All these factors indicate that the hydrate promotion effect has no simple correlation with the hydrophobicity or nature of the amino acid side chain. Therefore, the exact mechanism of hydrate promotion at this stage remains obscure. Nevertheless, certain amino acids, such as l-met, l-cys, l-nle, l-val, l-nva, etc. have been proved to be good promoters for CO_2 hydrate formation. The faster gas uptake kinetics and effective hydrate conversion at favourable thermodynamic conditions could be utilized for CO_2 gas storage applications.

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Low phytic acid peanut: a potential tool to overcome mineral malnutrition in humans

Malnutrition affects over one billion people worldwide and thus one out of six humans is malnourished. Though the green revolution solved the problem of malnutrition to the great extent, people living in developing and under-developed countries still face micronutrient malnutrition, which is a result of imbalanced diet and intake of insufficient micronutrients. Iron and zinc deficiencies together contributing to loss to GDP is at least US$ 5 billion in China and India alone[1].

Among nuts, peanut is considered as superfood and has been effective in treating malnutrition across the globe. Peanuts have more protein and 30 essential vitamins and minerals that are effective to combat acute malnutrition. Nutritive value of peanuts reveals that nearly half of the mass of the kernel is made of lipids, whereas protein and carbohydrate constitute nearly one-fifth to one-fourth of the kernel mass. The total mineral content of peanuts is in the range 2–3% and is a good source of iron, potassium, calcium, sodium and magnesium. It also contains appreciable amounts of manganese, copper, zinc and boron[2]. Peanut kernels contain more protein than meat and egg, and far more than any other vegetable foods, except soybean. The National Aeronautical and Space Administration, USA, has selected peanut as food for advance life-support systems for extended space missions[2].

In addition to the huge beneficial properties, peanuts also have very high levels of phytic acid than wheat, maize and barley and lower inorganic phosphorus content than pigeon pea, chickpea, urdbean and soybean[3]. Phytic acid content is 0.2–4% in peanuts and a huge variability among peanut genotypes with respect to phytic acid content has been observed (812.3–1713.8 mg/100 g seed)[4]. Phytate is a chelator of cations such as Fe^{2+}, Zn^{2+}, Ca^{2+} and Mg^{2+}, and reduces their bioavailability in humans and monogastric animals[5]. In developing countries where staple food is mainly seed-based, it leads to serious alimentary deficiencies in humans[3]. Non-ruminant animals are unable to digest phytic acid, and the undigested phytic acid promotes water eutrophication and environmental pollution[6]. This warrants the development of low phytic acid crops[7].

Phytic acid in plants is synthesized either by lipid-dependent pathway or by lipid-independent pathway, which begins with glucose 6-phosphate (G6P) (1) and 1D-myo-inositol 3-phosphate synthase (MIPS) catalysing this step. In lipid-dependent pathway, inositol gets converted into phosphatidylinositol (PtdIns) and is later phosphorylated to yield PtdIns(4,5)P_2, subsequently being hydrolysed via the action of a specific phospholipase C to yield Ins(1,4,5)P_3 and finally phytic acid. In lipid-independent pathway, inositol is sequentially phosphorylated to di-, tri-, tetra-, penta phosphates and finally to phytic acid[8].

A reduction in phytic acid content and increase in P content in seeds is desirable as it reduces the environmental impact due to animal waste. Efforts to reduce phytic acid mainly involve three approaches: (1) expression of recombinant microbial phytase; (2) generating low phytic acid mutant phenotypes through mutation – several such mutants have been identified in rice[9], wheat[10], maize[11], soybean[12] and other crops; (3) generating transgenic lines by suppressing genes involved in phytic acid biosynthesis. An advantage of the third approach is that genetic manipulations can be carried out in a developmentally and physiologically regulated system[13], which is otherwise lacking in the mutagenic approach.

Unlike cereals, molecular breeding or genomic assisted breeding efforts are limited in peanut. When compared to other genomic resources, molecular markers can be directly applied in crop breeding and for marker-assisted breeding to be utilized in developing low phytic acid genotypes, genes/quantitative trait loci (QTLs) involved in this pathway have to be identified[14]. At present, several genomic resources like expressed sequenced tags (ESTs), physical maps, molecular markers, QTL identification and identification of genes associated with the traits of interest are available. Recently, *AhPIPK1*, one of the genes involved in lipid-dependent phytic acid biosynthetic pathway[15], and *AhIPK2* and *AhITPK1* involved in lipid-independent phytic acid biosynthetic pathway[16] have been identified in peanuts. This opens up new avenues for practising genomic-assisted breeding for reducing phytic acid content in peanuts. Low phytic acid genotypes of maize, barley and soybean have increased feed P utilization in poultry, fish and pigs[17]. Consumption of low phytate maize in humans has increased Fe, Ca and Zn absorption by 30–50% (ref. 18). Development of low-phytate genotypes can be effective to combat malnutrition, since it has already been proven to increase 'fractional absorption' of Fe, Zn and Ca.

Breeding for low phytate peanut genotypes promises to be cost-effective intervention in the fight against micronutrient deficiencies in developing economies. However, tools and genomic resources are still not available to develop such varieties. Our study has identified genes in the phytic acid biosynthetic pathway that can be used to alter their expression, or identify genotypes that have lower expression of these genes that can be used in molecular breeding to reduce the phytate content in peanuts.

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