

# Phosphates<sup>1</sup> in our foods: benefits and risks

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## 1. Summary

Phosphorus-containing food additives are authorized substances widely used in the food industry, the use of which has many technological advantages. For a long time, these compounds had been regarded as practically harmless, however, recently more and more research results warn us that their extensive use and increasing consumption increases the risk of certain civilization hazards, such as cardiovascular diseases and osteoporosis at the population level. This publication clarifies the authorization process of these additives and the role of phosphates, presents some results of related research and formulates recommendations to prevent potential risks.

## 2. Introduction

Towards the end of 2017, the media threshold was reached by a news article of professional background about the possible ban on the use of phosphates in certain foods. As usual, news headlines were exaggerated, sensationalist and easy to misunderstand (e.g., „EP would kill doner kebab”; „Kebab is banned in the European Union”, „Doner discrimination taking place”). However, only a few journalists took the trouble to uncover the credible professional background. The legal dispute was not about prohibiting the use of phosphates in kebab, but about its possible authorization. The reason for this was that the issue had been omitted when drafting the relevant EU regulation, therefore, the use of phosphates in this product was not lawful. A professional debate emerged, because more and more scientific evidence suggests that the increasing use of phosphorus-containing additives may have a negative impact on health at the global level, and so further expansion of the product range is not desirable.

## 3. Occurrence and significance of phosphorus

In the form of its various compounds, phosphorus is one of the elements mined and used in the largest quantities on Earth. Phosphorus can be found in the body of practically all living organisms in varying amounts, in the form of organic compounds.

Attention has already been drawn by many people to the dangers of intensive phosphorus mining and to the exhaustion of phosphorus sources. In addition to its multi-purpose industrial use (e.g., detergent production, the manufacture of matches), it is also used in significant quantities in agriculture as a fertilizer, and as an additive in the food industry. By entering our natural waters, the phosphorus used has an unfavorable environmental impact by contributing to the eutrophication of water bodies.

### 3.1. The role of phosphorus in living organisms

Phosphorus is a mineral that is indispensable for the functioning of our bodies, playing a role mainly in the formation of bones and teeth. In addition, its presence in adequate amounts also contributes to the smooth operation of countless physiological processes, thus it plays an important role in protein, carbohydrate and fat metabolism, energy storage and signal transmission [1].

It is also indispensable in the structure of heritable material (DNA, RNA), in cell wall construction, in the energy cycle of cells, in regulation and in maintaining acid-base balance. 85% of the body's phosphorus content is found in the bones and teeth, 14% is found in the soft tissues (muscle, liver, kidney), and only 1% circulates in the extracellular fluid.

<sup>1</sup> By phosphates, in this publication, all of the authorized phosphorus-containing additives (phosphoric acid and certain mono-, di-, tri- and polyphosphates: E-338-E341; 343; 450-452) are meant.

\* National Food Chain Safety Office (retired)

According to the few available human studies, 55 to 80% of the phosphorus in the body is absorbed from the intestines, through active or passive diffusion. The degree of absorption depends on the amount of phosphorus in the food, its chemical structure (organic or inorganic), its origin (animal or plant), and also on the other components in the diet. Excretion mainly happens with the urine and the faeces [2].

### 3.2. The effect of low and high phosphorus intake on the body

In the case of a normal diet, our foods contain enough phosphorus to cover the body's phosphate needs. Abnormally low blood phosphorus levels (below 0.8 mmol/l) practically cannot be observed as a result of low dietary phosphorus intake, only in the case of a severe metabolic disorder. Symptoms of low phosphorus levels (hypophosphataemia) include muscle weakness, bone loss, growth retardation, inadequate development of teeth, rickets and osteomalacia. High phosphorus levels in healthy organisms occur only rarely, even in the case of a significant dietary phosphorus intake, it can mainly be expected in patients with impaired renal function. Permanently high levels of phosphorus (hyperphosphataemia) have led to secondary hyperparathyroidism in animal studies, and was accompanied by skeletal deformities and calcium phosphate calcification in the soft tissues. Such symptoms in humans were only found in patients with end-stage renal disease.

However, recent research has shown that a high phosphorus intake will also have a negative effect on the body even when a significant increase in blood phosphorus levels cannot be detected at the same time [3]. The reason for this is that, for organ damage, mainly the hormonal reaction triggered by the high phosphorus intake to restore homeostasis are responsible.

### 3.3. Hormonal regulation of phosphorus metabolism

Phosphorus homeostasis is closely related to that of calcium and is under a complex hormonal regulation. Its cycle in the bones, intestines and kidneys, its absorption and excretion is controlled primarily by the parathyroid hormone (PTH), vitamin D/hormone (1,25(OH)<sub>2</sub>D), and the not long known Fibroblast Growth Factor 23 (FGF 23). For the entire body, the ration of calcium to phosphorus has to be between 1.4 and 1.9 [10], and the internal regulation seeks to achieve this balance at any cost, even if it is necessary to mobilize calcium from the bones. Thus, during the assessment of the effects, in addition to phosphorus intake, calcium intake has to be taken into consideration as well.

A high phosphorus intake triggers the elimination of excess phosphorus, hormonal reactions aimed at restoring blood phosphorus levels, primarily the increased production of FGF 23, which leads to the hardening of the wall of blood vessels, atherosclerosis and the hypertrophy of the left ventricle in the case of a prolonged, excessive consumption of phosphorus, contributing to cardiovascular disease and increasing the risk of death [4]. FGF 23 also has a role in the inhibition of the so-called Klotho<sup>2</sup> gene, which is related to premature aging. The process also has an adverse effect on the production of vitamin D and PTH. Increased blood phosphorus levels cannot always be detected because of rapid excretion and the diurnal rhythm of phosphorus (phosphorus levels are lowest in the early morning hours).

### 3.4. Sources of phosphorus intake

The phosphorus content of the foods consumed comes from their original, natural phosphorus content and from the phosphorus-containing additives added to foodstuffs. Some drugs may also have a significant phosphorus content, which can increase phosphorus levels on an individual level, depending on the therapy. There is, however, a significant difference between the absorption of phosphorus of natural origin and that of artificial additives.

#### 3.4.1. Natural phosphorus content of foods

Foods with a high phosphorus content are primarily of animal origin. Milk and dairy products, meats and fish contribute to the intake to the greatest extent, followed by cereals and legumes, then fruits and vegetables. The phosphorus content of foods is not constant, and may be influenced by several factors. Naturally occurring organic phosphorus compounds cannot be fully utilized by the body, according to studies, 40 to 60% of them are eliminated with the faeces without absorption. Absorption is a slow, prolonged process, because it is a function of an enzymatic degradation, during which phosphorus is released from the bond with carbon. Phosphorus of animal origin is utilized to a greater extent, while phosphorus of plant origin is utilized less efficiently. The reason for this is that the phosphorus found in plants is present in the form of phytates, from which it cannot be absorbed in the absence of phytase enzymes [6].

#### 3.4.2. Phosphorus-containing additives

In addition to the natural phosphorus content of foods, the intake is increased by the phosphorus-containing additives used in processed foods. Phosphorus from food additives is absorbed easily and well, virtually in 100%, because it is already present in an inorganic, ionized form, as opposed to the organic phosphorus compounds found in foods [7].

<sup>2</sup> Clotho is one of the mythological Fates who spin, draw out and cut the thread of life

The use of phosphorus-containing additives is extremely widespread in the food industry because of their favorable technological properties. They are used in a wide variety of foods in large, and ever increasing quantities. Their use is authorized in a variety of products, in almost all food categories.

#### 4. Estimation of phosphorus intake with food

To estimate phosphorus intake with food, in the absence of more accurate measurement results, data from food consumption surveys can be used. During these surveys, a statistically representative fraction of the population is interviewed, total food consumption data for the number of days specified by the method are recorded, and based on this, using different software, the composition, as well as the macro- and micronutrient content of the diet is calculated.

##### 4.1. Uncertainty of phosphorus intake estimation

Food consumption surveys are burdened with a number of uncertainties [8]. Inaccuracies may arise from the recollections of the respondents and, consequently, from the subsequent determination of the quantity, type and composition of the food consumed. For the estimation, food composition databases from different sources are used, which are usually not based on up-to-date information and, with a high probability, they do not, or not in all cases, take micronutrients from additives and dietary supplements into account.

The use of phosphorus-containing additives increases year by year, however, changes can only be followed by the software used for the surveys with a certain delay. Thus, phosphorus intake data from food consumption surveys can only be considered as indicative [9]. It is likely that these data indicate an underestimated phosphorus intake, as most of them are based on the calculated natural phosphorus content of foods, rather than on actual measurements that take into account the phosphorus content entering the body with the additives [10]. It is estimated that food additives increase the intake significantly, and the extra intake in the USA was estimated to be between 300 and 1,000 mg/day (on average, 500 mg/day) already twenty years ago [11]. The diet of the population has changed significantly over the last decades in Hungary as well [12], which should be taken into account in risk assessments based on food consumption surveys.

##### 4.2. Optimal and actual phosphorus intake

According to the European Food Safety Authority (EFSA), the adequate intake (AI) of phosphorus is 160 mg/day for infants and 250 to 640 mg/day for children. The AI value for adults is 550 mg/day, which can be applied to pregnant and lactating women as well [10].

According to the analysis of food consumption data from 13 EU countries, the average phosphorus intake is 600-1,600 mg/day, depending on the age, 1,000-1,800 mg/day for adults [10], compared to the 550 mg/day value considered to be adequate.

According to the food consumption survey conducted by MÉBIH (the Hungarian Food Safety Office, the predecessor of NÉBIH) in 2009, the average phosphorus intake of the Hungarian population was 1,300 mg/day, while for women the value was 1,000 mg/day. Data of the representative survey clearly show that the average phosphorus intake exceeds the need significantly. In addition, the calcium intake of the population is lower than what is needed, which further enhances the adverse effects of the high phosphorus intake [13].

#### 5. Phosphorus-containing food additives

Phosphorus-containing additives are used by the food industry in a wide range of ready-to-eat or prepared foods, with a fairly high frequency and quantity. The reason for the widespread use of phosphates is their food technological usefulness and multipurpose applicability. The roles of phosphorus-containing additives may include, but not limited to: emulsifying salt, emulsifying agent, chelating agent, flour treatment agent, wetting agent, acidity regulator, stabilizer, thickener, hardening agent, raising agent. Examples of their beneficial properties in foods are shown in **Table 1**.

##### 5.1. Authorization of additives

The use of additives is subject to authorization. During the authorization process, it is determined in what kind of products and in what quantities the given additive can be used. In the case where the total intake of the given substance from all the products consumed does not exceed the acceptable daily intake (including natural and intentionally added substances), then it does not endanger health.

###### 5.1.1. Determination of the acceptable daily intake values of additives

In order to determine the applicable additive limit value for certain products, what is needed first and foremost is to know the acceptable daily intake (ADI) of the substance in question, or its tolerable daily intake (TDI) in case of a substance that seems to be more risky or is less investigated. ADI/TDI values mean that this amount can be consumed daily, from all sources to be considered, throughout our entire life, without it causing a health hazard. The ADI/TDI value is determined by risk assessment methods.

The fact that these chemical substances are added to foods deliberately and, therefore, it is certain that they will enter our bodies regularly means a particularly great responsibility during the risk

assessment of additives. To determine the ADI/TDI value, available scientific experimental results are reviewed by the relevant risk assessment institutions (e.g., JECFA<sup>3</sup>, EFSA). The essence of this process is that the least amount causing adverse effect on the most sensitive warm-blooded species is taken, it is divided by a safety factor, and this fraction (usually one hundredth) of the amount exerting an effect is considered to be the ADI or TDI for humans.

In the case of phosphorus, the maximum tolerable daily intake (MTDI) was determined in 1990 as 70 mg/kg body weight) by the predecessor of EFSA, the Scientific Committee of Food (SCF). This estimate was based on JECFA's risk assessment carried out in 1982 [14].

The safety assessment of compounds of concern has to be repeated from time to time in the light of new scientific findings. Phosphates are being reevaluated currently by EFSA. In connection with this reevaluation, a public call was announced in June 2017, requesting current toxicological and analytical results, as well as technological data from stakeholders (e.g., governments, relevant organizations, universities, research institutes, food enterprises) [15].

### 5.1.2. Determination of the legal limit values for the individual food groups

Since the ADI/TDI value refers to the total intake of the substance in question from all sources, it is necessary to assess the extent to which the population consumes foods that are expected to use the additive in question, taking into account the natural phosphorus content of foods and the technologically justified phosphate concentration. Following this, limit values for the individual food groups are proposed, the finalization of which is the task of so-called risk managers (decision makers, lawmakers), as here several different interests (industrial, commercial) has to/may be taken into consideration. From time to time, the regulation has to be reviewed, because the consumption of the foodstuffs concerned may increase or food producers may want to apply the given additive in new food groups [16]. This is exactly what happens with phosphates today: on the one hand, consumption has increased considerably, and on the other hand, they want to have the use of phosphates authorized for other foodstuffs (in this case kebab, the official definition of which is „frozen vertical meat spits“).

### 5.1.3. Current limit values in the European Union

According to the relevant EU food regulation [17], phosphorus-containing additives are authorized in practically all food categories, and within these in

many products, in relatively large quantities. The names and E numbers of phosphorus-containing additives authorized for use in foods are listed in **Table 2**.

A non-exhaustive list of examples for the use of phosphates as food industry additives is found in **Table 3**. This also indicates that the presence of these additives can be expected in many different products and in significant quantities. Of course, the fact that use is permitted does not mean that the additive is actually used in the given product. Information about this is found on the food label.

## 6. Labeling, monitoring

Both in terms of labeling and monitoring, foodstuffs are strictly regulated in the European Union, including Hungary. Ideally, available monitoring capacities are utilized by taking into account the risks.

### 6.1. Labeling regulations

European Union regulation requires that food additives are listed on the packaging of products, either by their E numbers or by textual phrasing (by specifying their function and chemical name). However, in the case of unpackaged foods, this information is not available, and so one cannot know what additives are contained in, for example, bakery products, breads, or cold cuts or cheese bought unpackaged from the deli counter.

As far as the amount of additives used is concerned, there is no way for consumers to obtain information, only the trust in the food entrepreneur/importer remains, and the belief that compliance with the rules is monitored by the authorities.

### 6.2. Authority monitoring of food additives

Authority monitoring of the proper dosage of phosphorus-containing additives is possible through laboratory tests as well as, in the case of a domestic producer, by comparing the manufacturing technology and the product sheet. Among other things, interpretation of the laboratory test results is made difficult by the fact that it has to be decided to what extent that measured amount of phosphorus is derived from the additive and the natural phosphorus content of the food raw material in question. Previously, taking into account the presumed relative safety of phosphorus, authority monitoring and laboratory analysis of phosphorus-containing additives was unlikely to be among the priorities of food monitoring.

## 7. Possible risks of increased phosphorus intake

<sup>3</sup> **JECFA** (The Joint FAO/WHO Expert Committee on Food Additives), the scientific advisory board on food additives and chemical food safety, jointly maintained and operated by the UN Food and Agricultural Organization (FAO) and the World Health Organization (WHO)

As for any substance that enters the body, it is true for phosphorus as well that if the intake exceeds a certain value adverse effects may occur. These can be compensated by a healthy body for a while, however, organs with impaired function can protect themselves less against harm.

### 7.1. Health risk of phosphorus intake in kidney patients

In healthy people, excess phosphorus is excreted through the kidneys. However, in the case of a reduced renal function, this process is impaired, so patients with kidney disease need to pay close attention to avoiding and preventing high phosphorus levels.

It has long been known that persistently high serum phosphorus levels may lead to hyperparathyroidism, skeletal deformities, soft tissue calcification, cardiovascular problems or atherosclerosis, and significantly increase the risk of mortality. Therefore, dietary advisers to kidney patients place great emphasis on keeping dietary phosphorus intake as low as possible, and especially on avoiding foods that contain phosphorus-containing additives. In severe kidney patients, to reduce harmful effects, phosphorus-binding drugs are also used. Dietary advice given to kidney patients has also been presented in a pyramidal form [18], which shows that the foods to be avoided the most are the ones that contain phosphorus-containing additives (**Figure 1**). However, avoiding the consumption of such foods is not an easy task at present, because a significant portion of commercially available foodstuffs contains phosphates.

One would think, and this is backed by the practice, that food regulation and food production do not have to take into account the needs of people with specific health problems, other than adhering to mandatory labeling regulations. However, the number of kidney patients is significant worldwide and, unfortunately, it is not a well-known fact that kidney disease can be considered an endemic in Hungary as well. According to the data of the National Kidney Program, there are nearly one million chronic kidney patients in Hungary today, and there are roughly fifteen thousand people who are either kept alive by dialysis or are living with a transplanted kidney. The number of people receiving renal replacement therapy increases by 6% annually [19]. This ratio represents a large portion of the population to which food regulation organizations and the food industry should pay attention, especially to yet undiagnosed potential patients who are not aware of the disadvantages of excessive phosphorus intake, as well as to the fact that there are very few processed foods that exist in a version free of added phosphate.

### 7.2. Effect of excess phosphorus intake on the average population

It has long been known that there is a correlation between the mortality of renal patients and an increase in phosphate levels, but it only received greater publicity in recent years that excessive phosphate intake increases the risk of cardiovascular disease in healthy people as well [20].

In 2013, the research team of the FDA, under the leadership of Mona S. Calvo, summarized the health effects of the increased phosphorus content of foodstuffs in a comprehensive publication [21]. In it they highlight that an elevated phosphorus intake will disrupt the hormonal homeostasis responsible for the regulation of calcium and phosphorus in healthy people as well, it damages the tissues, contributes to the development of cardiovascular disease, atherosclerosis, vascular damage, kidney damage, bone loss, osteoporosis and the speeding up of the aging process.

Increased phosphorus intake may also pose a risk to the healthy state of the bones [22]. For example, in a study conducted among adolescents, there was a significant correlation between the frequency of bone fractures and the consumption of phosphoric acid containing soft drinks [23].

It can be assumed that the increasing spread of phosphorus-containing additives in processed foods could have a negative effect on public health on a general population level. This is true even if the elevated phosphorus intake does not, or not always manifest itself in elevated serum phosphorus levels, thanks to the still intact renal function, since damages are triggered by the substances having a hormonal effect which are activated in order to maintain phosphorus balance.

German researchers, under the leadership of Ebenhard Ritz, after reviewing available research results and publications, have also come to the conclusion that phosphorus-containing additives that enter our bodies in ever increasing amounts contribute at the population level to cardiovascular mortality and are a cause for concern [24]. Especially those belong to high risk groups who consume large amounts of processed foods and fast foods.

### 7.3. Regulatory initiatives in the European Union

In response to all these findings and publications, the European Commission has asked the independent European Food Safety Authority (EFSA) to conduct a scientific analysis to assess whether there is a correlation between high phosphate additive consumption and the elevated cardiovascular risk of the average population [25].

In its reply, EFSA acknowledged the facts, however, it pointed out that it does not yet see the cause and effect relationship as proven, and it considers further studies necessary to determine whether the adverse effect is due solely to phosphorus-containing additives or to a diet that contains larger amounts of phosphorus-containing foods. It also indicated that it considers a priority task the reevaluation of phosphorus-containing additives, which will take place before December 31, 2018 [26].

Research and professional debates have not yet come to a standstill, and new studies are emerging constantly. In 2017, a 116-page comprehensive review of the 110 original communications published on the topic was issued by the Institute of Food Technologists [27]. It not only reviews the methods and results, but also the uncertainty factors that make an exact judgment difficult.

## 8. Conclusions

Conclusions that can be drawn from previous research, publications and experiences:

- In renal patients, high phosphate intake damages the heart, the vascular system and the bones, and increases the risk of premature death. In Hungary, nearly one million kidney patients are affected.
- More and more researchers think that the adverse effects of high phosphorus intake occur in the healthy population as well, even if elevated serum phosphorus levels cannot be detected.
- The body strives to maintain balanced calcium and phosphorus levels. There is an increased risk of health damage in the case of low calcium intake. In Hungary, the dietary phosphorus intake of the population is higher than necessary, while the calcium intake is lower than necessary.
- The use of phosphorus-containing additives and the consumption of foodstuffs made using these is significant and shows an upward trend.
- Although the additives used have to be listed among the ingredients, but in the case of unpackaged foods this information is not available, and the label does not provide information on the quantity. Indicating the phosphorus content on foods is not mandatory.
- Available food composition databases are generally not accurate and not up to date with respect to phosphorus content, especially in terms of the intake coming from phosphorus-containing additives, and so current phosphorus intake data are likely to be underestimated.
- The phosphorus content of foodstuffs is not yet a top priority either from a public information, a food industry product development or an authority monitoring point of view.

## 9. Recommendations

Ritz et al. noted in their above-mentioned communication [24] that it would be justified to take the initial steps immediately to improve the situation. In their opinion, doctors and the public should be informed that the phosphates added to foodstuffs are harmful to health. As today the population is already aware of the health risk of excessive salt consumption, an awareness-raising campaign would be necessary in the case of phosphate content. In addition, there is a need to indicate the amount of added phosphorus content on food labels, which, when supplemented by easy to understand markings, would indicate to the consumer whether the product contains low, medium or high amounts of added phosphate. The research team believes that for the dissemination of the knowledge, mass media should be used as well.

This requires the cooperation of the government, the food industry and health, food safety and consumer protection organizations. When a wide-ranging information campaign is launched, dissemination should be carried out in such a way that it is professionally credible and accurate. It is important that the information is understandable by laypeople, but it should not generate unnecessary aversion in consumers' minds or a panic reaction in general towards additives and industrially processed foods.

Hopefully, the ongoing reevaluation of phosphorus-containing additives by EFSA will provide answers to unclear points and will help initiatives and measures aimed at improving public health with credible, scientifically sound recommendations.

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