Functional properties of phytate

Propriedades funcionais do fitato

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ABSTRACT

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*Phytate [*myo-*inositol(1,2,3,4,5,6)hexakisphosphate], a naturally compound formed during maturation of plant seeds and grains, is a common constituent of plant-derived foods. The major concern about the presence of phytate in the diet is its negative effect on mineral uptake. Minerals of concern in this regard include* Zn^{2+}, $Fe^{2+/3+}$, Ca^{2+}, Mg^{2+}, Mn^{2+}, *and* Cu^{2+}. *Especially zinc and iron deficiencies were reported as a consequence of high phytate intakes. In addition, a negative effect on the nutritional value of protein by dietary phytate is discussed. Consumption of phytate, however, seems not to have only negative effects on human health. Dietary phytate was reported to prevent kidney stone formation, protect against diabetes mellitus, caries, atherosclerosis and coronary heart disease as well as against a variety of cancers. Furthermore, individual* myo-*inositol phosphate esters have been proposed to be metabolically active.* D-myo-*inositol(1,2,6)trisphosphate, for example, has been studied in respect to prevention of diabetes complications and treatment of chronic inflammations as well as cardiovascular diseases and due to its antiangiogenic and antitumour effects* myo-*inositol(1,3,4,5,6)pentakisphosphate was suggested as a promising compound for anticancer therapeutic strategies.*

Keywords: Phytate.
Nutrition. Negative effect.
Diet.

RESUMEN

El fitato, [(1,2,3,4,5,6) hexafosfato de mio-*inositol, compuesto que se forma naturalmente durante la maduración de las semillas y granos, es un constituyente común de los alimentos vegetales. La mayor preocupación con la presencia de fitato es su efecto negativo en la absorción de minerales, particularmente* Zn^{2+}, $Fe^{2+/3+}$, Ca^{2+}, Mg^{2+}, Mn^{2+}, *e* Cu^{2+}.
*Las deficiencias de zinc y hierro, fueron relacionadas con altas ingestas de fitato. Es discutido también su efecto negativo en el valor biológico de las proteínas. Sin embargo, el consumo de fitato parece no tener solamente efectos negativos para la salud humana. Fue descripto, por ejemplo, un efecto protector del fitato contra la formación de cálculos renales, contra la diabetes mellitus, formación de caries, ateriosclerosis y enfermedades coronarias, como también contra una gran variedad de tipos de tumores malignos. Además, ha sido propuesto que, individualmente, algunos ésteres de fosfato de mio-inositol sean metabólicamente activos. Hay estudios relacionando el (1,2,6) trisfosfato de D-*mio*-inositol con la prevención de complicaciones de la diabetes y con el tratamiento de inflamaciones crónicas y de enfermedades cardiovasculares; el (1,3,4,5,6) pentafosfato de* mio*-inositol, debido a sus efectos anti-angiogénicos y anti-tumorales, fue sugerido como un compuesto promisor en las estratégias terapéuticas contra el cáncer.*

Palabras clave: Fitato.
Nutrición. Efecto negativo.
Dieta.

RESUMO

O fitato, [(1,2,3,4,5,6) hexafosfato de mio-*inositol], composto que ocorre naturalmente e é formado durante a maturação de sementes e grãos, é um constituinte comum de alimentos vegetais. A maior preocupação com a presença de fitato na dieta é seu efeito negativo na absorção de minerais, particularmente* Zn^{2+}, $Fe^{2+/3+}$, Ca^{2+}, Mg^{2+}, Mn^{2+}, *e* Cu^{2+}.
As deficiências de zinco e de ferro, em especial, foram relacionadas com altas ingestões de fitato. É discutido, também, o efeito negativo do fitato no valor biológico de proteínas. Por outro lado, o consumo de fitato parece não ter somente efeitos negativos para a saúde humana. Foi descrito, por exemplo, um efeito protetor do fitato contra a formação de cálculos renais, contra diabetes Mellitus, formação de cáries, aterosclerose e doença coronariana, bem como contra uma grande variedade de tipos de tumores malignos. Além disso, foi proposto que, individualmente, alguns ésteres de fosfato de mio*-inositol sejam metabolicamente ativos. Assim, há estudos relacionando o (1,2,6) trisfosfato de D-*mio*-inositol com a prevenção das complicações do diabetes e com o tratamento de inflamações crônicas e de doenças cardiovasculares; o (1,3,4,5,6) pentafosfato de* mio*-inositol, devido a seus efeitos anti-angiogênicos e anti-tumorais, foi sugerido como um composto promissor nas estratégias terapêuticas contra o câncer.*

Palavras-chave: Fitato.
Dieta. Nutrição.
Efeito negativo.

INTRODUCTION

Phytates [*myo*-inositol (1,2,3,4,5,6)hexakisphosphates] are regarded as the primary storage form of both phosphate and inositol in plant seeds and grains, comprising 0.5-5% (w/w) (LOEWUS, 2002). In addition, phytate has been suggested to serve as a store of cations, high energy phosphoryl groups, and, by chelating free iron, as a potent natural antioxidant (REDDY; SATHE; SALUNKHE, 1982). It is formed during maturation and represents 60-90% of the total phosphate in the dormant seed (REDDY, 2002). Because phytate is naturally occurring in plant seeds and grains, it is a common constituent of plant-derived foods. Depending on the amount of such foods in the diet and the grade of food processing the daily intake of phytate can be as high as 4500mg (REDDY, 2002). In average, the daily intake of phytate was estimated to be 2000-2600mg for vegetarian diets as well as diets of inhabitants of rural areas in developing countries and 150-1400mg for mixed diets. Phytate behaves in a broad pH region as a highly negatively charged ion and has therefore a tremendous affinity for food components with positive charge(s), such as minerals, trace elements and proteins (CHERYAN, 1980; REDDY; SATHE; SALUNKHE, 1982). There is a large body of evidence that minerals are less available from foods of plant origin as compared to animal-based foods. In addition, phytate-phosphorus is less nutritionally available because phytate is not hydrolysable quantitatively in the human gut (SANDBERG; ANDERSSON, 1988). Furthermore, it was demonstrated that phytate-protein interactions negatively affect protein digestibility *in vitro* and that the extent of this effect depends on the protein source (CHERYAN, 1980). On the other hand, consumption of phytate was suggested to have potential positive effects on human health. Dietary phytate has been considered to have great nutritional significance in maintaining human health and in prevention of common nutrition-dependent diseases in Western societies such as diabetes mellitus, renal lithiasis, cancer, atheriosclerosis and coronary heart disease.

PHYTATE AS AN ANTINUTRIENT

The major concern about the presence of phytate in the diet is its negative effect on mineral uptake. Minerals of concern in this regard include Zn^{2+}, $Fe^{2+/3+}$, Ca^{2+}, Mg^{2+}, Mn^{2+}, and Cu^{2+} (LÖNNERDAL, 2002; LOPEZ et al., 2002), but also a negative effect on the nutritional value of protein by dietary phytate is discussed (CHERYAN, 1980). Formation of insoluble mineral-phytate complexes at physiological pH is regarded as the major reason for the poor mineral bioavailability, because these complexes are essentially non-absorbable from the human digestive tract. Furthermore, the human small intestine has only a very limited ability to hydrolyse phytate (IQBAL; LEWIS; COOPER, 1994) due to the lack of endogenous phytases and the low microbial population in the upper part of the digestive tract. This fact explains also why phytate-phosphorus is poorly available to single-stomached living beings (WALZ; PALLAUF, 2002). Phosphorus is absorbed as orthophosphate and thus utilisation of

phytate-phosphorus by single-stomached living beings will largely depend on their capability to hdrolyse phytate. Most studies have shown an inverse relationship between phytate content and mineral availability, although there are great differences in the behaviour of individual minerals. Zinc and iron were reported to be the essential minerals most adversely affected by phytate (LÖNNERDAL, 2002; LOPEZ et al., 2002). Solubility and stability of *myo*-inositol phosphate-mineral complexes have been found to decrease as the number of phosphate residues on the *myo*-inositol ring decreases. In isolated form only *myo*-inositol pentakisphosphate suppressed absorption of iron, zinc and calcium in humans, while *myo*-inositol tetrakis- and trisphosphates had no effect in the concentrations under investigation. In the presence of higher phosphorylated *myo*-inositol phosphates, however, *myo*-inositol tetrakis- and trisphosphates were shown to contribute to the negative effect of phytate on iron absorption (SANDBERG et al., 1999). Because a strong negative correlation was found between zinc absorption and the sum of *myo*-inositol tris- through hexakisphosphate from cereal and legume meals (SANDBERG, 1991), such a contribution is probably also true for zinc absorption.

Phytate is known to form complexes with proteins at both acidic and alkaline pH (CHERYAN, 1980). This interaction may effect changes in protein structure that can decrease enzymatic activity, protein solubility and proteolytic digestibility. However, the significance of protein-phytate complexes in nutrition is still under scrutiny. Strong evidence exists that phytate-protein interactions negatively affect protein digestibility *in vitro* and the extend of this effect depends on the protein source (CHERYAN, 1980). A negative effect of phytate on the nutritive value of protein, however, was not clearly confirmed in studies with monogastric animals (SEBASTIAN; TOUCHBURN; CHAVEZ, 1998). While some have suggested phytate does not affect protein digestibility, others have found improved amino acid availability with decreasing levels of phytate. This difference may be at least partly due to the use of different protein sources. Of nutritional significance might be also the inhibition of digestive enzymes such as α-amylase (KNUCKLES; BETSCHART, 1987), lipase (KNUCKLES, 1988) or proteinases (DESHPANDE; DAMODARAN, 1989; INAGAWA; KIYOSAWA; NAGASAWA, 1987) as shown in *in vitro* studies. The inhibitory effect increases with the number of phosphate residues per *myo*-inositol molecule and the *myo*-inositol phosphate concentration. The inhibition may be due to non-specific phytate-protein interactions, chelation of calcium ions which are essential for the activity of trypsin and α-amylase, or interaction with the substrates of these enzymes. So far, α-amylase is the only digestive enzyme which was clearly shown to be inhibited by phytate *in vivo* (YOON; THOMPSON; JENKINS, 1983).

POTENTIAL HEALTH BENEFITS OF PHYTATE-RICH DIETS

Consumption of phytate does not seem to have only negative effects on human health. Dietary phytate was reported to prevent kidney stone formation (GRASES et al.,

2000), protect against diabetes mellitus (YOON; THOMPSON; JENKINS, 1983), atherosclerosis, coronary heart disease (JARIWALLA et al., 1990), caries (KAUFMAN; KLEINBERG, 1971), and against a variety of cancers (VUCENIK; SHAMSUDDIN, 2003). The levels of phytate and its dephosphorylation products in urine, plasma and other biological fluids are fluctuating with ingestion or deprivation of phytate in the human diet (GRASES et al., 2001). Thus, the reduction in phytate intake in developed compared to developing countries might be a factor responsible for the increase in diseases typical for Western societies. It was suggested that phytate exerts its beneficial effects in the digestive tract and other target tissues through its chelating ability, but other mechanisms have also been discussed. Furthermore, it is not at all established that phytate itself is the active compound. Several *myo*-inositol phosphates were linked with different physiological effects (SHEARS, 1998). Thus, phytate dephosphorylation products generated during food processing or food digestion may act as the functional compounds.

PHYTATE AND HEAVY METAL INTOXICATION

The potential beneficial effects of phytate in prevention of severe poisoning by metals such as iron should be considered. 1-2% calcium phytate in the diet protected against dietary lead in experimental animals and in human volunteers (WISE, 1981). In addition, phytate was capable of lowering blood lead levels. Thus, phytate seems to be a helpful means to counteract acute lead toxicity. The effect of phytate on acute cadmium toxicity is still discussed controversially, but the majority of studies point to an improved cadmium absorption in the presence of phytate (RIMBACH; PALLAUF; WALZ, 1996). Thus, an increase in dietary phytate may result in a cadmium accumulation in liver and kidney.

PHYTATE AND DIABETES MELLITUS

Diabetes mellitus is one of the most common nutrition-dependent diseases in Western society. It may be caused by hypercaloric diets with a high percentage of quickly available carbohydrates. Foods that result in low blood glucose response have been shown to have great nutritional significance in the prevention and management of diabetes mellitus. Thus phytate-rich foods are of interest, since a negative relationship between phytate intake and blood glucose response was reported. Phytate-enriched unleavened bread for example reduced the *in vitro* starch digestibility besides flattening the glycemic response in five healthy volunteers in comparison to bread without phytate addition (YOON; THOMPSON; JENKINS, 1983). The opposite effect was demonstrated after consuming food from which phytate had previously been removed (THOMPSON; BUTTON; JENKINS, 1987). The *in vitro* reduction of starch digestion was positively correlated with the *myo*-inositol phosphate concentration and negatively with the

number of phosphate groups on the *myo*-inositol ring. However, it has to be noted, that there are also studies which have not found an inhibition of α-amylase and starch digestion by phytate.

PHYTATE AND CORONARY HEART DISEASE

Heart disease is a leading cause of death in Western countries, yet it is low in Japan and developing countries. Elevated plasma cholesterol or more specifically elevated LDL-cholesterol concentrations have been shown to be one of the risk factors. It has been proposed that dietary fibre or more specifically phytate as a component of fibre, may influence the aetiology of heart disease (POTTER, 1995). Animal studies have shown that dietary phytate supplementation resulted in significantly lower serum cholesterol and triglyceride levels (JARIWALLA et al., 1990). This effect was accompanied by a decrease in serum zinc levels and in zinc-copper ratios. Thus, the hypothesis was put forward that coronary heart disease is predominantly a disease of imbalance in regard to zinc and copper metabolism (KLEVAY, 1975). The hypothesis is also based on the production of hypercholesterolemia, which is a major factor in the aetiology of coronary heart disease, in rats fed a diet with a high ratio of zinc and copper. Because phytate preferentially binds zinc rather than copper (PERSSON et al., 1998), it was presumed that phytate exerts its effect probably by decreasing zinc without affecting copper absorption. Phytate may, however, affect serum cholesterol and triglyceride levels via flattening the glycemic response. Steep jump in blood glucose levels requires the secretion of considerable amounts of insulin and elevated levels of insulin have been discussed to result in higher blood triglyceride levels (CARLSON; BOTTIGER; AHFELDT, 1979). Foods that result in low blood glucose response normalise blood triglyceride levels in the case of hypertriglyceridemia and lower total and LDL-cholesterol (JENKINS et al., 1985). It should be pointed out that the support for the preventive role of phytate in heart disease is based only on a few animal and *in vitro* studies. Results from human studies are still lacking.

PHYTATE AND RENAL LITHIASIS

The increase of renal stone incidence in northern Europe, North America, and Japan has been reported to be coincident with the industrial development of these countries, making dietary intake suspect. Epidemiological investigations found that there were substantial differences in renal stone incidences between white and black residents of South Africa (ZHOU; ERDMAN, 1995). The major dietary difference is that, compared to the white population, blacks consumed large amounts of foods containing high levels of fibre and phytate. In addition, a high phytate diet has been used effectively to treat hypercalciuria and renal stone formation in humans (OHKAWA et al., 1984). In recent years, research on phytate as a potent inhibitor of renal stone formation has been

intensified. By comparing a group of active calcium oxalate stone formers with healthy people it was demonstrated that urinary phytate was significantly lower for stone formers (GRASES et al., 2000). Therefore, *in vitro* and *in vivo* experiments as well as clinical studies clearly demonstrate that phytate plays an important role in preventing the formation of calcium oxalate and calcium phosphate crystals, which function as nuclei for kidney stone development. Because excretion of low phytate amounts in the urine was shown to be an important risk factor in the development of renal calculi and urinary excretion of phytate decreased significantly after intake of a phytate-free diet (GRASES; COSTA-BAUZÁ, 1999), the importance of dietary phytate in maintaining adequate urinary levels to permit effective crystallization inhibition of calcium salts and consequently preventing renal stone development was demonstrated. Because the risk of renal stone disease increases with higher levels of calcium in the urine, phytate may positively affect renal stone formation by reducing calcium absorption from the digestive tract. A reduction of the amount of calcium excreted with the urine in the presence of dietary phytate was already demonstrated in rat experiments (OHKAWA et al., 1984).

PHYTATE AND CARIES

The higher incidence of caries in industrialised compared to developing countries was suggested to be nutrition-dependent. Phytate lowers the solubility of calcium, fluoride and phosphate, the major components of enamel (KAUFMAN; KLEINBERG, 1971). Thus, teeth are more protected against the leading cause of caries, the attack of acids and bacteria. Furthermore, the very high affinity of phytate for hydroxyl apatite may prevent the formation of plaque and tartar.

PHYTATE AND CANCER

The frequency of colonic cancer varies widely among human populations. It is a major cause of morbidity and mortality in Western society. The incidence of cancer, especially large intestinal cancer has been associated principally with dietary fat intake and is inversely related to the intake of dietary fibre. It was further suggested that the apparent relationship between fibre intake and rate of colonic cancer might arise from the fact that many fibre-rich foods contain large amounts of phytate and that this latter might be the critical protective element, since an inverse correlation between colon cancer and the intake of phytate-rich fibre foods, but not phytate-poor fibre foods has been shown (GRAF; EATON, 1985). A high phytate intake may also be an important factor in reducing the breast and prostate cancer mortality in man (VUCENIK; SHAMSUDDIN, 2003). Both *in vivo* and *in vitro* experiments have shown striking anticancer effects of phytate. It was demonstrated that phytate is a broad-spectrum antineoplastic agent, affecting different cells and tissue systems. Phytate inhibited the growth of various human cell lines in a dose- and time-dependent manner (reviewed

by VUCENIK; SHAMSUDDIN, 2003). However, cells from different origin have different sensitivity to phytate, suggesting that phytate may affect different cell types through different mechanisms of action. It was also demonstrated, that phytate has the potential to induce differentiation and maturation of malignant cells, which often results in reversion to the normal phenotype (SHAMSUDDIN; BATEN; LALWANI, 1992). Phytate was further shown to increase differentiation of several human cell lines (reviewed by VUCENIK; SHAMSUDDIN, 2003). The effectiveness of phytate as a cancer preventive agent was also shown in colon cancer induced in rats and mice. Phytate was effective in a dose-dependent manner given either before or after carcinogen administration. The phytate-treated animals demonstrated a significantly lower tumour number and size. Studies using other experimental models showed that the antineoplastic properties of phytate were not restricted to the colon (reviewed by VUCENIK; SHAMSUDDIN, 2003). Synergistic cancer inhibition by phytate when combined with inositol was demonstrated in several cancers in experimental animals (reviewed by VUCENIK; SHAMSUDDIN, 2003). The *in vivo* experiments were performed either by adding phytate to the diet or by giving phytate via drinking water. Comparable of even stronger tumour inhibition was obtained with much lower concentrations of phytate when it was given in drinking water.

The mechanisms involved in the anticancer activity of phytate are not fully understood. It was suggested that phytate exerts the beneficial effects through its chelating ability, but additional mechanisms have also been discussed. Because several *myo*-inositol phosphates, including phytate, are present as intracellular molecules and because the second messenger D-*myo*-inositol(1,4,5)trisphosphate is bringing about a range of cellular functions including cell proliferation via mobilising intracellular Ca^{2+} (SHEARS, 1998), phytate was proposed to exert its anticancer effect by affecting cell signalling mechanisms in mammalian cells (SHAMSUDDIN; BATEN; LALWANI, 1992). Depending on cell type, that is different receptors, phosphatases, and kinases, *myo*-inositol phosphates were linked with different physiological effects, such as basic cell functions like secretion and contraction as well as functions like cell division, cell differentiation and cell death. Therefore, practically every *myo*-inositol phosphate isomer extracellularly present and may have a metabolic effect by activating receptors, by being metabolised by phosphatases and kinases or by acting as inhibitors of these intracellular proteins after being internalised by cells. An effect of extracellular phytate on the concentration of several intracellular *myo*-inositol phosphate esters has already been demonstrated in human erythroleukemia cells (SHAMSUDDIN; BATEN; LALWANI, 1992). Furthermore, it has been recently reported that highly negatively charged *myo*-inositol polyphosphates can cross the plasma membrane and be internalised by cells. *Myo*-inositol hexakisphosphate was shown to enter HeLa cells followed by an intracellular dephosphorylation to partially phosphorylated *myo*-inositol phosphates (FERRY et al., 2002), whereas *myo*-inositol (1,3,4,5,6) pentakisphosphate showed a quite slow turnover after internalisation by SKOV-3 cells (MAFFUCCI et al., 2005). It was suggested that the anticancer activity of phytate is actually

due to its dephosphorylation to lower forms. *Myo*-inositol(1,3,4,5,6)pentakisphosphate for example inhibits specifically phosphatidylinositol 3-kinase, the enzyme catalysing the phosphorylation of inositol phospholipids at the D3 position to generate 3'-phosphorylated phosphoinositides, which act by recruiting specific signalling proteins to the plasma membrane. Activation of phosphatidylinositol 3-kinase is a crucial step in some events leading to angiogenesis, the formation of a mature vasculature from a primitive vascular network and angiogenesis is involved in pathologies such as arteriosclerosis and tumour growth. The observed anticancer effects of phytate could be mediated through several other mechanisms. Besides affecting tumour cells, phytate can act on a host by restoring its immune system. Phytate augments natural killer cell activity *in vitro* and normalises the carcinogen-induced depression of natural killer cell activity *in vivo* (BATEN et al., 1989). The antioxidant role of phytate is known and accepted. The 1,2,3-trisphosphate grouping in phytate has a conformation that uniquely provides a specific interaction with iron to completely inhibit its capability to catalyse hydroxyl radical formation from the Fenton reaction (HAWKINS et al., 1993). Chelation of iron to the 1,2,3-trisphosphate grouping may also reduce the likelihood for iron-catalysed lipid peroxidation (PHILLIPPY; GRAF, 1997). It is as yet uncertain whether physiological intakes of phytate can significantly improve the antioxidant status in man. The anticancer action of phytate may be further related to mineral binding ability or other positively charged compounds. By complexing Zn^{2+} and/or Mg^{2+}, phytate can affect activity of enzymes essential for DNA synthesis. Due to inhibition of starch digestion in the small intestine, undigested and unabsorbed starch will reach the colon where it may either contribute to faecal bulk and increase the dilution of potential carcinogens, or it may be fermented to short-chain fatty acids, which may subsequently decrease colonic pH. Increased production of short-chain fatty acid, particularly butyrate, may play a protective role in colon carcinogenesis, because butyrate has been shown in several *in vitro* studies to slow down the growth rate of human colorectal cancer cell lines (CORADINI et al., 2000). Decreased pH has been suggested to be protective of colon carcinogenesis (NEWMARK; LUPTON, 1990) by possibly causing alterations in the metabolic activity of colonic flora, altering bile acid metabolism and inhibiting ammonia production and absorption.

CONCLUSION

The most severe effects attributable to phytate have occurred in populations with unrefined cereals and/or pulses as a major dietary component. Especially zinc and iron deficiencies were reported as a consequence of high phytate intakes. To reduce the risk for mineral deficiency in vulnerable groups such as child-bearing women, strictly vegetarians, inhabitants of developing countries, especially fast growing children, different strategies have been developed. The most widely recognised are supplementation with pharmaceutical preparations, food fortification, dietary diversification and disease reduction. For various reasons, none has been

very successful. An alternative approach would be to increase the total level of micronutrients in the edible parts of stable crops while at the same time increasing the concentration of compounds which promote their uptake and/or decreasing the amount of compounds which inhibit their absorption. Recently low phytate mutants in maize, barley, rice and soybeans were isolated (RABOY, 2002) and their potential for improving the absorption of iron, zinc and calcium has been shown (MENDOZA, 2002). To improve rice as a source of iron, three proteins were expressed in the central endosperm of the rice seed: a *Phaseolus* phytoferritin, an endogenous cysteine-rich metallothionein-like protein, and an *Aspergillus fumigatus* phytase (LUCCA; HURRELL; POTRYKUS, 2002). If properly targeted, overexpression of phytase during seed development can result in reduced phytate levels in the mature seed (COELLO et al., 2001). Enhanced levels of seed phytase may also contribute to an improvement in mineral absorption by reducing phytate levels in plant-based food during processing and digestion in the human stomach once a meal is consumed. In addition, phytate degradation during food processing could be optimised by adding exogenous phytases or by adjusting favourable conditions for the native plant or microbial phytases. Besides enzymatic degradation, non-enzymatic hydrolysis of phytate during food processing or physical separation of phytate-rich parts of the plant seed could result in reduced levels of phytate in the final foods. In general, the lower phytate levels must be paid for by a loss of valuable nutrients which are either removed together with the phytate-rich parts of the plant or destroyed by the strong acids or high temperatures needed for non-enzymatic phytate dephosphorylation. Enzymatic phytate degradation, however, occurs also under mild conditions and does not affect other food components. Thus, there is a great potential for the use of phytases in processing and manufacturing of food, but up to now, no phytase product for a relevant food application has found its way to the market.

Marked mineral deficiency syndromes attributed to phytate have not been identified in highly developed countries. Phytate intake does not necessarily result in mineral deficiency. The absorption of minerals depends on the total composition of the meal and in a balanced diet containing animal protein, a high phytate intake does not imply a risk of inadequate mineral supply. Therefore, the recommendation for increasing dietary fibre in Western diets would not be expected to have any adverse effect on mineral absorption. The higher phytate intake with whole-grain products will undoubtedly lead to a percentage decrease in mineral absorption, but the absolute amount of absorbed minerals may remain unchanged, because of the large amounts of minerals in these products. In addition, the impact of phytate on phosphorus availability can be considered of little consequence in man, since the phosphorus intakes are usually high, and phytate-phosphorus represents only a small portion of the total phosphorus in the diets. Thus, in Western societies the proposed beneficial health effects exerted by dietary phytate especially in regard to common nutrition-dependent diseases such as diabetes mellitus, renal lithiasis, cancer, atheriosclerosis and coronary heart disease

are much more important than the antinutritive effects. The Japanese company TSUNO already commercialises phytate extracted from rice bran as a dietary supplement. The product is advertised as a cleanser of arteries, the heart, brain, kidney, liver, colon, gall bladder (stones), and many other tissues (www.tsuno.co.jp). According to the instructions of the company, the product should not be used by growing children or pregnant women who have high iron and calcium needs as well as anemic individuals. The product should be taken on an empty stomach with water only so as not to interfere with mineral absorption from foods.

Much scientific information has been reported in the last few years linking diet, specific foods, or individual food components with the maintenance of human health and the prevention of chronic diseases. Individual *myo*-inositol phosphate esters have been shown to have important physiological functions in man. D-*myo*-inositol(1,2,6)trisphosphate, for example, has been studied in respect to prevention of diabetes complications and treatment of chronic inflammations as well as cardiovascular diseases (CARRINGTON et al., 1993; CLAXSON et al., 1990) and due to its antiangiogenic and antitumour effects *myo*-inositol(1,3,4,5,6)pentakisphosphate was suggested as a promising compound for anticancer therapeutic strategies (MAFFUCCI et al., 2005). Because the number and distribution of the phosphate residues on the *myo*-inositol ring determines the metabolic effects triggered by the individual *myo*-inositol phosphate isomer, a controlled dephosphorylation of phytate may result in individual food components maintaining human health and preventing chronic diseases. So far enzymatic phytate dephosphorylation is the most promising approach to get access to an individual *myo*-inositol phosphate isomer. Different phytases may exhibit different phytate degradation pathways and therefore lead to the generation and accumulation of different *myo*-inositol phosphate intermediates (reviewed by KONIETZNY; GREINER, 2002). If individual phytate degradation products are established to be metabolically active, phytases may find application in food processing to produce foods with improved nutritional value, health benefits and maintained sensory properties (functional foods) (GREINER et al., 2002). By adding phytase to the raw material, phytate will be degraded to metabolically active *myo*-inositol phosphates during food processing. To end up with foods with a reduced content of phytate and a regulated content and composition of partially phosphorylated *myo*-inositol phosphate esters with health benefits, phytate dephosphorylation during food processing has to be tightly controlled. An alternative could be to generate metabolically active *myo*-inositol phosphates as food supplements by using pure phytate as the source material. Because partially phosphorylated *myo*-inositol phosphate esters are subjected to degradation in the human digestive tract even if all dietary phosphatases including phytases are inactivated, it might be necessary to enrich foods with a precursor of the true active *myo*-inositol phosphate ester to trigger the desired physiological effects.

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