Soymilk as source of nutrient for malnourished population of developing country: A review

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ABSTRACT

The aqueous extract of whole soybeans is very close to dairy milk in physical appearance, composition and source of energy, known as soymilk. Properly processed soymilk offered many neutraceutsical and health benefits. Soymilk is important source of high-quality protein for a long time. Soymilk is also used as an important replacer of milk for lactose-intolerant peoples well as a low-cost source of good-quality protein and energy, mainly in developing countries. The present article focuses on nutritional and non-nutritional such as phytochemicals aspects of soymilk and the probable use of soymilk as a source of protein, vitamins and minerals for malnourished people. Soymilk contained considerable amount of essential and branched chain amino acids except methionine and good source of B-vitamins particularly niacin, pyridoxine and folacin. Soymilk contains calcium lower than cow's milk but higher amount of iron though iron has low absorbance from soymilk. Nonetheless, a growing number of calcium-fortified soymilks are available. However, soymilk are rich in copper, zinc and magnesium

Key words: Amino acids, Developing country, Calcium, Phytochemicals, Protein, Soymilk.

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INTRODUCTION

Soybean is the best source of plant protein containing about 40% of protein (dry basis), highest among all legumes and cereals, and also rich in nutritive minerals and dietary fiber [1]. Soy proteins are highly digestible after proper heat treatment, and amino acid profile is almost well balanced except methionine to meet the requirements for human nutrition. Soybeans may transform into different varieties of soyfoods to provide tasty and easily digestible products. Soymilk is the most popular as a healthy food drink and an important high-quality protein source in the diet of Eastern people for a long time. Soymilk contains high amounts of protein, iron, unsaturated fatty acids, and niacin, but low amounts of fat, carbohydrates, and calcium as compared with cow milk and human milk. Soymilk has high concentration of fosfatidylcholine, vitamins and isoflavones, which are strong antioxidants.

The properly processed soymilk and its derivatives offer many nutraceutical and health benefits. In 1999, the US Food and Drug Administration approved a health claim for the cholesterol-lowering effects of soy protein, largely based on a meta-analysis of 38 clinical trials that reported significant decreases in total and low-density lipoprotein (LDL) cholesterol and triglycerides with soy protein intake (25 g/day) compared with animal protein consumption [2]. Several studies have demonstrated that the use of soy products could prevent the heart disease, obesity, blood cholesterol, cancer, diabetes, kidney disease, osteoporosis, and blood pressure regulation [3-6]. As soymilk contained high amounts of protein, poly -unsaturated fatty acids, vitamins, minerals and phytochemicals, it could be easily used as good source of nutrition food for malnourished people especially in developing countries. This article try to find the nutritional factors that can help the developing countries to reduce malnutrition problem through use of soymilk or soy drinks.

MALNUTRITION PROBLEMS IN DEVELOPING COUNTRIES

Malnutrition arises from eating a diet which cannot provide sufficient nutrients or provide too much nutrients. The nutrients re calories, protein, carbohydrates, vitamins or minerals. Lack of enough calories, protein or micronutrients specifically refer as under nutrition. However, malnutrition also includes over nutrition. Permanent physical and mental development problems may results if under nutrition occurs during either pregnancy or before the two years of age. Extreme under nourishment called starvation. It may have several symptoms such as short height, thin body, very poor energy levels, and swollen legs and abdomen. Micronutrient deficiencies symptoms mainly depend on the micronutrient that is lacking. However, common deficiencies of micronutrient are lack of iron, iodine, and vitamin A [7]. During pregnancy stage the deficiencies become more common and severe due to increased demand of nutrition [8]. On the other hand, some developing countries obesity is the over nutrition within the same communities as under nutrition. But the elderly malnutrition arises due to physical, psychological and social factors [9]. Undernourishment is the result due to not enough high quality food available to eat. This might be related to high food prices and poverty [10]. Undernutrition is common sign of daily life in developing countries [11]. In Bangladesh, chronic malnutrition is associated with poor socioeconomic position which retards the purchasing power of nutritious foods such as milk, meat, poultry, and fruits [12]. Food shortage might also be a contributing factor to malnutrition in developing countries with lack of proper technology. Food and Agriculture Organization has estimated that eighty percent of malnourished children living in the developing world even those countries produce food surpluses [13]. Nowadays, famine is one of the most critical problems for food distribution and/or poverty. Though there has been sufficient food to feed the whole population of the world, malnutrition and famine are more related to problems of food distribution and purchasing power [14].

PROTEIN SOURCES IN DEVELOPING COUNTRIES

Proteins are very much essential component of the diet needed for survival of both animals and humans. The basic functions of protein's in nutrition system to supply adequate amounts of essential and non-essential amino acids. However, the protein quality depends on its amino acid content and on the physiological utilization of specific amino acids after digestion, absorption, and minimal obligatory rates of oxidation. Table 1 shows the protein consumption in underdeveloped countries *vs* developing countries. Underdeveloped countries humans consume more low-quality proteins compared to those living in developed countries [15]. However, soymilk could be a good source of protein for developing countries.

Table1. Sources of protein in the developing and developed countries (USDA, 1993)

Source	Developing (%)	Developed (%)
Cereals	58.8	29.1
Meat	8.6	26.4
Pulses	7.4	1.7
Milk and dairy	5.6	16.7
Fish, seafood	4.1	7.3
Oil crops	3.8	1.9
Vegetables	3.5	3.5
Starchy roots	3.1	3.2
Eggs	1.6	4.3
Offals	1.2	2.2
Fruit	1.0	1.1

SOYBEAN AND SOYMILK

Soybean composition includes varying amounts of protein content (38–40%), carbohydrates (30%) and fat (18%) [1]. Among soy protein glycinin and β-conglycinin are the most important and in combination they represent more than 70% of the total soy proteins [5]. In soybean and its derivatives contained unsaturated fatty acids. Other component is soybean includes varying concentration of isoflavone; high levels of minerals including iron, calcium, zinc; vitamins including α-tocopherol, niacin, pyridoxine, and folacin. Soybeans are also a source of anti-nutrient factors such as saponins, phospholipids, protease inhibitors, phytates and trypsin inhibitors [1] and most of them could be destroyed by either heat treatment or other processing methods.

Soybeans could be easily transformed into many different varieties of foods to create versatility and provide tasty and easily digestible products. Among these soy foods, soymilk has gained much popularity as a healthy food drink. The aqueous extract of whole soybeans, is known as soymilk, which closely resembles dairy milk in physical appearance and composition [16]. Soymilk is a stable emulsion of oil, water and protein. The traditional soymilk is made from soaking the beans in water, wet grinding the beans, steaming the wet mash to improve flavor and nutritional value, and filtering [17]. Flavored versions of soymilk have received acceptance in mainstream market as meal replacement beverages and cow milk replacer. Soymilk is used as a base in a wide variety of soy dairy analogues, including tofu, soy yogurt/curd, ice cream, and soy-based cheeses [4]. Commercial soymilks and related products may be classified, according to their composition:

a) Plain (or traditional) soymilk: Made by water extraction of whole soybeans, using different ratio of bean to water. Contain approximately 4% protein which depends on process, soybean variety, amount of water and bean ratio.

b) Dairy-type soymilk: Formulated soymilk, however, composition roughly similar to that of dairy milk. Basically, bean to water ratio is 1:7. Protein content 3.5%, slightly sweetened, contains added oil and salt. Nonetheless, it may contain imitation milk flavor.

c) Soy beverages: Its sweet and flavored drinks, containing about 1% protein. High bean to water ratio 1:20.
d) Cultured products: Any of the above type after lactic fermentation or acidification with lactic acid.
e) Blends: Mixtures of soymilk and other vegetable or dairy milks.

WHY SOYMILK?

Basically, there are two main types of under nutrition i) protein-energy malnutrition and ii) dietary deficiencies. Protein-energy malnutrition also has two severe forms: i) lack of protein and calories, known as marasmus and ii) lack of just protein, called kwashiorkor [7]. Soymilk could be a good source of high quality protein with production low cost. Soymilk is very popular healthy drink and is important source of high-quality protein for a long time. Soymilk contains high amounts of protein, iron, unsaturated fatty acids, and niacin, but low amounts of fat, carbohydrates, and calcium as compared with cow milk and human milk. Nonetheless, Soymilk is also used as an important replacer of milk for lactose-intolerant people, as well as a low-cost source of good-quality protein and energy, mainly in developing countries [4, 18-19]. More importantly, polyunsaturated and monounsaturated fats of soymilk do not lead to deposition of fats in blood vessels including those in heart, and are therefore do not lead to heart diseases [1]. Soymilk is very good source of fosfatidylcholine and vitamins. It also contains considerable amount of isoflavones, which are strong antioxidants. The properly processed soymilk and its derivatives thus offer many health benefits.

COMPOSITION OF SOYMILK

Both soymilk and cow's milk were collected from local market and analysis for different composition. The composition of soymilk depends on milk extraction procedure, variety of soybean, water and bean ratio and so on. Cow's milk composition varies considerably among breeds of dairy cattle, interval of milking, age of cattle, stage of lactation and feeding regime and Completeness of milking. Soymilk contains high amounts of protein and unsaturated fatty acids but low amounts of fat and carbohydrates as compared to cow milk (Table 2).

Table 2. Composition and comparison between soymilk and cow's milk

Nutritional value per 100 g	Cow's milk	Soymilk
Energy, Kcal	67.0±0.5	52.0±0.5
Protein (g)	3.5±0.04	3.9±0.08
Fat (g)	3.7±0.6	2.4±0.1
Cholesterol (g)	11.0±0.06	0
Lactose (g)	4.8±0.03	0
Saturated fatty acids (%)	63.5±1.0	14.0±1.2
Mono-unsaturated fatty acids (%)	33.5±0.9	21.6±0.7
Poly-unsaturated fatty acids (%)	3.0±0.2	63.5±0.9

EXTRACTION OF SOYMILK

The basic steps of preparation of soymilk include selection of soybeans, soaking of beans, wet grinding and separation of soymilk from fiber (okara), cooking to inactivate lipoxygenase and trypsin inhibitors, formulation and fortification, and packaging of the soymilk. Various methods were developed to extract soymilk especially to remove the beany flavor of soymilk. Wilkens et al. [20] developed the Cornell process and later the Illinois process was developed by Nelson et al. [19] for the manufacture of soymilk. These conventional processes basically involve the soaking, grinding, filtering, and cooking steps. But now many process modifications have taken place over the years with the advancement of new processing technologies and considering consumer requirements. In large-scale production, mostly continuous high-temperature short-time (HTST) processes often takes place rather than normal low-temperature, long-time thermal processes. The ultra high-temperature (UHT) heating and aseptic packaging has further contributed to the production of long life soymilk. They are more convenient for transportation, distribution, and storage [21].

In this paper we discussed, the effect of extraction methods on characteristics soymilk for extraction of maximum solid content including protein and fat content. Soak the soybeans (Raitip brand, Nonthaburi, Thailand) prior to grinding in 0.5% sodium bicarbonate solution at the 50^{o}C for 2 h in a water bath (Schufzart DIN 40050IP20; MembartGmBH+ Co., Bϋchenbach, Germany). The ratio between soybean and water for soaking was 1:3. The beans were drained well afterwards. After discarding the water, the soaked soybean was dehulled before grinding of soybean. Soaked soybean was dehulled to remove unwanted substances using hands. Three methods were applied for blanching of hydrated soybeans to inactivate lipoxygenase and off flavor. Hydrated beans were blanched in 0.5% sodium bicarbonate solution at 80^{o}C and 95^{o}C for 10 min and 121^{o}C for 15 min in a gas retort (Ngowhuatyoo, Bangkok, Thailand) solution was drained well and washed with water for three times. The blanched soybean was ground with the addition of hot water (95°C) using super mass colloider (Masuko Sangyo Co., Ltd. MK- PB6-2, Kawaguchi, Japan) and a basket centrifuge (Wasino, Samutprakarn, Thailand). The ratio of soybean to water was 1:4. Soymilk was obtained after filtering through double layers of cheese cloths. Soymilk was pasteurized by low temperature long time (LTLT) method. LTLT involves heating the milk to 63°C and holding for 30 min. The pasteurized soymilk was in -20°C for further studies. Soymilk prepared by different methods was analyzed for the following parameters: refractive index, total solid, peroxide value and thiobarbituric reactive substances (TBARs) was determined immediately after extraction of soymilk (day 0). On the other hand, protein and fat were determined on the 2nd day after extraction of soymilk**.**

The composition of extracted soymilk by three different treatment methods is shown in Table 3. Although the treatments did not significantly affect the refractive index, soymilk had different total solid, protein, fat, and TBARs. Soymilk obtained from blanching at 80^{o}C for 10 min showed the highest solid content. However, Table 4 shows that increasing the temperature during blanching decreased the extracted solid content. This might be due to the formation of matrices capable of holding water. When the matrices are formed before extraction of soymilk, the amount of solid extraction reduced along with liquid content. Increasing blanching temperature to 95^{o}C could not increase the extraction of soymilk due to fixation of matrix at high temperature. Blanching and autoclaving at high temperature (95^{o}C and 121^{o}C, respectively) denatured soy protein and increased the water holding capacity of soybean, extraction of protein was dramatically reduced after denaturation and matrix formation.

Table 3. Composition of extracted soy milk by three different treatments

Parameter	Blanching conditions		
	80°C 10 min	95°C 10 min	121°C 15 min
Refractive index	1.345[a] ±0.005	1.339[a] ±0.001	1.3336[a]±0.007
Total solids %	7.65[a]±0.03	5.37[b]±0.05	4.05[c] ±0.03
Protein %	4.46[a]±0.07	4.02[b] ±0.05	2.13[c] ±0.06
Fat %	2.15[a] ±0.06	1.80[b] ±0.10	0.93[c] ±0.06
TBAR (absorbance at 432 nm)	0.027[b]±0.07	0.025[b]±0.05	0.057[a] ±0.03
Peroxide value (meq/kg)	< detection limit		

Means in the same row followed by different superscript are significantly different (P<0.05).

AMINO ACID PROFILE

Soymilk obtained from blanching at 80°C for 10 min and pasteurized at 63°C holding for 30 min were used for analysis of amino acid profile. However, heat processing time and temperature of heating significantly changed the amino acids profile of soymilk protein. Protein source, processing treatment and interaction with other components of the diet might affect the availability of amino acids. in general, proteins deficient in one or more amino acids are called poor quality proteins. For example, tryptophan and lysine are nutritionally limiting in corn, lysine in wheat and other cereals, and methionine in soybeans and other legumes. Soymilk contained considerable amount of essential and branched chain amino acids (Table 4). But the low content of the essential amino acid L-methionine in soy protein limits its nutritive value. Soy contains methionine for only 1.39 g/16 g of N; while the recommendation by the FAO is 3.5 g/16 g of N [22-23], much lower than that of cereal and meat proteins. Although cystine has a sparing effect on methionine, it does not make up for low methionine levels. Two reasons are identified for low methionine in soy proteins:

i) During food processing and storage, L-methionine and other amino acids are chemically modified, resulted reducing the nutritional quality. Methionine undergoes oxidation to methionine sulfoxides and methionine sulfone, racemization to D-methionine and general degradation to compounds with undesirable odors and flavors such as methional.

ii) Protein-bound methionine from some plants is poorly utilized, presumably because of poor digestibility [24-26]. To overcome these problems, efforts are being made to develop soybean lines that over express methionine-rich proteins [27-28].

Table 4. Composition and comparison between soymilk and cow's milk

Amino acid	Amount g/16 N	FAO,[a] g/16 g of N	mg/kg per day	mg/g protein[1]
Alanine	3.07±0.05	-	-	
Arginine	5.38±0.04	-	-	-
Aspartic Acid	8.98±0.03	-	-	-
Cystine	1.61±0.06	-	-	-
Glutamic Acid	14.99±0.07	-	-	-
Glycine	3.20±0.02	-	-	-
Histidine	2.06±0.09	-	-	-
Isoleucine	4.03±0.01	4.0	20	30
Leucine	7.89±0.04	7.0	39	59
Lysine	5.65±0.09	5.5	30	45
Methionine	1.44±0.11	3.5[b]	*10*	16
Phenylalanine	4.07±0.07	-	-	-
Proline	7.30±0.03	-	-	-
Serine	4.34±0.05	-	-	-
Threonine	3.07±0.02	4.0	15	23
Tryptophan	1.35±0.06		4	6
Tyrosine	2.90±0.08	6.0[c]	25	38
Valine	3.89±0.09	5.0	26	39

[a] Scoring pattern for an ideal protein [15, 22]
[1] Mean nitrogen requirement of 105 mg nitrogen/kg per day (0.66 g protein/kg per day).
[b] Cys + Met; [c] Tyr + Phe.

SOY ISOFLAVONE

Soymilk contains approximately 4–7 mg total isoflavones with considerable variations both in composition and content [29-30]. Isoflavones are generally consisting of two benzyl rings joined by a three-carbon bridge, which may or may not be closed in a pyran ring. They are known as flavonoids, which are the largest and found in wide range of plant phenolics [5, 31]. The isoflavones have basically three types, with each type being present in four chemical forms. Isoflavones in soybean are mainly found as aglycones (genistein, daidzein, glycitein) (Figure 1), β-glucosides (daidzin, genistin, glycitin), malonyl-β-glucosides (6´´-O-malonyldaidzin, 6´´-O-malonylgenistin, 6´´-O-malonylglycitin) and acetyl-β-glucosides (6´´-O-acetyldaidzin, 6´´-O-acetylgenistin, 6´´-O-acetylglycitin) [32]. Aglycones are flavonoid molecules without any attached sugars or other derivatives and important among other isoflavone due to their bioavailability to humans [32]. β-glucosides may also carry additional small molecular modifiers, such as malonyl and acetyl groups. Sugar-linked flavonoids are called glucosides due to their glucose linkage to flavonoids.

Researches revealed that soy isoflavones and their glycosides which are available on soymilk are associated with a lower incidence of cardiovascular disease [33], hormone-dependent breast and prostate cancers [34], colon cancer [35], menopausal symptoms [36] and osteoporosis [37]. Glycosidic isoflavones are poorly absorbed in the small intestine, due to their higher molecular weight and hydrophilicity. However, gut bacteria in the intestine could biologically activate by action of β-glucosidase to their corresponding bioactive aglycone forms. Hydrolyzed aglycone isoflavones are absorbed in the upper small intestine by passive diffusion. Healthy adults can absorb isoflavones rapidly and efficiently. The average time to ingested aglycones reach peak plasma concentrations is about 4–7 h, which is delayed to 8–11 h for the corresponding β-glycosides [38].

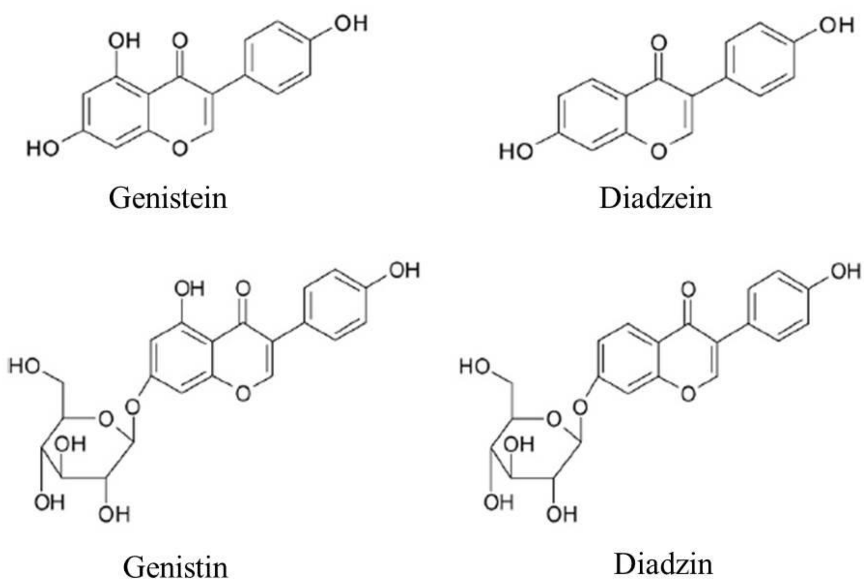

Fig 1: Chemical structure of genistein, diadzein, genistin and diadzin

VITAMINS CONTENT OF SOYMILK

Soymilk is very good source of B-vitamins particularly niacin, pyridoxine, folacin, vitamin E and negligible amount of vitamin A as pro-vitamin A (Table 5), which are very low in terms of per day requirements. Provitamin A is non-animal source vitamin A which turned into vitamin A by the liver following the oxidation process. Under the name of "provitamin A" are grouped different molecules and the body uses them to produce vitamin A. Preformed vitamin A in animal foods occurs as retinyl esters of fatty acids and pro-vitamin A carotenoids in foods of vegetable origin are also associated with cellular lipids. However, pro-vitamin A are embedded in complex cellular structures such as the cellulose-containing matrix of chloroplasts or the pigment containing portion of chromoplasts. Vitamin A functions in the visual cycle in the retina of the eye and systematic maintain of growth and the soundness of cells.

Table 5. Vitamin content of soymilk [39]

Components	Amounts/ 100g soymilk	FAO/WHO, Recommended nutrient intake (mg/day)			
		Adults (Men) 19+	Adults (Women) 19+	Pregnant	Lactation
Thiamin (vitamin B_1)[1]	0.20±0.4 (mg)	1.2	1.1	1.4	1.5
Riboflavin (vitamin B_2)1	0.1.0±0.3 (mg)	1.3	1.1	1.4	1.6
Niacin (vitamin B_3)*	0.15 (mg)	16	14	18	17
Panthotenic acid (vitamin B_5)	0.05 (mg)	5	5	6	7
Vitamin B_6	0.04 (mg)	1.3-1.7	1.3-1.5	1.9	2.0
Folic acid (vitamin B_9)	1.5 (µg)	200	200	420	270
Vitamin A**	3.0 (µg)	600	600	600	850
Vitamin E	0.01 (mg)	-	-	-	-

* NEs: niacin equivalents; ** Vitamin A as pro-vitamin
[1]Thaiamin and riboflabin were determined in the laboratory after soymilk extracted at 80^{o}C for 10 min and pasteurized at 63°C holding for 30 min.

MINERALS CONTENT OF SOYMILK

Soymilk contains about 4 mg of calcium per 100 g soymilk (Table 6). Nowadays growing number of calcium-fortified soymilks are available; these might be contained around 200 to 300 mg of calcium per serving. But soyfoods are rich in both oxalates and phytate, could inhibit the calcium absorption, the calcium from soyfoods is very well absorbed and has a fractional absorption rate equal to that of milk. Both phytate and soy protein reduce iron absorption, resulted the iron in soyfoods is generally poorly absorbed. However, vitamin C can increase the amount of iron absorbed from soyfoods, although absorption rates are still low. Iron may be better absorbed from fermented soyfoods like tempeh and miso than soymilk. Zinc also poorly absorbed from soyfoods.

Table 6. Minerals content of soymilk [39]

Component	Amounts/ 100g soymilk	FAO/WHO, Recommended nutrient intake (mg/day)							
		10-18 years		Men, Years		Women, years		Pregnant	Lactation
		Boy	Girl	19-65	65+	19-Menopau	Post-menopause		
Calcium, Ca [A]	4.7±0.7 (mg)	1000		750	800	750	800	800	750
Iron, Fe [A]	1.0±0.4 (mg)	23*	48*	23	23	48**	19***	76	26
Magnesium, Mg	19.0 (mg)	220	230	260	224	220[1]	190[2]	220	270
Phosphorus, P	49.0 (mg)	-	-	-	-	-	-	-	-
Potassium, K	141.0 (mg)	-	-	-	-	-	-	-	-
Manganese, Mn	0.17 (mg)	-	-	-	-	-	-	-	-
Sodium, Na	12.0 (mg)	-	-	-	-	-	-	-	-
Zinc, Zn	0.23 (mg)	7.2	8.6	7.0	7.0	4.9	4.9	5.5[7] 7.0[8] 10.0[9]	9.5[a] 8.8[b] 7.2[c]
Copper, Cu	0.12 (mg)	-	-	-	-	-	-	-	-
Selenium, Se	1.3 (µg)	26	32	34	33	26[1]	25[2]	28[3] 30[4]	35[5] 42[6]

[A] Calcium and iron were determined in the laboratory soymilk extracted at 80°C for 10 min and pasteurized at 63°C holding for 30 min .
Menopau = Menopause;
Calcium (theoretical) allowances based on an animal protein intake of 20–40 g
* 16–18 years; ** Non pregnant or lactating women;*** above 60 years
[1] Adults, 19–65 years; [2] above 65 years
[3] 2nd trimester; [4] 3rd trimester; [5] 0–6 months' post-partum; [6] 7–12 months post-partum
[7] 1st trimester; [8] 2nd trimester; [9] 3rd trimester
[a] 0–3 months; [b] 3–6 months; [c] 9–12 months

CONCLUSION

Soymilk is a good source of low-cost protein and poly unsaturated fatty acids. Soymilk also contained high amount of vitamin B-complex but very low or negligible amount of vitamin A as pro-vitamin A and minerals such as calcium, iron and zinc. Even at low content but useful for pregnant and lactating women. Nonetheless, lack of iodine, low vitamins and minerals could be minimized by fortification of iodine and enrichment of vitamin A, iron and zinc. However, it's an easy method to enrichment of minerals as calcium fortified minerals are available in the market.

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