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Total and phytate phosphorus contents of various foods and feedstuffs of plant origin

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Samples of 29 common foods and 10 feedstuffs of tropical origin were analysed for their total and phytate phosphorus (P) contents. In cereal grains, oilseeds and grain legumes, high levels of phytic acid were obtained, and phytate P constituted the major portion (60–82%) of total P. The various roots and tubers contained moderate amounts of phytic acid and phytate P accounted for 21–25% of the total P in this food group. Leafy greens contained negligible amounts of phytate P. In rice bran and the various oilseed meals, phytate P constituted 56–77% of the total P. Phytic acid contents were highest for gingelly (3·87%), gingelly meal (3·76%) and rice bran (3·65%).

INTRODUCTION

In most plant materials, a large portion of phosphorus (P) is present in the form of phytate. Phytate is a complex salt of calcium or magnesium with myoinositol (1, 2, 3, 4, 5, 6-hexakis dihydrogen phosphate) and is regarded as the primary storage form of P and inositol in almost all seeds (Cosgrove, 1980). During germination, the phytate is hydrolysed by the phytase present in seeds and serves as a source of inorganic P and cation for the emerging seedling (Williams, 1970).

P in phytate form is either unavailable to or poorly utilised by monogastric animals and humans (Nelson, 1967; Erdman, 1979; Reddy *et al.*, 1982) because they lack the phytase enzyme required to hydrolyse the phytate and release the P. In addition, the phosphoric acid moiety of the phytate molecule has a strong capacity to form complexes with multivalent cations, including calcium, magnesium, zinc, iron, manganese and copper. These phytate–mineral complexes are generally insoluble at physiological pH and hence render the minerals biologically unavailable to monogastric animals and humans. The adverse effects of phytate on mineral bioavailability have been the subject of several excellent reviews (Erdman, 1979; Maga, 1982; Reddy *et al.*, 1982).

Foods and feedstuffs derived from plants play a significant role in the nutrition of humans and animals in tropical regions. As a result, their contribution of phytate P to diets becomes nutritionally important. Whereas the phytate P contents of foods (Common, 1940; McCance & Widdowson, 1960; Reddy *et al.*, 1982) and feedstuffs (Nelson *et al.*, 1968; Kirby & Nelson, 1988) in the temperate regions are well documented, corresponding information on plant materials of tropical origin is limited. The present study was nitiated to assay a variety of tropical foods and feedstuffs for their total and phytate P contents.

MATERIALS AND METHODS

The study included 29 common foods and 10 feedstuffs. Samples, approximately 1 kg in size, were collected from local farms or retail outlets around Peradeniya. Cassava leaf meal and ipil ipil leaf meal were prepared in the laboratory using methods described previously (Ravindran *et al.*, 1986; Ravindran & Wijesiri, 1988).

Samples were dried at 100°C in an oven to constant weight and ground in a Wiley Laboratory mill to pass through a 60 mesh sieve. The ground samples were stored at room temperature in air-tight containers prior to chemical analyses.

All samples were assayed in triplicate for moisture (AOAC, 1975) and for total P using the ammonium vanadate method (Chapman & Pratt, 1961). Phytate P was determined by the colorimetric method of Wheeler and Ferrel (1971) as modified by Reddy *et al.* (1978). In this method, phytate was extracted using trichloroacetic acid and precipitated as ferric phytate. The ferric phytate was converted to ferric hydroxide (precipitate) by the addition of sodium hydroxide and boiling. The ferric hydroxide precipitate was dissolved in dilute hydrochloric acid and the iron content was measured colorimetrically (AOAC, 1975) using *o*-phenanthroline reagent. The phytate P content was calculated from the

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iron concentration by assuming a constant Fe : P molecular ratio of 4 : 6 in the precipitate.

RESULTS AND DISCUSSION

The total and phytate P contents of the cereals, roots, tubers, fruit vegetables and leafy greens are summarised in Table 1. Phytate P constituted the major portion of total P in cereal grains. The proportion of phytate P varies from 64–85% of the total P in most cereals, the exceptions being polished rice and finger millet. In polished rice and finger millet, the phytate P accounted for 55 and 58 % of the total P, respectively. The lower phytic acid content of polished rice compared with unpolished rice is due to the removal of bran layers during the polishing process. It is well documented that over 80% of the phytate in rice grain is present in the outer bran layers and aleurone layers of the kernel (O'Dell *et al.*, 1972; De Boland *et al.*, 1975).

The dark-coloured sorghum grains contained somewhat higher levels of phytic acid than the light-coloured grains. The significance of this observation is unclear. It is perhaps of interest to note that the dark-coloured sorghum grains are considered bird-resistant owing to their high tannin contents (Hulse *et al.*, 1980).

The various roots and tubers contained only moderate amounts of phytic acid. In this type of food, phytate P accounted for 21–25% of the total P. Published information on the phytate contents of roots and tubers is limited. The phytate values obtained for cassava roots compare closely with that reported by Jongbloed and Kemme (1990). However, the values determined for potatoes are lower than those obtained by Samotus and Schwimmer (1962). These workers determined that phytate P accounted for up to 35–40% of the total P in mature potato tubers.

Plantains, breadfruit and jak fruit are popular fruit vegetables; widely used for human consumption in tropical regions. They contain moderate amounts of phytic acid. The high level of phytic acid in jak seeds is as expected, since phytate is considered to be the chief storage form of P and inositol in seeds (Cosgrove, 1980). Phytate P constituted 61% of the total P in the jak seed. The two leafy greens analyzed, spinach and sweet potato, contained low amounts of phytic acid. This is in agreement with the observation of Oberleas (1973) that leafy vegetables appear to be essentially devoid of phytate. According to Bieleski (1968), over 70% of the P in plant leaves is found in the form of inorganic P with the remainder in the form of ribonucleic acids, phospholipids and acid-soluble phosphate esters.

Oilseeds had higher levels of phytic acid (Table 2) than cereals. The phytate P content in groundnut and gingelly constituted over 80% of the total P. The phytic acid concentration in gingelly seeds amounted to 3·87% of the dry weight. This value is, however, lower than the values of 4·7–5·2% reported for North American samples of gingelly by De Boland *et al.* (1975) and Toma *et al.* (1979).

The various grain legumes were found to contain 0·60–1·03% phytic acid (Table 2) and these values are

Table 1. Total and phytate phosphorus contents of various cereals, root and tubers and fruit vegetables of tropical origin (mean ± SE)

	No of samples	Phosphorus (g/100 g DM)		Phytate P (as% of) total	Phytic acid (g/100 g DM)[a]
		Total	Phytate		
Cereals					
Maize (*Zea mays*)	4	0·26 ± 0·01	0·22 ± 0·02	84·6	0·78
Rice *Oryza sativa*), brown unpolished	3	0·38 ± 0·03	0·28 ± 0·02	73·7	0·99
Rice, polished	2	0·31 ± 0·02	0·17 ± 0·01	54·8	0·60
Sorghum (*Sorghum vulgare*), dark-coloured seeds	2	0·41 ± 0·01	0·27 ± 0·01	65·9	0·96
Sorghum, light-coloured seeds	3	0·36 ± 0·02	0·23 ± 0·02	63·9	0·82
Foxtail millet (*Setaria italica*)	4	0·27 ± 0·01	0·19 ± 0·02	70·4	0·67
Finger millet (*Eleusine coracana*)	3	0·24 ± 0·01	0·14 ± 0·01	58·3	0·50
Common millet (*Panicum miliaceum*)	6	0·26 ± 0·01	0·17 ± 0·01	65·4	0·60
Roots and Tubers					
Cassave (*Manihot esculenta*), roots	2	0·16 ± 0·01	0·04 ± 0·003	25·0	0·14
Sweet potato (*Ipomea batatas*), tubers	2	0·21 ± 0·01	0·05 ± 0·004	23·8	0·18
Taro (*Colocasia esculenta*), corms	2	0·38 ± 0·01	0·09 ± 0·004	23·7	0·32
Dioscorea (*Dioscorea esculenta*), yam	3	0·12 ± 0·01	0·03 ± 0·008	25·0	0·11
Dioscorea (*Dioscorea alata*), yam	6	0·17 ± 0·01	0·04 ± 0·01	23·5	0·14
Potato (*Solanum tuberosum*), tubers	2	0·24 ± 0·01	0·05 ± 0·002	20·8	0·18
Miscellaneous					
Plantains (*Musa paradisica*), cooking type, unripe, peeled	2	0·12 ± 0·01	0·04 ± 0·008	33·3	0·14
Bread fruit (*Artocarpus altilis*), unripe, peeled	1	0·22	0·04	18·2	0·14
Jak fruit (*Artocarpus heterophyllus*), unripe, peeled	1	0·20	0·04	20·0	0·14
Jak seeds	3	0·31 ± 0·02	0·19 ± 0·02	61·3	0·67
Dates (*Phoenix dactylifera*), fruit, without seeds	2	0·18 ± 0·01	0·04 ± 0·008	22·2	0·14
Spinach (*Basella rubra*), leaves	2	0·44 ± 0·04	0·02 ± 0·004	4·5	0·07
Sweet potato, leaves	2	0·33 ± 0·02	0·02 ± 0·002	6·1	0·07

[a] Calculated phytic acid content assuming 28·20% phosphorus in the molecule.

Table 2. Total and phytate phosphorus contents of some oilseeds and grain legumes (mean ± SE)

	No of samples	Phosphorus (g/100 g DM)		Phytate P (as % of total)	Phytic acid (g/100 g DM)[a]
		Total	Phytate		
Oilseeds					
Soya bean (*Glycine max*)	3	0·60 ± 0·02	0·37 ± 0·01	61·7	1·31
Groundnut (*Arachis hypogea*)	4	0·49 ± 0·02	0·40 ± 0·02	81·6	1·42
Gingelly (*Sesamum indicum*)	3	1·34 ± 0·04	1·09 ± 0·05	81·3	3·87
Grain legumes					
Chick peas (*Cicer arietinum*)	2	0·41 ± 0·01	0·21 ± 0·01	51·2	0·74
Cowpeas (*Vigna unguiculata*)	4	0·39 ± 0·01	0·28 ± 0·02	71·8	0·99
Green gram (*Vigna radiata*)	2	0·38 ± 0·01	0·24 ± 0·01	63·2	0·85
Black gram (*Vigna mungo*)	3	0·39 ± 0·02	0·29 ± 0·01	74·4	1·03
Pigeon peas (*Cajanus cajan*)	3	0·32 ± 0·02	0·24 ± 0·02	75·0	0·85
Lentils (*Lens culinaris*)	2	0·31 ± 0·01	0·20 ± 0·02	64·5	0·71
Winged bean (*Psophocarpus tetragonolobus*)	2	0·33 ± 0·02	0·19 ± 0·02	57·6	0·67
Velvet bean (*Mucuna deeringiana*)	3	0·29 ± 0·02	0·17 ± 0·02	58·6	0·60

[a] Calculated phytic acid content assuming 28·20% phosphorus in the molecule.

similar to those determined for cereal grains (Table 1). In general, phytate P accounted for 60–75% of the total P in grain legume seeds. These results are in close agreement with those reported by Kumar *et al.* (1978) and Reddy and Salunkhe (1980).

The total and phytate P contents of some common feedstuffs are presented in Table 3. Rice bran and wheat bran contained high amounts of phytic acid and, this finding is consistent with the reports that phytic acid in rice and wheat is concentrated in bran layers of the kernels (De Boland *et al.*, 1975; Erdman, 1979). Phytate P accounted for 77 and 50% of the total P, respectively. The relatively lower levels of phytate P in wheat bran were unexpected, but may be due to the reported presence of phytase enzyme activity in wheat bran (Lim & Tate, 1971). The values obtained for rice bran in the present study are similar, whilst those obtained for wheat bran are lower than those reported by Kirby and Nelson (1988).

The various oilseed meals contained high amounts of phytic acid (Table 3). Gingelly meal contained 3·76% phytic acid based on the dry weight which is in agreement with earlier reports (Lease *et al.*, 1960; Cuca & Sunde, 1967; Nelson *et al.*, 1968). In general, about 60–77% of the total P in oilseed meals was found to be in the form of phytate. The leaf meals analysed had low levels of phytate. Similarly, Nelson *et al.* (1968) determined only traces of phytate in dehydrated alfalfa meal.

The present results indicate that the concentration of phytate is dependent on the portion of the plant that is consumed. The various types of seeds (cereals, oilseeds and grain legumes) contained large amounts of phytate, whereas roots, tubers and fruit vegetables had moderate amounts. Low levels of phytate were determined in the leafy green materials.

In developing country situations where cereals and other plant-based foods provide a large proportion of the food consumption, the dietary P intake as phytate will be greater. Although this might theoretically cause profoundly adverse effects on the bioavailability of phosphorus and cationic minerals, such populations do not suffer from nutrient deficiencies as much as would be anticipated (Hegsted, 1968; Hazell, 1985). Popula-

Table 3. Total and phytate phosphorus contents of some feedingstuffs of tropical origin (mean ± SE)

	No of samples	Phosphorus (g/100 g DM)		Phytate P (as % of total)	Phytic acid (g/100 g DM)[a]
		Total	Phytate		
Cereal by-products					
Rice bran	4	1·34 ± 0·03	1·03 ± 0·05	76·9	3·65
Wheat bran	2	1·15 ± 0·02	0·57 ± 0·03	49·6	2·02
Oilseed meals					
Soya bean meal, solvent extracted, dehulled	2	0·63 ± 0·02	0·38 ± 0·01	60·3	1·35
Soya bean meal, expeller extracted, with hulls	3	0·64 ± 0·02	0·39 ± 0·02	60·9	1·38
Coconut (*Cocos nucifera*) meal, expeller extracted	5	0·59 ± 0·03	0·33 ± 0·02	55·9	1·17
Gingelly meal, expeller extracted, with hulls	3	1·37 ± 0·04	1·06 ± 0·04	77·4	3·76
Rubber (*Hevea brasiliensis*) seed meal, expeller extracted	1	0·58	0·35	60·3	1·24
Kapok (*Ceiba pentandra*) seed meal, expeller extracted	1	0·93	0·64	68·8	2·27
Miscellaneous					
Ipil ipil (*Leucaena leucocephala*) leaf meal	1	0·22	0·02	9·1	0·07
Cassava leaf meal	2	0·42 ± 0·01	0·04 ± 0·007	9·5	0·14

[a] Calculated phytic acid content assuming 28·20% phosphorus in the molecule.

tions in developing countries are apparently able to adapt to high phytate intakes by the secretion of phytase enzyme (Lotz *et al.*, 1968) or phytates are likely to be broken down through indigenous food preparation methods. While evidence to support the earlier suggestion is lacking, it is well known that phytic acid contents of foods can be significantly reduced by milling, soaking, germination, cooking, fermentation and leavening (Reddy *et al.*, 1982).

It is, however, relevant to note that the adverse effect of phytates on mineral availability may have been overemphasised. Most foods that contain phytates are also good sources of dietary fibre which are known to have a high affinity for minerals (Reinhold *et al.*, 1975; Harland & Morris, 1985). Unless the phytates and fibre components can be separated and evaluated separately, it may be difficult to attribute the negative effects on mineral availability to phytates alone (Torre *et al.*, 1991).

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REFERENCES

AOAC (1975). *Official Methods of Analysis* (11th edn). Association of Official Analytical Chemists, Washington, DC, USA.

Bieleski, R. L. (1968). Levels of phosphate esters in spirodella. *Plant Physiol.*, **43**, 1297–308.

Chapman, H. H. & Pratt, P. C. (1961). *Methods of Analysis for Soils, Plants and Water*. Division of Agricultural Science, University of California, Davis, CA, USA.

Common, R. H. (1940). The phytic acid content of some poultry feedingstuffs. *The Analyst*, **65**, 79–83.

Cosgrove, D. J. (1980). *Inositol Phosphates: Their Chemistry, Biochemistry and Physiology*. Elsevier Scientific Publishing Company, New York, USA.

Cuca, M. & Sunde, M. L. (1967). The availability of calcium from Mexican and Californian sesame meals. *Poultry Sci.*, **46**, 994–1002.

De Boland, A. R., Garner, G. B. & O'Dell, B. L. (1975). Identification and properties of phytate in cereal grains and oilseed products. *J. Agric. Food Chem.*, **23**, 1186–9.

Erdman Jr, J. W. (1979). Oilseed phytates: nutritional implications. *Am. Oil Chem. Soc. J.*, **56**, 736–41.

Harland, B. F. & Morris, E. R. (1985). Fibre and mineral absorption. In *Dietary Fibre Perspectives: Reviews and Bibliography*, Ed. A. R. Leeds & A. Avenell. John Libby Co. Ltd, London, UK, pp. 72–82.

Hazell, T. (1985). Minerals in foods: dietary sources, chemical forms, interactions bioavailability. *World Rev. Nutr. Diet.*, **46**, 1–123.

Hegsted, D. M. (1968). Present knowledge of calcium, phosphorus and magnesium. *Nutr. Rev.*, **26**, 65–70.

Hulse, J. H., Laing, E. M. & Pearson, O. E. (1980). *Sorghum and Millets: Their Composition and Nutritive Value.*, Academic Press, New York, USA.

Jongbloed, A. W. & Kemme, P. A. (1990). Apparent digestible phosphorus in the feeding of pigs in relation to availability, requirement and environment. 1. Digestible phosphorus in feedstuffs from plant and animal origin. *Neth. J. Agric. Sci.*, **38**, 567–75.

Kirby, L. K. & Nelson, T. S. (1988). Total and phytate phosphorus content of some feed ingredients derived from grains. *Nutr. Rep. Int.*, **37**, 277–80.

Kumar, K. G., Venkataraman, L. V., Jaya, T. V. & Krishnamurthy, K. S. (1978). Cooking characteristics of some germinated legumes: Changes in phytins, Ca, Mg and pectins. *J. Food Sci.*, **43**, 85–8.

Lease, J. G., Barnett, B. D., Lease, E. J. & Turf, D. E. (1960). The biological unavailability to the chick of zinc in a sesame meal ration. *J. Nutr.*, **72**, 66–70.

Lim, P. E. & Tate, M. E. (1971). The phytases. I. Lysolecithin—activated phytase from wheat bran. *Biochem. Biophys. Acta*, **250**, 155–64.

Lotz, M., Zisman, E. & Barter, F. C. (1968) . Evidence for a phosphorus-depletion syndrome in man. *New England J. Med.*, **278**, 409–15.

Maga, J. A. (1982). Phytate: its chemistry, occurrence, interactions, nutritional significance and methods of analysis. *J. Agric. Food Chem.*, **30**, 1–9.

McCance, R. A. & Widdowson, E. M. (1960). *The Composition of Foods*. HMSO, London, UK.

Nelson, T. S. (1967). The utilization of phytate phosphorus by poultry—a review. *Poultry Sci.*, **46**, 862–71.

Nelson, T. S., Ferrara, L. W. & Storer, N. L. (1968). Phytase phosphorus content of feed ingredients derived from plants. *Poultry Sci.*, **47**, 1372–5.

Oberleas, D. (1973). Phytates. In *Toxicants Occurring Naturally in Foods*. National Research Council, National Academy of Sciences, Washington, DC, USA, pp. 363–71.

O'Dell, B. L., De Boland, A. R. & Koirtyohann, S. R. (1972). Distribution of phytate and nutritionally important elements of cereal grains. *J. Agric. Food Chem.*, **20**, 718–21.

Ravindran, V. & Wijesiri, C. J. (1988). *Leucaena leucocephala* leaf meal as an animal feed. I. Composition and nutritive value for growing chicks. *Sri Lankan J. Agric. Sci.*, **25**, 94–100.

Ravindran, V., Kornegay, E. T., Rajaguru, A. S. B., Potter, L. M. & Cherry, J. A. (1986). Cassava leaf meal as a replacement for coconut oil meal in broiler diets. *Poultry Sci.*, **65**, 1720–7.

Reddy, N. R. & Salunkhe, D. K. (1980). Effects of fermentation on phytate phosphorus and minerals of blackgram, rice and blackgram/rice blends. *J. Food. Sci.*, **45**, 1708–12.

Reddy, N. R., Balakrishnan, C. V. & Salunkhe, D. K. (1978). Phytate phosphorus and mineral changes during germination and cooking of blackgram (*Phaseolus mungo* L.) seeds. *J. Food Sci.*, **43**, 540–2.

Reddy, N. R., Sathe, S. K. & Salunkhe, D. K. (1982). Phytates in legumes and cereals. *Adv. Food Res.*, **28**, 1–92.

Reinhold, J. G., Ismail-Beigi, F. & Faradji, B. (1975). Fibre vs phytate as determinant of the availability of calcium, zinc and iron of breadstuffs. *Nutr. Rep. Int.*, **12**, 75–85.

Samotus, B. & Schwimmer, S. (1962). Phytic acid as a phosphorus reservoir in the developing potato tuber. *Nature* (London), **194**, 578–9.

Toma, R. B., Tabekhia, M. M. & Williams, J. D. (1979). Phytate and oxalate contents in sesame seed. *Nutr. Rep. Int.*, **20**, 25–31.

Torre, M., Rodriquez, A. R. & Saura-Calixto, F. (1991). Effects of dietary fiber and phytic acid on mineral availability. *CRC Crit. Rev. Food Sci. Nutr.*, **30**, 1–22.

Wheeler, E. L. & Ferrel, R. E. (1971). A method for phytic acid determination in wheat and wheat fractions. *Cereal Chem.*, **48**, 312–15.

Williams, S. G. (1970). The role of phytic acid in the wheat grain. *Plant Physiol.*, **45**, 376–9.