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FAO/INFOODS Databases

FAO/INFOODS/IZiNCG

Global food composition database for phytate version 1.0 - PhyFoodComp1.0

User guide



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FOREWORD

Micronutrients (vitamins and minerals), though required only in small quantities, are essential building blocks for healthy bones, brains and bodies. Such nutrients need to be obtained from food, ideally from a balanced and varied diet. However, in many parts of the world, diets are found to contain either insufficient amounts of micronutrients and/or antinutrients hindering their absorption. Iron and zinc represent some of the common forms of micronutrient deficiencies in terms of global public health, posing a threat to the health and development of the world's populations, especially for children and pregnant women who reside in low-income countries. In resource-poor households, the consumption of animal-based foods is usually low thereby leaving plant-based diets as the main source of energy and nutrients. Iron and zinc are however known to have low bioavailability in these diets, partly due to the presence of antinutrients that bind minerals in the human gut and consequently, hinder their absorption.

One of such antinutrients is phytate, a stored form of phosphorus which is mostly found in unrefined cereals, seeds and pulses. Once these foods are processed, their phytate content can decrease significantly, however, the extent of reduction that occurs in each processed food is not usually known. Data on the phytate content of foods are rarely ever included in national or regional food composition tables or databases (FCTs/FCDBs) (even though much data has been generated over time in this regard). Reliable compositional data regarding the phytate content of raw and processed foods are essential, but usually unavailable, for establishing meaningful recommended nutrient intakes (RNI), for formulating diets or products that minimize the mineral-binding effect of phytate, or for developing efficient programs and policies which lead to significant decreases in malnutrition.

In order to close this knowledge gap, efforts have been combined to develop a phytate database known as the FAO/INFOODS/IZiNCG Global Food Composition Database for Phytate. The database contains phytate data (in its different forms and determined by different chemical methods), as well as iron, zinc, calcium, water, and different phytate:mineral molar ratios. The database will not only constitute an important tool for policy makers in nutrition and agriculture, but it will also assist the efforts of nutritionists seeking to design programs aimed at eliminating micronutrient deficiencies using food-based approaches. It will provide an opportunity to revise the RNI that takes into account the negative effects of dietary phytate on mineral nutrition. As a result, the database will contribute to the reduction of mineral deficiencies and will raise awareness on food-based approaches for increasing the bioavailability of these essential minerals in foods.

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Our special thanks go to the European Food Safety Authority (EFSA), especially to Francesco Vernazza, Senior Scientific Officer, who gave the FoodEx2 training at FAO in June 2017. This course has been essential for learning about coding food composition data using FoodEx2, the food classification and description system developed by EFSA. FoodEx2 facilitates food matching and linking of different datasets, e.g. data from food composition to those of food consumption.

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ABBREVIATIONS

DW	Dry Weight
EFSA	European Food Safety Authority
EP	Per 100 g edible portion on fresh weight basis
FAO	Food and Agriculture Organization of the United Nations
FCT/FCDB	Food Composition Table/Food Composition Database
FoodEx2	EFSA's Food classification and description system for exposure assessment, version 2
HPLC	High-Performance Liquid Chromatography
FW	Fresh Weight
GIFT	FAO/WHO Global Individual Food Consumption Data Tool
HPAE	High-Performance Anion-Exchange
INFOODS	International Network of Food Data Systems
IP3	Inositol Triphosphate
IP4	Inositol Tetraphosphate
IP4_A_IP5_A_IP6	Inositol Tetra + Penta + Hexaphosphate
IP5	Inositol Pentaphosphate
IP5_A_IP6	Inositol Penta + Hexaphosphate
IP6	Inositol Hexaphosphate
IPSUM	Total Inositol Phosphates (SUM of all IP forms)
IZiNCG	International Zinc Nutrition Consultative Group
LOD	Limit of Detection
N	Number of independent analytical samples
PHY:FE	Phytic acid (by HPLC/HPAE) : Iron ratio
PHY:ZN	Phytic acid (by HPLC/HPAE) : Zinc ratio
PhyFoodComp	FAO/INFOODS/IZiNCG Global Food Composition Database for Phytate
PHYT-	Phytic acid, unknown or variable method
PHYT-:FE	Phytic acid (by unknown method) : Iron ratio
PHYT-:ZN	Phytic acid (by unknown method) : Zinc ratio
PHYTAC	Phytic acid (global, old tagname)
PHYTC-	Phytic acid, determined by colorimetry (unknown)
PHYTC-:FE	Phytic acid (by unknown colorimetry) : Iron ratio
PHYTC-:ZN	Phytic acid (by unknown colorimetry) : Zinc ratio
PHYTCA	Phytic acid, determined by colorimetry after an alkaline phosphatase hydrolyzation
PHYTCA:FE	Phytic acid (by K-PHYT kit) : Iron ratio
PHYTCA:ZN	Phytic acid (by K-PHYT kit) : Zinc ratio
PHYTCPP	Phytic acid, determined by anion exchange
PHYTCPP:FE	Phytic acid (by anion exchange) : Iron ratio
PHYTCPP:ZN	Phytic acid (by anion exchange) : Zinc ratio
PHYTCPPD	Phytic acid, determined by direct precipitation
PHYTCPPD:FE	Phytic acid (by direct precipitation) : Iron ratio
PHYTCPPD:ZN	Phytic acid (by direct precipitation) : Zinc ratio
PHYTCPPI	Phytic acid, determined by indirect precipitation
PHYTCPPI:FE	Phytic acid (by indirect precipitation) : Iron ratio
PHYTCPPI:ZN	Phytic acid (by indirect precipitation) : Zinc ratio
PP	Phytate phosphorus
PP-	Phytate phosphorus, determined by colorimetry (unknown)
PPD	Phytate phosphorus, determined by direct precipitation
PPI	Phytate phosphorus, determined by indirect precipitation
RNI/RDI	Recommended Nutrient Intake/ Recommended Dietary Intake
WHO	World Health Organization
XP	Conversion factor for phytate phosphorus

INTRODUCTION

Background

There are approximately 2 billion people in the world who suffer from micronutrient deficiencies (Global Nutrition Report, 2016). An estimated 17.3% of the world's population is at risk of inadequate zinc intake (Wessells *et al.*, 2012) while almost the 30% are anaemic, many due to iron deficiency (WHO, 2013). Thus, both zinc and iron deficiencies constitute a significant public health problem.

Phytate is the storage form of phosphorus in plants and is found in high concentrations in seeds, cereals and pulses to allow the future germ to sprout adequately using its own nutrients – including the stored phosphorus. Since humans are unable to digest or fractionate phytate in the gut, and owing to its high mineral binding capacity, phytate is often classified as an antinutrient. Phytate is one of the important elements to be considered when determining the bioavailability of zinc and iron from different diets and the required dietary intake levels. For example, the recommended nutrient intakes (RNIs) for zinc and iron are about 3-times higher for diets with a low bioavailability compared to those with a high bioavailability for all age groups (FAO/WHO, 2004). These high RNIs for iron and zinc make it very difficult for individuals consuming plant-based diets to achieve their RNIs through foods alone. The low bioavailability of the minerals bound to the phytic acid can lead to deficiencies in human populations where staples like wheat, rice and maize are the main source of nutrition (Bohn *et al.*, 2008). Therefore, fortification is becoming the norm, especially in developed countries, in order to achieve the recommended intakes for zinc and iron.

Most of the phytate data available at the time of the FAO/WHO expert consultation on vitamin and mineral requirements (1998) were on total phytate content in raw foods (FAO/WHO, 2001). Since then however, it has been shown that some processing methods (fermenting, boiling, roasting, etc) can reduce the phytate content of foods. There have been very few cases where phytate data have been included in food composition tables (FCTs) and, in most of such cases, the values included only represent the content for raw products, with no details of analytical methods used to generate the phytate values.

FAO/INFOODS staff, therefore, decided to compile phytate data from the literature for raw and processed foods. These data will assist in re-evaluating certain assumptions concerning phytate and improve the basis for zinc and iron RNIs. The IZiNCG joined this process at a later stage and contributed expertise and funding received through a Bill and Melinda Gates Foundation project.

Objectives

The FAO/INFOODS/IZiNCG Global Food Composition Database for Phytate (PhyFoodComp) has several objectives:

For food composition and data compilers:

- ❖ To provide, at a global level, phytate data together with selected mineral data (iron, zinc and calcium), water, and different phytate:mineral molar ratios.
- ❖ To report these compositional data according to international quality standards with a comprehensive documentation following FAO/INFOODS standards and guidelines.
- ❖ To illustrate the differences in phytate values when using different analytical methods to determine either total phytate or the individual inositol phosphate forms.
- ❖ To provide a basis for recommending the most appropriate analytical methods for determining total phytate and the individual inositol phosphate forms.
- ❖ To allow compilers to include relevant phytate values into their national or regional food composition tables or databases (FCTs/FCDBs).
- ❖ To provide the necessary data for generating phytate retention factors from plant-based foods subjected to preparation and processing practices known to reduce their phytate content.
- ❖ To identify knowledge gaps in terms of missing compositional data.

For policies and programmes:

- ❖ To demonstrate the variability in phytate composition in raw foods due to geography, season and biodiversity by incorporating cultivars, varieties, and underutilized foods. This might assist agricultural programmes and policies to select and improve those cultivars and varieties with a low phytate content coupled with positive agricultural characteristics.
- ❖ To build an evidence-base for providing advice on processing methods, either at household or industrial level, in order to lower the phytate content and/or its mineral binding capacity, and therefore lead to an increase in mineral bioavailability.
- ❖ To enable governments and nutritionists to revise their advice on processing of legumes, seeds and cereals in order to increase the bioavailability of iron and zinc.
- ❖ To provide the basis for advice regarding improvements in infant and young child feeding, diet formulations, or product developments.
- ❖ To design and implement better nutrition projects, programmes, interventions and policies aimed at reducing mineral deficiencies such as iron and zinc.
- ❖ To increase the quality and precision of recommended nutrient intakes.
- ❖ To raise awareness of food-based methods that increase the bioavailability of iron and zinc.

Phytate structure and influence on mineral bioavailability

Myo-inositol phosphates are saturated cyclic acids found in many plant tissues, being most abundant in pulses, cereals and oleaginous seeds. They are considered the main storage form of phosphorus in plants (Mullaney *et al.*, 2007; Frank *et al.*, 2013). These products contribute greatly to human nutrition by representing about 40% or 60% of the total energy intake in the diets of developed or developing countries, respectively (Gupta *et al.*, 2015).

Phytate refers to phytic acid (myo-inositol hexaphosphate), made up of an inositol ring with six phosphate ester groups, and it's associated salts: magnesium, calcium, or potassium phytate (Gibson *et al.*, 2010). The antinutritional effect of phytate in the human diet is caused by the inability of the human digestion system to degrade it because of the absence of the intestinal phytase enzyme in humans. The phosphate groups in phytate are double charged and they strongly bind cations, mainly Fe, Zn and Ca, and impede their absorption (Hlynka 1964 ; Gupta *et al.*, 2015). The cation binding capacity is a function of the number of phosphate groups on the inositol ring (Figure 1) and their cis and trans positions. There are six inositol phosphate forms, each of which is named according to the number of phosphate groups attached to the inositol ring, i.e. IP1 to IP6. In mature unprocessed cereals, legumes and oleaginous seeds which have not been stored, myoinositol phosphates are almost exclusively in the inositol hexaphosphate (IP6) form, making it is the most abundant inositol phosphate and the strongest in terms of mineral binding capacity. In general it appears that at least five of the six sites on the inositol ring must be phosphorylated for the inositol to form a strong association with mineral ions (Sandberg *et al.*, 1999). The inhibitory effect of phytate on zinc and iron absorption is dose-dependent. In the case of iron the inhibitory effect occurs at very low phytate concentrations (i.e., 2-10 mg/meal) (Hurrell, 2003).

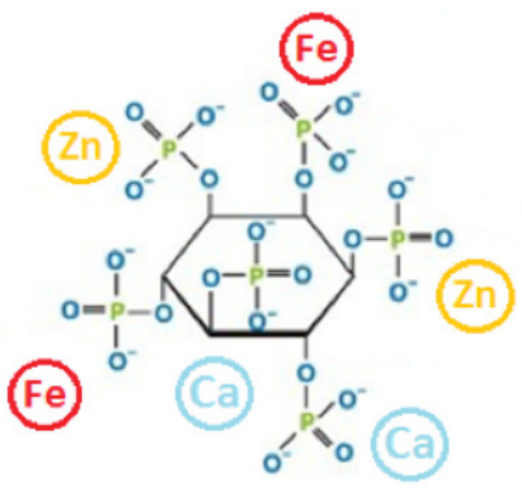

Figure 1. IP6 structure and mineral binding capacity

Available evidence indicates that phytate in pulses, cereals and other products can be reduced by simple processing methods such as soaking, germination and fermentation, thereby enhancing bioavailability of zinc and iron to some degree. However, the extent of the reduction depends on the plant species, food matrix, pH, humidity, length and conditions of the processing method; minimal reductions are achieved after soaking whole seeds or legumes. Phytate is relatively heat stable during normal household boiling temperatures of 100°C, but in industrial processing such as canning or extrusion cooking when higher temperature are used there will be some loss (Schlemmer *et al.*, 2009). Mechanical processing such as milling unrefined cereals and dehulling legumes can also lead to significant reductions in phytate, as well as minerals. Because the negative effects of phytate on zinc and iron absorption are dose dependent, molar ratios of phytate to zinc and phytate to iron minerals have been calculated to estimate the likely proportion of dietary zinc, and to a lesser extent iron, absorbed.

FAO/INFOODS/IZINCG – GLOBAL FOOD COMPOSITION DATABASE FOR PHYTATE 1.0 (PHYFOODCOMP1.0)

The FAO/INFOODS/IZiNCG Global Food Composition Database for Phytate (PhyFoodComp) is the first global repository containing analytical data on the phytate content of foods. PhyFoodComp represents the equivalent of an archival database, which means that no nutrient or antinutrient values were calculated or estimated to complete the compositional profile of a food entry. The database holds data of different edible parts of the same food; different processing stages (from raw to ultra-processed); different stages of maturity, growing and field conditions and storage; and also homemade and industrial complex recipes (composite foods).

The database can be downloaded in excel format together with its documentation (the present User Guide) free-of-charge from the INFOODS page (http://www.fao.org/infoods/infoods/en/) or from the IZiNCG website (http://www.izincg.org/).

Data sources and principles of data compilation

In 2016, FAO/INFOODS carried out a detailed literature search on the phytate content of different foods. Data sources included scientific papers, theses, university reports, FCT/FCDB and data received from the INFOODS network. The papers were mainly obtained from an exhaustive scopus search, where the information and the abstracts of each article were examined to determine the presence of useful data. Analytical data from five FCTs/FCDBs (National Food Composition Tables and The Planning of Satisfactory Diets in Kenya, 1993; Indian Food Composition Tables, 2017; Food Composition Table for use in The Gambia, 2011; FAO/INFOODS Food Composition Database for Biodiversity, 2017; FAO/INFOODS Analytical Food Composition Database, 2017) were obtained. From the 6020 articles found in the scopus search, 1859 contained employable data, of which 251 articles could be compiled in the database.

The data were evaluated and compiled according to international standards for food composition and the INFOODS food component identifiers (Klensin *et al.*, 1989), the Compilation Tool (FAO/INFOODS, 2012) and the compilation process as outlined by Greenfield and Southgate (2003). The Guidelines for Checking Food Composition Data prior to Publication of a User Database (FAO/INFOODS, 2012) were used as a tool for the final checks of the data.

Foods, food groups and coding

PhyFoodComp contains 3,377 food entries and recipes which were categorized into 19 food groups and their subgroups (see Table 1). These food groups and subgroups were adapted from the '*Food groups for simple indicators*' classification system developed by FAO for the GIFT platform (FAO/WHO, 2017), which is based on the FoodEx2 food classification and description system (EFSA, 2015).

Each food entry was assigned a unique food code (food item ID), which was constructed using the same principle throughout all food groups. The first four figures indicate the food group and subgroup followed by four sequential figures representing the food number within the respective food group. In addition, every food was coded using FoodEx2 (see Annex 1) which was useful for harmonization, for fostering food linkage across domains and for providing the possibility of semi-automated food matching thereby, making the process quicker, more robust and consistent for attaining a high quality of data linking and matching. An exact match between the PhyFoodComp foods and FoodEx2 was possible in 35% of the food entries (indicated as 'Yes' in the column called 'Exact match'). Non-exact food matches were marked by 'No' and an explanation on the missing facet/species is provided in the column 'Matching comments' of the PhyFoodComp (Table 4).

Table 1. Food groups/subgroups and numbers in the PhyFoodComp

Code of food group	Name of food groups and subgroups	N. of foods
01	Cereals and their products	1,180
	01 Rice and rice-based products	346
	02 Maize and maize-based products	148
	03 Wheat and wheat-based products	237
	04 Sorghum and sorghum-based products	74
	05 Millet and millet-based products	141
	06 Other cereals, mixed cereals or unidentified cereals and their products	233
02	Roots, tubers, plantains and their products	168
	01 Potato, sweet potato and their products	54
	02 Cassava, similar roots (excluding taro) and their products	33
	03 Taro and taro-based products	15
	04 Yam and yam-based products	21
	05 Other starchy roots and tubers (excluding sugary roots and tubers) and their products	31
	06 Plantain and plantain-based products	14
03	Legumes and their products	923
	01 Pulses (excluding soybeans) and their products	729
	02 Soybean and soy-based products	194
04	Vegetables and their products	378
	01 Leafy vegetables: fresh	234
	02 Yellow and orange vegetables: fresh	9
	03 Vegetables (excluding leafy and including fresh legumes): fresh	103
	04 Vegetables - all types: dried	33
05	Fruits and their products	139
	01 Yellow and orange fruits: fresh	46
	02 Fruits: fresh	82
	03 Fruits: dried	7
	04 Fruits: processed (excluding dried and candied)	4

06	Seeds, nuts and their products	201
07	Meat	1
	01 Offal - all types: fresh and processed (excluding dried)	0
	02 Mammals, reptiles and amphibians (excluding offal): fresh and processed (excluding dried)	1
	03 Birds (excluding offal): fresh and processed (excluding dried)	0
	04 Meat - mixed or unspecified: fresh and processed (excluding dried)	0
	05 Meat - all types: dried	0
08	Insects and grubs	5
09	Eggs: fresh and processed	0
10	Fish and shellfish	6
	01 Freshwater fish (excluding offal): fresh and processed (excluding dried)	1
	02 Diadromous fish (excluding offal): fresh and processed (excluding dried)	1
	03 Marine fish (excluding offal): fresh and processed (excluding dried)	1
	04 Offal - fish and shellfish: fresh and processed (excluding dried)	0
	05 Shellfish (excluding offal) - all types: fresh and processed (excluding dried)	0
	06 Fish and shellfish - mixed or unspecified: fresh and processed (excluding dried)	0
	07 Fish and shellfish (including offal) - all types: dried	3
11	Milk and milk products	2
	01 Milk: fresh and processed (excluding fermented, cream, whey, cheese and other milk products)	2
	02 Fermented milk products	0
	03 Cream, whey and any other milk products excluding fermented milk products and cheese	0
	04 Cheese	0
12	Fats and oils	4
	01 Vegetable fat and oil (excluding red palm oil)	3
	02 Red palm oil	1
	03 Animal fat and oil	0
13	Beverages	24
	01 Alcoholic drinks	0
	02 Drinking water	1
	03 Tea, herbal tea, coffee and cocoa	21
	04 Clear broths	0
	05 Soft drinks	1
	06 Fruit and vegetable drinks	0
	07 100% fruit and vegetable juices	1
14	Sweets and sugars	43
	01 Dough-based sweets	29
	02 Chocolate-based sweets	1
	03 Fruit and nut-based sweets	12
	04 Other sweets	0
	05 Sugars	2
15	Spices, herbs and condiments	114
	01 Herbs and spices	84
	02 Condiments	30
16	Foods for particular nutritional uses	111
	01 Infant formulas and ready-to-eat meals for infants and young children	107
	02 Foods for weight reduction	0
	03 Foods for sporting people	0
	04 Foods for medical purposes	4
	05 Food supplements and similar	0
17	Food supplements and similar	9
18	Food additives	2
	01 Sweeteners and flavorings	0
	02 Colorants	0
	03 Other food additives	0
	04 Home-preparation aids	0
	05 Ingredients for food fortification/enrichment and supplements	0
	06 Microbiological or enzymatic ingredients	2
19	Complex recipes	66
	01 Industrial recipes	6
	02 Homemade / Food service recipes	60
	TOTAL ENTRIES	3,377

Phytate data were not available for all the food groups and subgroups; therefore, some groups/subgroups remained empty. Data on food groups that contain no phytate (e.g. some beverages, animal-source foods, etc.) were included when available in order to emphasize the absence of phytate in these groups.

In some cases, the assignment of a food to one specific food group was difficult, e.g. peanuts are botanically legumes but are considered as nuts in terms of their consumption and nutrient profile. This should be taken into consideration when searching for a food, as the assignment to a single food group might not be unequivocal.

It is also recognized that the identification of the scientific names of species, subspecies and other lower species levels (especially for wild and underutilized foods), can often be difficult. English and scientific names are therefore presented in this paper as found in the original literature, if available, and may result in the use of different names for the same food (e.g. maize or corn as English name for *Zea mays*).

Components, their definitions and expressions

1. Phytate

All values, including liquids, are presented per 100 g edible portion (EP). All compositional data were standardized to this expression according to the *FAO/INFOODS Guidelines for converting units, denominators and expressions* (FAO/INFOODS, 2012b). Data that could not be converted to 100 g edible portion were excluded (e.g. when data are published as per 100 g dry matter and no value for the water content was available to calculate the values as per 100 g EP).

INFOODS component identifiers, also called tagnames, were used to describe the 35 food components considered. The tagnames were developed for the identification of food components facilitating the data interchange (Klensin *et al.*, 1989).

Because the different chemical methods use different principles and instruments, they generate significantly different phytate values. In addition, advances in analytical methods allow the separation and determination of different forms of inositol phosphates (IPs) – IP3 to IP6. Therefore, new INFOODS tagnames had to be created prior to data compilation (see Table 2). The previous tagname '*Phytic Acid*' PHYTAC, which was used for all the different available methods for analysing phytate, is now considered out-dated. Hence, all data that were previously reported under PHYTAC, were reclassified according to the corresponding new tagnames by reviewing the original source.

In general, the values of food components (water and minerals) given in the original documents were included in the database, alongside with the calculated values as given in the original source, e.g. values for phytate. Thus, the values in this database have not been estimated or calculated for any nutrient or antinutrient data (except for changing units).

Table 2. Tagnames, description and units considered in the PhyFoodComp

Component	INFOODS tagname	Unit	Comment
Water	**WATER**	g	-
Iron	**FE**	mg	-
Zinc	**ZN**	mg	-
Calcium	**CA**	mg	-
Phytic acid, determined by indirect precipitation	**PHYTCPPI**	mg	Phytic acid, based on phytate phosphorus estimated by indirect ferric precipitation
Phytic acid, determined by direct precipitation	**PHYTCPPD**	mg	Phytic acid, based on phytate phosphorus estimated by direct ferric precipitation
Phytic acid, determined by colorimetry after an alkaline phosphatase hydrolyzation	**PHYTCA**	mg	Phytic acid, based on phosphate estimated after an alkaline phosphatase treatment (K-PHYT kit developed by Megazyme)
Phytic acid, determined by anion exchange	**PHYTCPP**	mg	Phytic acid, based on phytate phosphorus estimated by ferric precipitation with an additional anion-exchange purification step
Phytic acid, determined by colorimetry (unknown)	**PHYTC-**	mg	Phytic acid, based on phytate phosphorus estimated by unknown ferric precipitation type or additional purification steps
Phytate phosphorus, determined by indirect precipitation	**PPI**	mg	-
Phytate phosphorus, determined by direct precipitation	**PPD**	mg	-
Phytate phosphorus, determined by colorimetry (unknown)	**PP-**	mg	-
Conversion factor for phytate phosphorus	**XP**	-	Conversion factor used to convert phytate phosphorus to phytic acid
Inositol triphosphate	**IP3**	mg	Analyzed and expressed as inositol triphosphate
Inositol tetraphosphate	**IP4**	mg	Analyzed and expressed as inositol tetraphosphate
Inositol pentaphosphate	**IP5**	mg	Analyzed and expressed as inositol pentaphosphate
Inositol hexaphosphate	**IP6**	mg	Analyzed and expressed as inositol hexaphosphate
Inositol penta + hexaphosphate	**IP5_A_IP6**	mg	SUM of IP5 and IP6 forms
Inositol tetra + penta + hexaphosphate	**IP4_A_IP5_A_IP6**	mg	SUM of IP4, IP5 and IP6 forms
Total inositol phosphates (SUM of all IP forms)	**IPSUM**	mg	SUM of IP3, IP4, IP5 and IP6 forms
Phytic acid, unknown or variable method	**PHYT-**	mg	-
Phytic acid (by indirect precipitation) : Iron ratio	**PHYTCPPI:FE**	-	Phytate:Iron ratio calculated using phytic acid analyzed by indirect ferric precipitation (PHYTCPPI) - *See equation 2*
Phytic acid (by indirect precipitation) : Zinc ratio	**PHYTCPPI:ZN**	-	Phytate:Zinc ratio calculated using phytic acid analyzed by indirect ferric precipitation (PHYTCPPI) - *See equation 1*
Phytic acid (by direct precipitation) : Iron ratio	**PHYTCPPD:FE**	-	Phytate:Iron ratio calculated using phytic acid analyzed by direct ferric precipitation (PHYTCPPD) - *See equation 2*
Phytic acid (by direct precipitation) : Zinc ratio	**PHYTCPPD:ZN**	-	Phytate:Zinc ratio calculated using phytic acid analyzed by direct ferric precipitation (PHYTCPPD) - *See equation 1*
Phytic acid (by K-PHYT kit) : Iron ratio	**PHYTCA:FE**	-	Phytate:Iron ratio calculated using phytic acid analyzed by colorimetry after an alkaline phosphatase hydrolyzation (PHYTCA) - *See equation 2*

Phytic acid (by K-PHYT kit) : Zinc ratio	**PHYTCA:ZN**	-	Phytate:Zinc ratio calculated using phytic acid analyzed by colorimetry after an alkaline phosphatase hydrolyzation (PHYTCA) - *See equation 1*
Phytic acid (by anion exchange) : Iron ratio	**PHYTCPP:FE**	-	Phytate:Iron ratio calculated using phytic acid analyzed by ferric precipitation with an additional anion-exchange purification step (PHYTCPP) - *See equation 2*
Phytic acid (by anion exchange) : Zinc ratio	**PHYTCPP:ZN**	-	Phytate:Zinc ratio calculated using phytic acid analyzed by ferric precipitation with an additional anion-exchange purification step (PHYTCPP) - *See equation 1*
Phytic acid (by unknown colorimetry) : Iron ratio	**PHYTC-:FE**	-	Phytate:Iron ratio calculated using phytic acid analyzed by unknown ferric precipitation (PHYTC-) - *See equation 2*
Phytic acid (by unknown colorimetry) : Zinc ratio	**PHYTC-:ZN**	-	Phytate:Zinc ratio calculated using phytic acid analyzed by unknown ferric precipitation (PHYTC-) - *See equation 1*
Phytic acid (by unknown method) : Iron ratio	**PHYT-:FE**	-	Phytate:Iron ratio calculated using phytic acid analyzed by an unknown method (PHYT-) - See equation 2
Phytic acid (by unknown method) : Zinc ratio	**PHYT-:ZN**	-	Phytate:Iron ratio calculated using phytic acid analyzed by an unknown method (PHYT-) - *See equation 1*
Phytic acid (by HPLC/HPAE) : Iron ratio	**PHY:FE**	-	Phytate:Iron ratio calculated using phytic acid analyzed by HPLC/HPAE (IP4, IP5 and IP6 forms) - *See equation 4*
Phytic acid (by HPLC/HPAE) : Zinc ratio	**PHY:ZN**	-	Phytate:Zinc atio calculated using phytic acid analyzed by HPLC/HPAE (IP5 and IP6 forms) - *See equation 3*

2. Analytical methods for detecting phytate and separating the inositol phosphate forms

The methods for PHYTCPPI, PHYTCPPD, PHYTCA, PHYTCPP, PHYTC-, PHYT- provide values which are said to represent total IP6. They are based on indirectly measuring phosphorus from phytate, on the assumption that all the phosphate originated from the IP6 form, which may not necessarily be the case. The methods also assume that the phosphate has not been derived from other phosphorylated compounds that may exist. Hence, these procedures may overestimate the IP6 content of some foods, especially plant-based foods and diets when food preparation or processing has resulted in varying degrees of phosphorylation and/or other nucleotides are present. Consequently, the information provided may be misleading in relation to the bioavailability of iron and zinc because their absorption is inhibited primarily by the IP6 and IP5 forms. When comparing between precipitation methods, the indirect precipitation appears to be more convenient and rapid than direct methods. However, when the phytate level is low, it is subject to large errors. The method designated by the tagname PHYTCPP, developed by Harland and Oberleas (1986), includes an additional step in which the phytate extract is first purified and concentrated by anion-exchange chromatography prior to converting it to phosphate. The phytic acid (IP6) content termed more correctly ‘phytic acid equivalents’ is then calculated on the basis that 1 g phytic acid phosphorus is equivalent to 3.55 g phytic acid (IP6).

More specific methods of measuring the various forms of inositol phosphates often involve high-performance liquid chromatography (HPLC). Several HPLC methods are available, each of which uses anion exchange columns to purify and concentrate the phytate extract, followed by HPLC to separate and detect the individual inositol phosphate forms (Schelmmert *et al.*, 2009). Depending on the degree of phosphorylation, the tagnames assigned in the Global Food Composition Database for phytate range from IP3 to IP6 for the individual inositol forms. Various combinations of inositol phosphate forms are also designated by different tagnames (Table 2).

3. Phytate:mineral molar ratios

The International Zinc Nutrition Consultative Group (IZiNCG) recommends the use of phytate:zinc molar ratios of the diet, and Hurrell and Egli (2010) recommend the use of dietary phytate:iron molar ratios to estimate the negative effect of phytate on zinc and iron bioavailability, respectively. IZiNCG concluded that in most diets, neither dietary calcium (or protein) adds significant predictive power to the algorithm used to predict the percent zinc absorption (Brown *et al.*, 2004).

While defining the best approach for the ratio calculation for calcium, it was concluded that the influence of phytate on calcium absorption is uncertain. It is also currently unknown if the adverse effect of inositol phosphates on calcium absorption is restricted to the higher inositol phosphates, such as IP5 and IP6. For all these reasons, phytate:calcium ratios were not reported in this database (Gibson *et al.*, 2010).

The different tagnames were used to express the calculated molar ratios for phytate to zinc or iron. The following formulas were used to calculate the Phytate:Zn and Phytate:Fe molar ratios:

$$\frac{\frac{Phytate\ (mg)}{660\ (MW)}}{\frac{Zn\ (mg)}{65.38\ (AtW)}}$$

Equation 1. PHYT:ZN formula

$$\frac{\frac{Phytate\ (mg)}{660\ (MW)}}{\frac{Fe\ (mg)}{55.845\ (AtW)}}$$

Equation 2. PHYT:FE formula

$$\frac{\frac{IP6\ (mg)}{660\ (MW)}+\frac{IP5\ (mg)}{580\ (MW)}}{\frac{Zn\ (mg)}{65.38\ (AtW)}}$$

Equation 3. PHYT:ZN formula

$$\frac{\frac{IP6\ (mg)}{660\ (MW)}+\frac{IP5\ (mg)}{580\ (MW)}+\frac{IP4\ (mg)}{500\ (MW)}}{\frac{Fe\ (mg)}{55.845\ (AtW)}}$$

Equation 4. PHYT:FE formula

Where:
- Atw : Atomic weight
- MW : Molar weight

The two first formulas listed above (equation 1 and 2) were used to calculate the phytate to mineral ratios for the entries in which the phytate quantification was done by precipitation or unknown methods (PHYTCPPI, PHYTCPPD, PHYTCA, PHYTCPP, PHYTC-, PHYT-). These procedures provide phytate values, assumingly representing IP6, even though the phytate phosphorus (PP) is released from IP4, IP5 and IP6. Therefore, in the equation, the molar weight of IP6 (660 g/mol) is used. This may result in an overestimation of the phytate content of plant-based foods, especially if processed, and of the values calculated by these ratios.

For the entries in which the specific amount of each inositol phosphate form was defined (IP4, IP5, IP6, IP5_A_IP6, IP4_A_IP5_A_IP6, IPSUM), the specific molecular weight corresponding to each form was considered for the calculation (equation 3 and 4). For the phytate:iron ratio calculation, IP4, IP5 and IP6 were used in the equation (equation 4), as those are the ones that can bind to the iron. For the phytate:zinc equation, only IP5 and IP6 were considered (equation 3), as no effect has been described with the lower forms.

The molar ratios for iron and zinc were calculated, when the required data were available. The phytate to mineral molar ratios calculated can be used to predict the inhibitory effect of the antinutrient on the mineral bioavailability. It is assumed that, for foods, the bioavailability of iron is affected by a molar ratio for phytate:iron above 1, or even above 0.4 for a significant effect on iron absorption (Hurrell *et al.*, 2010) because the inhibitory effect is observed at very low phytate concentrations (i.e., 2-10 mg/meal) (Hallberg *et al.*, 1989). In contrast, IZiNCG tentatively suggests that phytate:zinc molar ratios characterizing unfermented, cereal-based diets (i.e., > 18) were likely to adversely affect zinc bioavailability (Brown *et al.*, 2004). In the WHO/FAO semi-quantitative algorithm, diets were classified mainly on the basis of their source of dietary protein and their phytate-zinc molar ratios, with ratios > 15 likely to compromise zinc bioavailability (WHO/FAO, 2004).

Arrangement of the Excel database and worksheets

For an easy standardization of the data, the Compilation Tool (FAO/INFOODS, 2011) was used, which is a simple food composition database management system in MS Excel. The Compilation Tool was adapted for this purpose by adding new fields to the overall structure in order to capture additional information (Table 4). The PhyFoodComp contains different worksheets with specific information:

Table 3. Worksheets in the PhyFoodComp

Title	Description
'Introduction'	Gives an introduction to the database, including information on copyright and disclaimer
'Codes'	Contains an overview of all the codes, acronyms and abbreviations that are included in the PhyFoodComp datasheets (sheets *'01'* to *'19'*). They include the codes for the Sample type, Processing/ influencing factors, Compilers identification (ID) and data abbreviations
'Components'	Gives an overview of all the components covered by the PhyFoodComp datasheets (sheets *'01'* to *'19'*), including their component names, INFOODS tagnames and comments, units and denominators
'Food groups'	Contains the food group classification based on the '*Food groups for simple indicators*' system developed by the FAO/WHO GIFT platform that is used in PhyFoodComp (see Table 1)
'01 Cereals and their products'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'02 Roots, tubers, plantains and their products'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'03 Legumes and their products'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'04 Vegetables and their products'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'05 Fruits and their products'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'06 Seeds, nuts and their products'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'07 Meat'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'08 Insects and grubs'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'10 Fish and shellfish'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'11 Milk and milk products'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'12 Fats and oils'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'13 Beverages'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'14 Sweets and sugars'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'15 Spices, herbs and condiments'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'16 Foods for particular nutritional uses'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'17 Food supplements and similar'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'18 Food additives'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'19 Complex recipes'	Used to present data for the specific food group individually, including compiled and calculated values for the components considered per 100 g EP on FW
'Bibliography'	Presents the entire reference list with the corresponding biblioID

The following variables can be found in most food groups and information is provided as completely as possible, i.e. as given in the data source.

Table 4. Variables capturing general information of a food entry in the PhyFoodComp

Column title	Description
'Food item ID'	Indicates a unique identification code for each food entry (the first four figures indicate the food group and subgroup followed by four sequential figures representing the food number within the respective food group)
'Old code (as in the original source)'	Indicates the unique identification code for the food entry used in the original FCT/FCDB
'Food group'	Indicates which of the 19 groups considered is the product part of (see section Foods, food groups and coding)
'Subgroup'	Indicates the corresponding subgroup of the product (see section Foods, food groups and coding)
'FoodEx2 code'	Indicates the FoodEx2 identification code assigned to each of the food entries
'FoodEx2 name'	Gives the description of the FoodEx2 code given to the food entry
'Missing facet'	Gives the FoodEx2 code that would have to be applied as facet of a facet described within the main code
'Exact match'	'Yes' indicates a full match between the food entry and FoodEx2 code, while 'No' indicates that the food entry couldn't be completely described within the system
'Matching comments'	Gives the reasons why the exact match wasn't possible
'Country, region'	Indicates the sampling place (country/region)
'Food type'	Gives the type according to the '*Cultivar/Variety/Accession name*' column and the information extracted from the original source: C: cultivar, A: accession, V: variety, Cn: clone, BC: breeding clone, G: genotype, B: breed, H: hybrid, W: wild, T: transgenic, U: underutilized, L: landrace, Li: line, M: mutant
'Food name in own language'	Gives the food name in the own/local language
'Food name in English'	Gives the food name in English along with a food description
'Processing/Influencing factor'	Minuscule letters indicate the state of the food: r= raw; p=processed; d=dried And the processing method or nutrient content influencing factor: ws: water-soaked, wss: water and salt-soaked, as: ash-soaked, s-: soaked (other or unknown), f: fermented, f-: unknown fermentation, pb: parboiled, wb: water-boiled, wsb: water and salt-boiled, b-: boiled (other or unknown) bk: baked, rp: recipe (mix of ingredients, not industrialized, cooked), rpi: industrial recipe (mix of ingredients, industrialized, cooked), ro: roasted, st: steamed, fr: fried, ac: autoclaved, mw: microwaved, c: cooked (unknown exact process), bl: blanched, t: toasted, sk: smoked, cn: canned, dt: defatted, ex: extruded, ir: irradiated, fz: frozen, a: abrased, th: thermally treated (in solution), dh: dehulled, g: germinated, sd: stored, ft: soil fertilization, pt: pesticide application, ly: lyophilization, gr: grilled, ch: chemically treated
'Species/Subspecies'	Gives the scientific name as stated in the original source
'Cultivar/Variety/Accession name'	Gives the specific name of the type (cultivar, variety…) according to the original source
'Season'	Indicates the sampling season
'Other'	Gives additional information on factors that can influence the nutrient composition (e.g. slaughter weight, size, sex, practices, maturity stage, soil conditions, storage time, cooking and preserving methods)
'n'	Gives the number of independent analytical samples (often composite samples). It should not be confused with the number of replicates
'Comments on data processing/methods'	Gives information on value conversion (e.g. conversion from dry matter to fresh weight, conversion of denominator to per 100 g EP), information on analytical methods and/or assumptions made on data expression or any other information on the data that are not captured in another field
'Publication year'	Publication year of the source
'BiblioID'	Indicates the reference as ID to link the sheet 'Bibliography'
'Compiler ID'	Gives the identification of the compiler (two/three capital letters of initials). Compilers, who revise and change data of a food entry, add their acronym to the former ID (separated by a coma)

Documentation and quality of data

Data were evaluated for quality according to relevant sections of the Guidelines on Checking Food Composition Data prior to the Publication of a User Database/Table (FAO/INFOODS, 2012). Systematic checks at the component level were applied on the entire dataset, in order to detect errors, e.g. typing/ unit errors or unreasonably high or low values of a component. Published data in FCT/FCDB were also re-checked.

In some of the databases from which analytical data were extracted and compiled, suspicious values (e.g. phytate values of ≈1 mg for ground bean) were marked using brackets if no reasonable explanation could be found (e.g. analytical method or genetic variance). These data were retained within the database in order to reflect the original expression of the values by the corresponding authors.

It is important to note that, in some cases, data in PhyFoodComp can be difficult to use in a FCT as the water value is very low –in many sources the processed samples were dried again to achieve a similar water content as the raw ones to allow comparison–. For these cases, if compilers want to use the data in FCT, we recommend to adjust the phytate value to the corresponding water content of their foods.

Symbols and abbreviations used in the PhyFoodComp:

- tr - trace
- [ ] - for data of low quality or implausible data
- < LOD - below limit of detection
- n - number of independent analytical samples

FUTURE STEPS

FAO/INFOODS/IZiNCG aim to continue to collect and compile high quality compositional data of foods and to publish new versions of this database, working to acquire and disseminate adequate and reliable data in order to meet the needs of its various users (including government agencies, nutrition scientists and educators, health and agriculture professionals, policy makers and planners, food producers/processors/ retailers and consumers). Although foods containing high phytate values were covered in PhyFoodComp, phytate data for other food groups and subgroups might become available in the near future. It is also possible that more analytical data, e.g., centered on separate forms (IP3-IP6) rather than only total phytate and/or including coverage of all relevant food preparation and processing methods, will become available in the future. Furthermore, it is expected that more researchers will share available data in their custody and that a closer collaboration with scientific journals will be established in order to have access to these data. This will encourage data owners to contribute more actively to further populate the FAO/INFOODS/IZiNCG Global Phytate Food Composition Database, while being recognized as data compilers.

Following this, the next step is to establish retention factors for phytate based on various food processing practices that could be applied to mixed dishes and specific food and food subgroups, in an effort to improve the accuracy of the phytate values for prepared foods and diets. This will also provide much needed information on the most suitable processing methods per food category to reduce the phytate content and thus have the potential to increase the bioavailability of iron and zinc in plant-based foods and diets. Increasing the intake of bioavailable micronutrients through food-based approaches remains a highly sustainable means of ensuring the long-term prevention and treatment of micronutrient deficiencies. Such phytate-reducing processing strategies for raw, cooked and/or processed foods should be integrated into national food, agriculture, nutrition and health programmes/policies to enhance their effectiveness and sustainability (Gibson *et al.*, 1998).

Studies suggest that IP6 and IP5 bind zinc and iron sufficiently strongly to inhibit both zinc and iron absorption. Additional research is necessary to determine the specific affinity of iron to IP4 or IP3. Such affinity factors could then be used in the molar ratio equations reflecting more closely the effect of the individual inositol phosphate forms on the bioavailability of iron, and possibly zinc.

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The complete list of data sources can be found in the PhyFoodComp 1.0 Excel sheet available on www.fao.org/infoods/infoods/tables-and-databases/faoinfoods-databases.

ANNEX 1. FoodEx2 coding system

FoodEx2 is a comprehensive but flexible food classification and description system aimed to describe and group foods in data collections across different domains in a harmonized way to facilitate data linking and matching. It was developed by the European Food Safety Authority (EFSA, 2015). FAO is working with EFSA to render FoodEx2 more globally applicable. FAO, EFSA and other organizations aim to code existing and future data using FoodEx2, e.g. food composition, food consumption, food safety, food prices and other food-related data to facilitate national and international data linkages across domains. Therefore, the FAO/INFOODS/IZiNCG Global Food Composition Database for Phytate foods were also coded using the FoodEx2 system standards.

The FoodEx2 code consists of a main base term describing the food. Other descriptors can be included in the code by adding a hash character '#' after the base term, and then the sequence of facet codes to describe the food as in detail as necessary.

A typical FoodEx code looks like the following:

A001D#F09.A0EXD$F28.A07LK$F28.A07GL

It describes: *Rice grain (A001D), PROCESS = Parboiling / pre-gelatinising (F09.A0EXD), PROCESS = Boiling (F28.A07LK), FORTIFICATION-AGENT = Iron (F28.A07GL)*. The level of detail (added facets) is always based on the available information. Hence, in other cases it might be a much simpler code like:

A001D

Meaning '*Rice grain*' without any further detail.

It is important to make clear that after its first release in 2011, the FoodEx2 system has been broadly tested in various practical situations, allowing its evaluation, and the identification of areas for improvement. As a consequence, FoodEx2 has been reviewed and revised to accommodate the needs expressed by the different users. To code PhyFoodComp1.0, the last version available (June 2017, https://www.efsa.europa.eu/en/data/data-standardisation) was used. Due to an extremely detailed food description in PhyFoodComp1.0, some food descriptions and foods could not be coded exactly. Therefore, possible future improvements were identified that could be incorporated in future FoodEx versions. These were communicated to EFSA and could also be included in future editions of PhyFoodComp enabling exact coding matches to be achieved (EFSA, 2015).

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