INFANT NUTRITION

Complementary Foods & Global Fortification Challenges

A critical window of opportunity lies in the first two years of life wherein optimal feeding would ensure appropriate growth and development of infants.

by Michael Joseph, Sajid Alavi and Quentin Johnson

The quality of nutrition in the First 1,000 Days – from the start of mother's pregnancy through the child's second birthday – can decide the future of the child. This is the period of rapid development of brain and body, which will have a lasting effect throughout the life of the child. During the post-natal period of growth, many physiological changes occur, enabling infants to consume foods of varying composition and texture. Exclusive breastfeeding for 6 months is the right way of providing ideal nutrition during the early phase of life of infants. Thereafter, to meet the additional energy and nutritional needs, complementary foods (CFs) should be introduced into the diet along with breast feeding up to 2 years of age or beyond. Nutrient density is an important component of CFs if they have to achieve their purpose. A critical window of opportunity lies in the first two years of life wherein optimal feeding would ensure appropriate growth and development of infants.

› *Fortified complementary foods are distributed worldwide through assistance programs run by government and non-profit institutions to address the challenges of infant and child nutrition in vulnerable populations.*

The Role of Complementary Foods

Complementary foods have an important role in infant nutrition. Traditional CFs are often cereal-based and prepared at home, such as ogi (fermented cereal porridge), moin-moin (steamed bean cake) and rice paste/porridge. Other such foods are made from fruits, vegetables and dairy ingredients. Creating awareness of best practices among caregivers, who prepare and feed the CFs, is a first step towards addressing infant nutrition. Good complementary feeding practices have shown to lower the incidences of stunting. On the other hand, deficiency in timely introduction of CFs is a huge problem as highlighted by the fact that globally only 60 percent of children aged 6-8 months receive solid, semi-solid or soft foods. Low frequency of feeding and low amounts of feeding are also commonly encountered issues. In addition, CFs are often riddled with quality problems, such as being too dilute, lacking in nutrition profile and energy content, and having poor micronutrient profile and bioavailability. Thus focus is also needed on increasing energy and enhancing nutrient bioavailability of CFs, and macro- and micronutrient fortification would be an important way to address this need. The challenges associated with CFs and potential approaches are discussed in more detail in the next section.

Complementary Food Challenges

Due to the various challenges associated with complementary foods including caregiver practice and quality, and also the complexities of understanding the exact pathways of nutrient bioavailability and absorption in the body, there is limited consensus on the "fit for purpose" role of CFs in the debate on infant nutrition. The role of food matrices (components of food and their molecular interactions), form of nutrients available for consumption and various inhibitory and synergistic factors, all have a major role in the nutritional quality of CFs and health outcome for infants. Traditional home-made CFs being of cereal and legume origin, contain anti-nutritional factors, such as phytate, lectins, tannins and digestive enzyme inhibitors, which reduce the bioavailability of macro and micronutrients and could exacerbate nutritional deficiencies. For example, phytate or phytic acid can inhibit absorption of essential minerals such as zinc, iron, calcium, magnesium and phosphorous. In fact, the presence of phytic acid can bind up to 80% of phosphorous. A lack of phosphorous may limit the deposition of lean body mass and linear growth of infants. The impact of common inhibitory components of food matrices on nutritional outcomes is summarized in table 1.

Food matrices are modified by processing and storage, which brings numerous benefits like increasing digestibility, enhancement in bioavailability of micronutrients and improving shelf-stability. However, in some cases foods can undergo nutritional degradation when subjected to processing. The exposure to air, light, transition metal elements (particularly iron & copper), heat and moisture during processing and storage affects vitamins, minerals and other nutrients. For example, loss of vitamin C due to common food processing methods like freezing, drying, cooking, cooking and draining, and reheating has been reported up to 30%, 80%, 50%, 75% and 50%, respectively, when compared to raw foods. The role of processing in modification of food matrices and impact on nutrient bioavailability can be complex. Cooking improves digestibility of cereals and other grains. However, in the case of sorghum, a staple in many parts of the world, traditional cooking methods actually decrease protein digestibility, due to changes in molecular structure.

Impact on Taste

An often overlooked aspect of processing is that it can make foods taste batter. Taste and acceptability are important factors that determine effectiveness of CFs. A product can be considered acceptable if more than 75% of the serving is consumed and adverse reaction is reported in less than 10% of cases. A tastier product would increase the consumption by infants, and addition of flavor enhancers, lipids and sugars during processing can also help in improving the overall acceptability. Water content in the food matrix during processing can affect energy density and viscosity, especially in the case of mashes or porridges that are often fed to infants as CFs. Too much water reduces the energy density and increases the bulk causing recipients to consume less solids thereby lowering the nutritional efficacy. On the other hand, viscous foods can have poor acceptability and may create difficulty for child in swallowing and consumption, thus leading to lower nutritional benefits.

Besides cooking, simple matrix modification methods or primary processing techniques, like malting, germination, fermentation, soaking or pounding, are often employed for homemade CF preparation and tend to increase nutrient bioavailability. For example, they can reduce the phytate content of grains. Other than reducing anti-nutritional factors, processes like malting, germination and fermentation improve the starch and protein digestibility of foods. However, these techniques cannot compensate for the overall low iron and zinc content in homemade CFs.

Homemade CFs generally lack variety and are not fortified, thus leading to a nutrient deficient preparation that affects child's growth and nutritional status. These foods are low in "problem nutrients" – iron, zinc, and calcium, vitamin A, and also carry too few essential fatty acids.

Many times, in low resource settings the infants are fed with "family foods" which put them at risk of multiple micronutrient deficiencies.

› *Fortified blended foods, such as corn soy blend (CSB), are complementary foods that are fortified with dairy protein, oil and micronutrients. Every year the US government ships hundreds of millions of tons of CSB to several countries around the world, in dry and bagged form, where it is rehydrated and consumed as porridge in homes.*

Commercial CFs are also often available for purchase and are usually fortified with micronutrients, but their adoption is limited by the purchasing power of the family. Other reasons for low preference for commercial CFs are the beliefs that homemade foods are fresh and have no added preservatives, and are cleaner, healthier and more nutritive. The latter is, however, not often the case, unless homemade CFs are prepared from a mix of plant and animal derived foods such as dairy ingredients. Other than products from multi-national companies, many locally manufactured lower cost CFs are also available in low income countries. But local CF manufacturers do not give much consideration to suitability of level and also form of fortificants used in their products. This could be partly attributed to the lack of data on the bioavailability of minerals from high phytate CFs made using local cereal and legume ingredients. Most of the mineral bioavailability studies have been done on adults, and often molar ratios of phytate:mineral is used to estimate the proportion of mineral absorption. There is uncertainty on whether these molar ratios would be applicable to CFs.

Micronutrient Levels

Another concern with some commercial CF formulations is that the level of micronutrients exceed the upper limits as prescribed by WHO/FAO in 2006. A research study compared 57 cereal-based CFs procured from 5 countries each in Asia and Africa. It found that even though 84% of the products stated being fortified, only two could meet the WHO standards for iron and calcium. Similarly, only one product could meet the standards for zinc level. The form of fortificant used is also an important criterion while formulating CFs. A case in point being iron is generally supplied through ferrous fumarate or ferric pyrophosphate. Ferrous fumarate is as bioavailable as ferrous sulfate but is less soluble in water and soluble in dilute acids. It's not sure if the gastric acid output by infants is enough to solubilize this fortificant. Ferric pyrophosphate is less bioavailable than ferrous sulfate as it is insoluble in water and partly soluble in dilute acids. Due to this feature, ferric pyrophosphate is less soluble in gastric juice than ferrous fumarate and therefore WHO recommends using it in twice the amount of ferrous fumarate. Though ferrous sulfate would be the most effective iron compound that can be added to foods but changes in organoleptic properties makes its addition less preferable. Similarly, zinc sulfate has been considered as safe for addition in CFs but zinc lactate is also used by some manufacturers. A recent study conducted by William Masters of Tufts University reported that there was a widespread inconsistency in the nutritional content of 108 commercially available CFs procured from low and middle income countries. Lack of uniform quality standards and poor enforcement of available standards is a major challenge/impediment in providing the right level of fortification of CFs.

CFs are also distributed to millions of children worldwide through programs run by governments, non-profit institutions and humanitarian organizations. These programs and their products, such as the commonly used corn soy blend or other fortified blended foods, are also beset by similar and multiple challenges as in the case of homemade and commercial CFs. Considering the enormity of the issues that impair the effectiveness of nutritional assistance programs and products, the US government and its Agency for International Development (USAID) commissioned a study by the Friedman School of Nutrition

Science and Policy at Tufts University to thoroughly review food aid programming and products including complementary foods, and bring forth recommendations to improve their quality and efficacy. The study resulted in the Food Aid Quality Review (FAQR) report that was published in 2011.

Looking Ahead

For effective infant nutrition, the food matrix must have a balance of macro and micro nutrients and should be prepared in the right way to maximize the bioavailability and health benefits. Diverse and nutrient-rich dietary intake of complementary foods, either as freshly prepared or fortified processed foods, would be one of the several methods to achieve this goal. One of the primary recommendations made by the FAQR is to improve not only protein quantity but also the quality. A PDCAAS value (measure of protein quality) of 0.80 is suggested for good quality protein. One way to improve the nutritional quality of diets that have low PDCAAS value proteins, is to add animal sourced ingredients like milk, meat, fish and eggs. If possible, animal based proteins should form one-third of the total protein content to make significant impact on growth. Also on an average 30-45% of the energy requirements should come from fats to enable essential fatty acids intake, improve the absorption of fat soluble vitamins and increase energy density of foods. Essential fatty acids are poly unsaturated fatty acids (PUFAs), and can be provided through linoleic and α-linolenic acids present in vegetable oils. Other recommendations include increasing the micronutrient profile of complementary foods by adjusting the levels of various mineral and vitamin fortificants and also using the most appropriate sources, based on state-of-the-art science. Many of the FAQR recommendations are currently being tested in ongoing field studies in various countries.

Simple primary processing techniques can also enhance the accessibility of nutrients in food matrices. For example, germination and malting can increase the bioavailability of iron eight- to twelve-fold. Improvement in bioavailability of carotenoids in green, leafy vegetables can be achieved by application of mild heat treatment. Heating releases the carotenoids from binding proteins in the food matrix. Similarly, a study showed that the absorption of beta carotene from cooked spinach and carrots (major ingredient in homemade and commercial CFs) increased three-fold as compared to raw. Similarly, lycopene, an antioxidant found abundantly in tomatoes, shows an increase in bioavailability after heat treatment due to transformation of the isomers from trans to cis form.

If dietary diversity is lacking in homemade CFs, or if such foods are not available through affordable commercial means or nutritional assistance programs, the addition of complementary food supplements (CFS) should also be considered. CFS could consist of crushable or water dispersible micronutrient tablets, micronutrient sprinkles added to food right before feeding and fortified spreads. Care should be taken not to provide vitamin and mineral supplements in the first year of life of infants unless prescribed by a healthcare provider. For commercial CFs, care has to be taken in the choice of level and form of fortificants as well as adherence to the specified standards and regulations to ensure that consumption does not exceed the corresponding upper limits. Finally, proper coordination between nutritional scientists, food sector and government agencies is the need of the hour to overcome the enormous challenges of malnutrition facing the population that will drive the world of tomorrow.▼

Michael Joseph works at The Gerald J. and Dorothy R. Friedman School of Nutrition Science and Policy, Tufts University, Boston, Massachusetts, USA. Sajid Alavi works at the Department of Grain Science and Industry, Kansas State University, Manhattan, Kansas, USA and Quentin Johnson Quican, Inc., Rockwood, Ontario, Canada.

This article would not have been possible without the collaboration between Tufts University and Kansas State University under the Food Aid Quality Review Project. The authors acknowledge support provided by Dr. Patrick Webb, Shelley Walton and Gloria Alvarez of the Friedman School of Nutrition Science and Policy at Tufts University (Boston, Massachusetts, US). They would also like to thank United States Agency of International Development (USAID) and its Office of Food for Peace (FFP) for their technical support.

Table 1: Common Anti-Nutritional Factors In Food Matrices, Their Nutritional Impact and Methods of Reduction

Anti-Nutritional Factors	Food Sources (and molecular structure)	Nutritional Impact	Methods to Reduce Anti-Nutritional Factors & its Mechanism
Phytate	Unrefined cereals, legumes, nuts, oilseeds	Binds certain cations to form insoluble compounds in gut especially zinc, iron, calcium, magnesium and phosphorous being poorly absorbed.	Soaking, germination, and fermentation activates phytase that reduces phytates, thermal treatment like roasting and extrusion hydrolyzes the phytate molecule, milling removes bran that has the most concentration of phytates.
Polyphenols (including tannins)	Red sorghum, legumes, spinach	Inhibits iron absorption from plants by forming insoluble complexes, reduces thiamine absorption by inactivating thiamine, reduces starch, protein & lipid digestibility by binding certain salivary and digestive enzymes.	Soaking & boiling removes tannins through leaching, dehulling removes the tannin rich hulls.
Oxalates	Spinach, sweet potato, sesame seeds, tea, coffee	Reduces absorption of calcium and iron by forming insoluble complexes with them.	Boiling- improves calcium absorption; Soaking-leaches out a part of soluble calcium oxalate.
Trypsin Inhibitor	Soybeans, nuts (type of protein)	Reduces protein digestibility by inhibiting protease enzyme.	Thermal processing including roasting, boiling, extrusion denatures the inhibitors.
Lectins	Legumes, cereal grains, tomatoes, potatoes, pepper (type of protein).	Cause damage to gut lining by binding to glycoproteins and gut cells.	Soaking, sprouting, fermenting or boiling inactivates lectins.