.04

a, b – $P < 0.05$

Recent Polish recommendation for macro-elements are shown in Table 8. Phosphorus for pigs is expressed in both forms: total and digestible (apparent).

Table 8. Polish standards (1993) for macro-elements in pigs (g/kg)

Tablica 8 - Poljski standardi (1993.) za makro elemente u svinja (g/kg)

Growing pigs Svinje u porastu	Ca	P- total	P- digestible	Na
-10	8-10	7.0	3.5	1.5
10-30	8-9	6.5	3.0	1.5
30-70	7-8	5.5	2.5	1.2
70-110	5-7	4.0	1.8	1.0
30-110	6-7	5.0	2.2	1.2
Sows:				
pregnancy - brede krmače	7-8	4.5	2.0	1.5
lactation - krmače dojne	8-9	6.0	2.3	2.0

CONCLUSIONS

Availability of phosphorus in feed compounds for pigs is mostly depends on its digestibility in feedstuffs of plant origin. Both intrinsic plant and microbial phytase improve the availability of P in such feedstuffs. In a mixture of feeds with low and high activity of intrinsic phytase and/or supplemented with commercial phytase the P availability are additives. However, it seems that exceeding the P availability equaling 60-70% is unrealizable even at large microbial phytase doses.

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SAŽETAK

U članku se izlaže pregled aktualnih istraživanja raspoloživosti fosfora iz raznih izvora. Istaknuta su krmiva biljnog podrijetla. Može se reći da raspoloživost P u raznim krmivima biljnog podrijetla varira od 10 do 60%. Uzrok tome je omjer fitata P i postojanje prirodne fitaze. Omjer fitata P u ukupnom P veoma varira (40-90% u žitaricama, nusproizvodima i visoko bjelančevinastoj hrani /hrani s mnogo bjelančevina). Isto tako aktivnost prirodne fitaze veoma varira (0-5000 PTU/kg). Dodavanje mikrobne fitaze poboljšava raspoloživost P. To se već vidi kod doze do 500-PTU/kg. Veća doza povećava raspoloživost P, ali manje izrazito. U krmnoj smjesi niske i visoke aktivnosti prirodne fitaze i/ili dodatkom komercijalne fitaze raspoloživost P su aditivi. Međutim, s obzirom na aktualne rezultate čini se da je prekoračenje raspoloživosti P 60-70% neostvarivo čak i u velikim dozama mikrobne fitaze.