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SUPPLEMENTARY ARTICLE

Soy Plant-based Formula with Fiber: from Protein Source to Functional Food

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Abstract

Several factors are fundamental to support child growth and development, including nutrition. Other than energy, protein is the key to balanced dietary macronutrients intake as the building block of child growth. While several micronutrients, i.e. calcium, iron, zinc and vitamins are needed for both optimal growth and development. Among protein-rich foods for young children, cow's milk formula has several limitations, i.e. cow's milk allergy and low fiber content. Although has a low bioavailability for iron absorption, plant-rich protein can be an alternative for young children to be used, i.e. as a soy isolate protein formula. However, due to the fact of low fiber content in soy isolate protein formula, further consideration is needed to have a fiber enrichment. We highlight the fiber content in child formulas to the extent of its benefit for gastrointestinal health in relation to gut movement in preventing constipation, or its role as a functional food with its prebiotics capacity. This article aims to review a suitable type of fiber used for the enrichment for a soy isolate protein formula.

Keywords fiber, functional foods, plant-protein, prebiotics, soy-isolate protein

Important nutrition to support child growth and development

Growth is a typical characteristic of childhood, a sensitive indicator of a child's nutritional status. Deviations in growth are associated with greater risk of disease both in the short and the long run. Monitoring growth is therefore an important tool for assessing the health and well-being of children.[1] Child growth and development is affected by several factors, i.e. nutrition, care, stimulation and health conditions. Considering on nutrition alone, there are nutrition that supports growth.[2] Among others are energy and protein as the fuels and building blocks for rapid linear growth. Energy from dietary intake is needed to build body tissues relative to body weight. Lack of energy intake can delay growth spurts and lead to stunting. Protein, it has to be present in sufficient quantity as well of high quality to be able to get all the nine essential amino acids. The high-quality protein originated from animal

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including dairy products, eggs, meat and poultry, while from plant protein is mostly soy because other plant protein sources, such as peas or nuts, have to be consumed with complementary protein to provide all the nine essential amino acids.[2]

Other than energy and protein, adequate intake of iron is essential as a major component of blood and muscle tissues, especially to form the haemoglobin molecule needed to carry oxygen and myoglobin component for growing muscle. For growing the skeleton, then calcium is the main component of bones while vitamin D assure that calcium will reach the growing bones. We know that numerous metabolic reactions are essential for growth in which zinc is highly required to act as a catalyst for dozens of reactions, especially those metabolic processes related to growth.[2]

Nutrition responsible to support child development, i.e. cognitive and sensory development, is related to neuron growth (including myelin sheath), synthesis of neurotransmitters to relay messages to the brain, and development of the eye. Among others, iodine and zinc are responsible to help regulate brain and nervous system development. Dietary intake of iodine plays a huge role in cognitive development because it is required for synthesis of thyroid hormones. Thyroid hormones is essential for regulating many biochemical processes, in particular are those related to brain development. Zinc also has a role in cognitive development because it is essential for the nervous system growth, i.e. formation of neurons and synapses that allow neurons to communicate to each other. Besides myelin sheath is also important to enable nerve signals to journey rapidly across the neuron, in which iron has a role in developing the myelin. There is also a potential role of omega-3 long chain polyunsaturated fatty acids as a primary component of every cell membrane in the body, including nerve cells. Lots of study still try to confirm the role of DHA, a specific long-chain omega-3 fatty acid to improving learning and memory. As well as of B vitamins (i.e. vitamin B6, vitamin B12, and folate) and choline to cognitive health through their possible roles in nerve cell myelination, neurotransmitter synthesis, and regulation of gene expression in the central nervous system. In developing the senses, vitamin A is essential for the transduction of light into neural signals in the eye. While lutein and zeaxanthin are carotenoids or pro-vitamin A that are found in the retina and in brain tissue to serve as important antioxidant protection and play a role in neural development.[1,2]

Consideration why soy isolate protein formula can be alternative nutrition for young children

We all agree that human milk is the ideal source of nutrition for infant feeding, however some infants are receiving some formula as human milk substitute, cow-milk based, or non-cow-milk based infant formula (i.e. soy-based infant formula). Both human milk substitute should provide a source of nutrition for an extended interval and their nutritional adequacy should be confirmed, especially for the soy protein-based formulas.[3]

Soy protein-based formulas have been provided for almost 100 years since there is a need for a milk substitute for an infant who unable to tolerate a cow milk protein-based formula by changing the formulation to the current soy protein isolate.[3] A systematic review with meta-analysis entitled, “Safety of soya-based infant formulas in children” concluded, “Modern soy-based infant formulas are evidence-based safety options to feed children requiring them. The patterns of growth, bone health and metabolic, reproductive, endocrine, immune and neurological functions are similar to those observed in children fed cow milk formula or human milk” Soy is the only plant protein source containing a complete amino acid profile.[4] Soy-based formulas are well tolerated in infants with CMPA (cow milk protein allergy). Soy formulae used to contain phytates which were blamed for their chelating capacity, preventing the proper absorption of micronutrients. Today, however, phytates are almost totally removed from the soy formula.[5]

Isolated soy proteins are sometimes referred to as the most functional of the soy proteins. These virtually pure, bland-flavored isolates containing a minimum of 90% protein have been designed to function in a given system in the same way as animal proteins. Soy protein supplies all nine essential amino acids and provides many functional benefits to food processors and for a healthy diet. Both isolated and concentrated soy proteins are easily digested by humans and the protein quality is

equal to milk, meat, and eggs. The most refined forms of soybean proteins are the isolates, which contain 90% or more protein. They are prepared by removing the water-insoluble polysaccharides, as well as the oligosaccharides and other low-molecular-weight components that are separated in making protein concentrates. Isolates may contain more than 95% protein but contain 2% to 5% ash and 3% to 4% of minor constituents. Soy concentrates and isolates provide highly concentrated protein sources, high lysine content, bland flavor, and reduction of flatulence factors and reducing sugars, and they may lead to improve overall product quality.[6]

Considering its composition, the isolated soy protein-based formulas provide 67 kcal/dL, iron fortified and meet the vitamin, mineral and electrolyte specification as recommended. The protein is provided from a soy isolate and supplemented with L-methionine, L-carnitine, and taurine. Vegetable oils primarily used for its fat content, include soy, palm, sunflower, olein, safflower, and coconut, in which docosahexaenoic and arachidonic acids are added. Carbohydrate sources are coming from corn maltodextrin, corn syrup solids, and sucrose. The calcium and phosphorous contents are 20% more than cow milk-based formula, and fortified with iron and zinc, because soy phytates and fiber oligosaccharides bind with iron and zinc.[3]

A potential concern for soy protein-based formulas is in relation to phytoestrogens/ isoflavones that consist with the highest amount in soybeans. They have potential negative effects on sexual development and reproduction, neurobehavioral development, immune function and thyroid function. However, up till now there is no conclusive evidence from any animal, human or infant population that dietary soy isoflavones may adversely affect human development, reproduction, or endocrine function.[3] There is also another issue on the relatively high content of aluminium in soy-based formulas that can result in aluminium toxicity in infants and children. Aluminium competes with calcium for absorption, thus increased amount of dietary aluminium from isolated soy protein-based formula may contribute to the reduced skeletal mineralization (osteopenia). However, it is the case for preterm infants and infants with intrauterine growth retardation, and do not seem to be at substantial risk for term infants with normal renal function. Thus, the cow milk protein-based formulas designed for preterm infants are clearly superior to soy protein-based formula for preterm infants.[3]

Consideration to use soy protein-based formula is safe and cost-effective as a dietetic alternatives for infants with galactosemia or primary lactase deficiency or families wishing to avoid feeding their infants formulas containing animal products. However, it is contraindicated in sucrase-isomaltase deficiency and hereditary fructose intolerance. In acute infantile diarrhea, by using soy protein-based formula, it revealed that the duration of diarrhea to be shorter and duration of liquid stools may also shortened. Although the most common reason for use of soy protein-based formula is for relief of perceived formula intolerance (i.e. spitting, vomiting, and fussiness) or symptoms of colic, however there is no significant benefit from soy protein-based formula as compared to cow milk. Also, there is a high frequency of sensitivity to both cow milk and soy antigens in infants, resulting to the need to have a hydrolyzed protein formulas for these infants, and even an extensively hydrolyzed protein formula for infants allergic to cow milk formula.[3]

The nutritional composition of soy isolate protein formula in Indonesia – highlighting low fiber content

In terms as an oil seed, soybean contains several nutrients, i.e. protein, carbohydrate, vitamins and minerals. In dried condition, a dry soybean has 36% protein, 19% oil, 35% carbohydrate of which 17% is dietary fiber, 5% minerals and several other components including vitamins.[7] For its protein quality as protein digestibility corrected amino score, it is found that soybean protein has a biological value of 74, in which 96 for soybeans as a whole and 91 as soybean milk, as compared to 97 for eggs.[6]

Concerning to its fiber content, among plant protein source form legumes, fiber content of soybeans is second lowest after peanuts (9.3 g/100g versus 8.5 g/100g, respectively) as compared to the highest content found in green peas (25.5 g/100g).[8] Although found in a small amount as raffinose and stachyose and other oligosaccharides, however it

cannot be digested in small intestines because the lack of enzyme alpha-galactosidase. Thus, it passes into the colon and serves as an energy substrate for colonic bacteria or so called prebiotics, but also causes flatulence. Furthermore, the soybean dietary fiber are believed having a role in antioxidant scavenging activity in plant tissues and maybe also for human.[9]

The benefit of fiber enrichment in soy protein isolate formula

Considering to the low fiber content and beneficial role of dietary fiber found in soybeans as prebiotics and antioxidants, it is then wise to have fiber enrichment to soybean product such as in soy protein isolate formula. Moreover, the low fiber content will be perturbed during food processing. Further study should be done to find the optimal amount of fiber enrichment needed to have its beneficial effects with a minimal negative effect on gastrointestinal symptoms and absorption of micronutrients, i.e. calcium, iron and zinc. Fiber may role as prebiotics. Prebiotics are non-digestible components of food that in a selective manner trigger the expansion of microbes in the gut with valuable effects for host health. All these demands are completed by non-digestible oligosaccharides that consist of three to ten sugar molecules, and are naturally present in fruits, vegetables, cereals, milk, *etc*., or can be industrially produced.[10]

Majority of clinical studies concerning the effects of supplementation of infant formulas with prebiotics confirmed increase in frequency of defecation and/or softer consistency of stools, similar to that of breast-fed infants. Acidic environment in colon increases solubility of certain minerals. Bioavailability of calcium when consuming prebiotic ingredients has been well-studied. Recent observations show that prebiotic oligosaccharides enhance iron absorption in deficient rats. A meta-analysis that summarized positive context of prebiotics in infant formulas and increased weight gain; Whether this is the result of intensified energy harvests by intestinal bacteria and/or increased absorption by enterocytes is not yet clear.[10]

Prebiotics are being added to infant formula to promote growth and development in infants. However, there is not enough evidence to state that supplementation of term infant formula with prebiotics does result in improved growth or clinical outcomes in term infants. The health benefits include increased mineral absorption. Moreover, food supplements containing prebiotics have beneficial effects on Ca, Mg mineral absorption. Prebiotics also have other positive effects on health, i.e. improving body functions and bone health, decreasing disease risks, reinforcing immune functions, preventing infections and intestinal diseases, and enhancing bioavailability of (calcium and magnesium) minerals.[11]

Prebiotic supplementation of paediatric nutritional products is associated with increased levels of lactic acid bacteria and bifidobacteria, decreased diarrhea, improved allergy symptoms, and decreased rates of infection in infants and children.[12] An increase in bifidobacteria, a decreased stool pH, softer stools and an increase in stool frequency compared to standard infant formula is an almost constant finding.[13] It is widely known that oligosaccharides constitute the third most abundant component in human milk after lactose and lipids. While oligosaccharides are virtually absent from most infant formula, which may account in part for the difference in GI microbiota reported among breast-fed and formula-fed infants.

What will be the suitable fiber/oligosaccharide for soy isolate protein formula that should be plant source, i.e. fructo-oligosaccharides (FOS) and inulin with the right combination? We realize that we could not use gluco-oligo-saccharides (GOS) because it is from lactose/cow's milk, thus not suitable for children who avoiding cow's milk. Study suggested that term infants fed soy-based formulas supplemented with scFOS demonstrated good tolerance and hydration comparable to the control soy-based formula with history of safe use.[14] A beneficial effects of both FOS and inulin enriched in the soy protein-based formula, have to proceed several steps, i.e. preparation of the formula by FOS and inulin enrichment in percentage (%) of total product weight, measurements of active acidity (pH), microbiology and sensory analysis before doing a medical study or clinical trial to assess the different faecal microbiota composition for pathogenic and conditionally pathogenic variety.[15] Based on

Generally Recognized As Safe (GRAS) Notification for fructo-oligosaccharides, the office of food additive safety (HFS-255) from Center for Food Safety and Applied Nutrition Food and Drug Administration USA (January 2017) stated that the typical use levels of FOS in infant formula as starter formula and follow-on formula is 31.5 mg/g powder and 39 mg/g powder, respectively, with the use levels of 400 mg/100mL and 500 mg/100mL, respectively.[16]

Conclusions

Soy isolate protein-based formulas may serve as an alternative for parents to provide foods for their infants and under-five children with sufficient nutrition to support optimal growth and development, as well maintaining gastrointestinal health, especially to those who cannot consume cow-based formula. This is particularly true if the soy isolate protein-based formula has been enriched with dietary fiber, such as FOS and inulin to have a prebiotics role as a functional food.

Conflict of Interest

Authors declared no conflict of interest regarding this article.

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