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Review Article

FOOD FORTIFICATION: A NUTRITIONAL MANAGEMENT STRATEGY IN INDIA

ANJULI SIROHI[1], ADITYA PUNDHIR[2], SAMPAT GHOSH[3]*

[1]Department of Biotechnology, Shobhit Institute of Engineering and Technology (Deemed-to-be University), Meerut, Uttar Pradesh, India. [2]Instrumentation Laboratory, FICCI Research and Analysis Centre, Dwarka, New Delhi, India. [3]Department of Biological Sciences, Sardar Patel University, Balaghat, Madhya Pradesh, India. Email: sampatghosh@yahoo.co.in

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ABSTRACT

Although the concept and implementation of food fortification are not novel in India, still since Food Safety and Standards Authority of India (FSSAI) introduced it mandatory, the paradigm of food fortification has been broadened. In the current regulation, common staple foods such as wheat flour, rice, edible oil, milk in addition to salt, and Vanaspati have been selected as food vehicle for different micronutrient fortifications. In the present review, we discussed different policies and strategies to address the public health problem associated with nutritional deficiencies with a special emphasis on food fortification. We used data and information in regard to different policies and food fortification published on governmental websites and several published scientific reports and papers were used to understand and discuss the topic. Although there are continuous efforts to mitigate nutritional deficiencies in the country, the optimum results are yet to receive. Food fortification mandate can be expected a potential tool in this context. So far, the trials conducted with fortified foods in India mostly were found having positive results to improve the nutritional status of the subjects included in the study. However, there is sufficient scope and necessity to broaden the trial design including the population of different age groups and socioeconomic status with special emphasis on female of childbearing age and geriatric population. Awareness of nutrition through continuous monitoring of the nutritional profiling of population and timely implement and revision of policies are utmost important to achieve the goal of nutritional security of the country.

Keywords: Nutrition security, Micronutrients, Minerals, Vitamins, Policies, Hidden hunger.

INTRODUCTION

Despite high economic growth in the past few decades, India still exists as the house of the largest number of undernourished people of the world, the number arrives 194.6 million accounting for the 15.2% of the country's total population [1]. The recent report of National Family Health Survey 4 [2] has come up with several facts of unimproved; even deterioration in some family health situations in comparison to previous NFHS 3 [3] report and seeking national attention. The number of wasted and severely wasted children of age under 5 has been increased. A similar trend has been found for obesity. Although improved than the before, the anemia due to iron deficiency is still prevalent among more than 50% pregnant women in the country. The scenario among the children aged between 6 and 59 months including anemic situation is more pathetic and infant mortality rate is higher. Another alarming condition is Vitamin D deficiency, despite receiving plentiful sunshine, at least 70% of Indian population suffering from Vitamin D deficiency [4] which could lead to calcium deficiency, bone diseases, and even cardiovascular diseases. Deficiency of folic acid has been reflected by the statistics showing the number of neural tube defects (NTDs), i.e., 50.8/10,000 births [5]. The deficiency of micronutrients is often termed as hidden hunger and predominant, especially in the sections such as poor and underprivileged pregnant women and children. However, the situation of micronutrient deficiency is not only standing in the Indian context but also it is quite evident in different parts of the world, accounting for almost 2 billion people suffering from hidden hunger [6].

STRATEGIES TAKEN TO ADDRESS THE PROBLEM OF NUTRITIONAL SECURITY

With the scientific progression and in-depth understanding, "food security" has been transformed into "nutritional security." To secure nutritional situation several measures have been taken like the development of nutri-farms concept including wheat, rice, maize, pearl millet, and finger millet; increasing content of protein and micronutrients, namely vitamins and minerals, contained in the Midday Meal Scheme and Integrated Child Development Scheme, development of efficient public distribution system and food fortification (Fig. 1). Another concern is undesired biodiversity loss as a result of intensive agriculture, leading to unsustainable dietary shift and limiting contribution to a healthy diet [7] in India or elsewhere (as a case of Pima Indian tribe in America [8,9]). Promoting utilizing the local food resources associated with tradition and culture is an essential driver of food system sustainability as well as ensure good health [10]. Furthermore, underutilized resources should be properly explored (to cite examples, snails in many parts of the country [11]; insects in northeast [12-14]). Of course, combinational holistic approach is much effective to reduce the burden of micronutrient deficiencies and global experiences agree to that. However, the policies always have emphasized on cereals or carbohydrate-based foods.

FOOD FORTIFICATION: NOT A NEW APPROACH

Food fortification or enrichment is the process of addition of key vitamins and minerals to the staple foods to improve their nutritional value and could address nutritional gaps in the population. The concept of food fortification is not new. One of the earliest evidence of food fortification has been found almost in 4000 BC when Persian physician Melampus added iron filings to sweet wine to strengthen the sailor's resistance to spears and arrows and to enhance sexual potency. In the modern era, adding iodine to salt has been started simultaneously in the United States and Switzerland in 1920 [15]. Later, they started adding Vitamin D and then Vitamin A to the dairy products by 1932 and by 1941 thiamin addition to flour got started [15]. Subsequently, the addition of iron and folic acid to flour become common in the western countries. In the Indian context also, food fortification is not novel at all. Vanaspati has been fortified with Vitamin A since 1953 [16] and iodine-fortified salt since the late 1950s took significant role eradicating goiter from the country [17]. However, the attention was not enough which could satisfy the nutritional level of the population. Despite evidential malnutrition, according to Food Safety and Standard (Food Products Standards and Food Additives) Regulation 2011, manufacturers

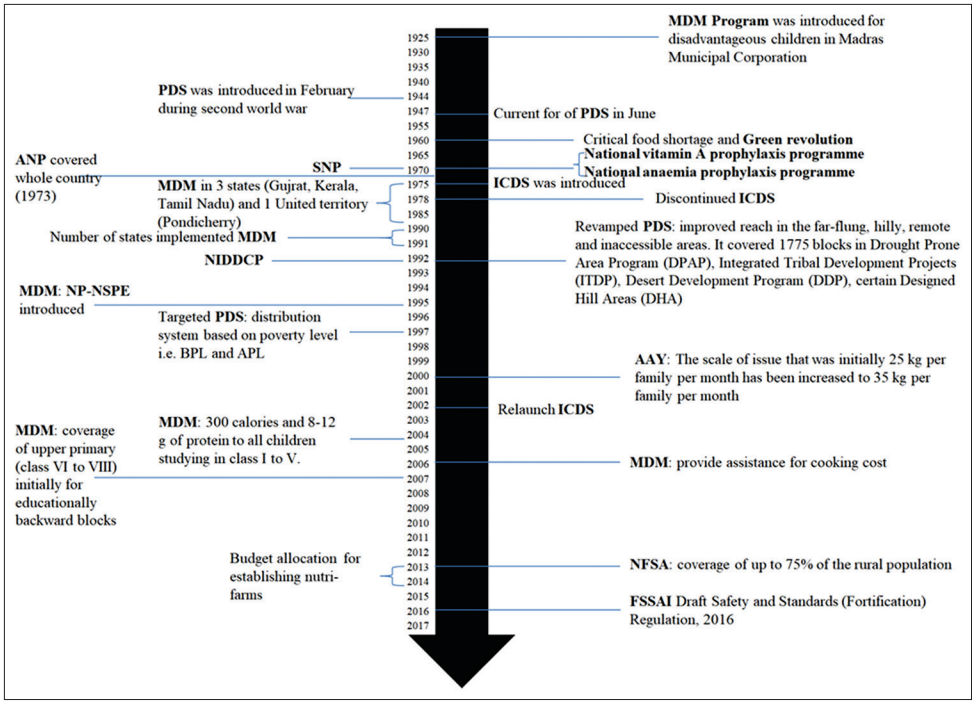

Fig. 1: Schematic diagram of policies in India to address food and nutrition crisis. AAY: Antyodaya Anna Yojana, APL: Above Poverty Line, BPL: Below Poverty Line, ANP: Applied nutrition programme, ICDS: Integrated Child Development Scheme, MDM: Midday meal, NFSA: National Food Security act, NIDDCP: National Iodine Deficiency Disorder Control Programme, NSPE: National Program of Nutritional Support to Primary Education, PDS: Public Distribution System, SNP: Special Nutrition Programme. The figure has been compiled using information available on the different websites, i.e., www.mdm.nic.in; www.icds-wcd.nic.in; www.dfpd.nic.in/nfsa-act.htm; and www.epds.nic.in accessed on August 15, 2018

were not obliged to fortify a significant number of foodstuffs except margarine and infant formula. Realizing the gravity of the problem, FSSAI constituted a panel on food fortification and nutrition to identify critical nutritional gaps in the Indian diet. Draft food safety and standards (fortification) regulation 2016 introduces mandatory fortification of rice, salt, milk, flour (products), and Vanaspati (Table 1). Apart from this, there are several fortified foods available in the market (Table 2) and with the increasing awareness of human health and nutrition, the size of functional food industry is being increased.

FOOD FORTIFICATION: CHANGING THE LANDSCAPE IN INDIA

Rice and wheat are the main staple foods in India, especially the eastern and southern parts mostly depend on rice while the northern and western part of the country depends on wheat. India is one of the top rice-producing countries, accounting for 158.8 million tonnes in 2016. From the world scenario, on average 30% of calories come from rice and it could reach up to more than 70% in some low-income country [18]. According to the GAIN report, the domestic consumption of milled rice is estimated at about 97.6 MMT in 2017/18 and wheat consumption has been estimated at about 93 million. Moreover, the milling process causes the loss of almost all vitamins and minerals of nutritional importance [19]. Therefore, rice and wheat could be excellent vehicles for delivering micronutrients. Although in Indian context rice has been recommended for iron, folic acid, and Vitamin B12 fortification, there is practice of rice fortification with some other micronutrients also such as Vitamin B1, niacin, zinc, and few cases selenium and Vitamin A and E. Oil is almost indispensable part of daily diet, accounting for 99% of the households in India. The consumption of edible oil in the country is about 12–18 kg/per annum per person and Vitamin A and D are fat-soluble vitamins; thus, oil is a suitable vehicle for delivery of these two micronutrients.

FEW CONCERNS

Iron

Iron ethylenediaminetetraacetic acid sodium salt (NaFeEDTA) and ferric pyrophosphate are considered as important ingredients for iron fortification. Except for few special cases, ferrous sulfate has been restricted to use due to its interaction with rice matrix. Unlike other cereal fortifications, ferrous fumarate and elemental iron are not to be used for rice fortification for negative effects on color, taste, and low bioavailability [20].

Selection of the ingredients primarily depends on absorption and non-toxic effects on human body. All dietary non-heme iron is in the ferric (Fe^{+3}) form which is to be in the ferrous (Fe^{+2}) form before it is transported across the intestinal epithelium by a transporter called divalent metal transporter 1. The absorption of non-heme iron is diminished by coadministration of phytate contained high-fiber diet, phenolics contained tea and coffee, calcium as well as administration of few drugs such as proton-pump inhibitors and antibiotics like tetracyclines [21]. On the other hand, Vitamin C or ascorbic acid helps in the absorption of iron [22]. Thus, iron is often taken in conjunction with Vitamin C. However, concern exists because cosupplementation of ferrous form of salt with ascorbic acid exacerbates oxidative stress in the gastrointestinal tract and then this could lead to ulceration [23] as elevated ingestion of ferrous leads to generation of reactive oxygen and nitrogen species, lipid peroxidation, and oxidative stress [24,25]. Furthermore, the study demonstrates that high concentration of iron in the tissue could be associated with a number of diseases including cancers, inflammation, diabetes, and even liver and heart disease [26]. The situation could be alarming while daily intake of iron using supplemental consumption or fortified food reaches much higher than the recommended dietary allowance. A case may be cited as Korean iron supplement users intake iron which is higher (1874% of RDA) than the amount of iron (62% of RDA) generally intake by non-supplement users [23]. Assuming good bioavailability, higher intake of iron can presumably help increasing serum ferritin level which is associated with higher risk of diabetes mellitus, especially for men and post-menopausal women [27,28] and hypertension among middle-aged men [29]. However, in general, food is fortified not more than 50% of the dietary recommendation and thus could avoid the possible negative effects. Ferrous sulfate with mucoprotease showed to be associated

Table 1: List of mandatory food fortification in India

Food item	Nutrient	Level of fortification	Source nutrients	Cost of fortification
Salt	Iodine (manufacturer level)	Not less than 30 ppm on dry weight	Potassium iodate	Rs. 2–3 per kg
	Iodine (distribution channel)	Not <15 ppm on dry weight	Potassium iodate	
	Iron	850–1100 ppm	Ferrous sulfate or ferrous fumarate	
Oil	Vitamin A	25 IU/mg	Retinyl acetate, retinyl palmitate, and retinyl propionate	10 paisa per L
	Vitamin D	4.5 IU/mg	Cholecalciferol and ergocalciferol	
Milk	Vitamin A	770 IU	Retinyl acetate, retinyl palmitate, and retinyl propionate	
	Vitamin D	550 IU	Cholecalciferol and ergocalciferol	
Vanaspati	Synthetic Vitamin A	Not <25 IU per g	Retinyl acetate and retinyl palmitate	
Atta	Iron	20 mg	Sodium iron (III) ethylene diamine tetra acetate, trihydrate (sodium federate-Na Fe EDTA)	20–25 paisa per kg
	Folic acid	1300 µg	Folic acid	
	Vitamin B12	10 µg	Cyanocobalamin and hydroxycobalamin	
Maida	Iron	60 mg	Ferrous citrate, ferrous lactate, ferrous sulfate, ferrous pyrophosphate, electrolytic iron, and ferrous fumarate. Sodium iron (III) ethylene diamine tetra acetate, trihydrate (sodium federate-Na Fe EDTA)	20–25 paisa per kg
	Folic acid	1300 µg	Folic acid	
	Vitamin B12	10 µg	Cyanocobalamin and hydroxycobalamin	
Rice	Iron	20 mg	Ferric pyrophosphate. Sodium Iron (III) ethylene diamine tetra acetate, trihydrate (sodium federate-Na Fe EDTA)	
	Folic acid	1300 µg	Folic acid	
	Vitamin B12	10 µg	Cyanocobalamin and hydroxycobalamin	

EDTA: Ethylenediaminetetraacetic acid

Table 2: List of fortified foods available in Indian market (adopted from the websites of the respective companies/manufacturers)

Name of fortified food	Fortificants added	Manufacturer
Bread	Vitamin enriched bread - Vitamin B	Britannia
Types included	Whole grain bread with oats, ragi, and baked with linseed,	
Vitamin enriched bread	sunflower, soybean, sesame, and melon	
Multigrain bread	Good old oats, sweetened with a touch of honey	
Honey oats bread	Whole grains fiber meets the distinctive flavor of malt	
Brown bread	extract to create a treat enriched with Vitamin B	
Atta bread	Whole grain fiber with a boost of Vitamin B	
Wheat	With iron, folic acid, and Vitamin B12	ITC general mills (Aashirwaad) Hindustan Unilever (Pillsbury) Cargill (nature fresh)
Milk	With Vitamin A and D	Amul
Amul Lite	With Vitamin A and D (milk variants)	Mother Dairy
Mother Dairy	a+a + Pro-grow	Nestle India
Nestle	Pure cow's milk	Nestle India
Tru	Vitamin A and D	MDVL farms
Danone	Soymilk with calcium and Vitamin D	NDDB
Soffit		Hershey Company
Biscuits	With iron, calcium, folic acid, and Vitamin A and D	Britannia
tiger		
Rice	Fortify rice kernels	Christy foods
Path	With Vitamin A, B, B6, B3, and B12	IARI
Asbah power basmati rice	Fortified with Vitamin A and B	WFP
Rice		DCP India Pvt., Ltd. Adani Wilmar K.K.R. Group (Nirapara) Pattabhi Agro Pvt., Ltd. Hindustan Unilever Limited Daawat Rice

(Contd...)

Table 2: (*Continued*)

Name of fortified food	Fortificants added	Manufacturer
Edible oil	Vitamin A and D	Patanjali
Rice bran health	Vitamin A and D	Fortune
Refined oils	Vitamin A and D	Cargill
International sunny fortified oils lite	Power of 5 - Vitamin A, D, E, antioxidants, and omega-6	Sunny
International sunny soya fit	Power of 5 - Vitamin A, D, E, antioxidants, and omega-3	Sunny
Saffola gold	With natural antioxidants and Vitamin A and D	Marico India
Saffola active	With antioxidants and LOSORBTM Technology along with	Marico India
Saffola tasty	omega -3	Marico India
Refined oil	Oryzanol and LOSORB Technology with fatty acids, MUFA,	Priya foods
Sundrop oil	and PUFA	ConAgra Foods
Sundrop gold lite	With Vitamin A and D	ConAgra Foods
Healthy and tasty oil	With Vitamin A and D, natural Vitamin E, and omega-6	EmamiAgrotech Ltd.
Refined sunflower oil	Natural antioxidants and essential fatty acids	EmamiAgrotech Ltd.
Dhara Health Refined Sunflower oil	With Vitamin A, D, E and no cholesterol and tocotrienols	Mother dairy
Gold Winner Refined Sunflower oil	Enriched with Vitamin A, D, E, and rich in natural	Kaleesuwari Refinery Pvt., Ltd.
Gemini Sunflower oil	nutrients, PUFA	Gemini cooking oil
	With Vitamin A and D, low absorb	
	With Vitamin D3+ve	
	Nutri V	
Yogurt Greek Yogurt (EPIGAMIA)	a+pro-grow (high protein low fat)	Nestle India
PobioticDahi	acti plus	Nestle India
Everyday Dahi	a+Dahi	Nestle India
Dahi (Probiotic Dahi)	B – active	Mother Dairy
Advanced Dahi	Probiotic Dahi	Mother Dairy
Amul (Probiotic Dahi)	Pro-life	Amul India
Dahi	Nutri+With various flavors Nutri+	Danone India
Lassi		Danone India
Juices	Calcium and Vitamin D (100% orange juice) non-GMO	Minute maid
Minute maid	Essential probiotics	Tropicana products Inc.
Tropicana	Essentials - iron (3.2 mg=15% iron RDA)	Tropicana
Tropicana	Essentials - fruit and veggies (Vitamin A and C)	Tropicana
Tropicana		
Cereals - infants	Iron fortified	Nestle India Limited
Ceregrow		
Maggi masala	e-Magic	Nestle India Limited

with lower number of gastrointestinal adverse effect incidence. Ferric is absorbed poorly ranging 3–16 times less than ferrous formulations at higher supplemental level [30,31]. Most of the trials conducted in India include micronized ferric pyrophosphate followed by ferrous fumarate and NaFeEDTA (Table 3).

Zinc

Zinc is an essential mineral required for more than 300 biochemical reactions including carbohydrate, protein, lipid, nucleic acid metabolism, transcription, and process of gene expression. Zinc is widely present in foods, particularly foods of animal origin such as meats, fish, shellfish, as well as legumes and nuts which is often beyond the affordability for a large section of Indian population. As the consequence zinc deficiency is highly prevalent among children, pregnant and lactating women in South Asian population including India [32]. In the changing landscape of fortification, there is ample scope to consider zinc fortification. According to a report published in 2010, almost 22 countries already participated in zinc-fortified cereals (mainly wheat) programs either by making it mandatory or voluntarily. The levels of fortification were ranged between 14 and 33 mg/kg. Mexico, South Africa, Uganda, and Zambia included zinc in maize fortification program with a level ranged within 14–25 mg/kg [33]. The available scientific studies demonstrate that zinc fortification can increase dietary zinc intake and thus total daily zinc absorption without affecting the absorption of other minerals negatively [34]. Mostly dietary zinc is absorbed by the small intestine, primarily by jejunum, and the efficiency of zinc absorption increased when there is zinc depletion [35]. Similar trend is found in case of zinc-fortified food, the percentage of dietary zinc intake that absorbed decreases with increasing zinc intake [34]. There is an increasing interest in the possible role of NaEDTA as enhancer of zinc and iron absorption [36]. Several zinc compounds are generally regarded as safe for human consumption. One of the widely used compounds is zinc oxide for cereal or maize fortification. Zinc oxide is used in rice fortification unless the final product is desired to be highly water soluble. Zinc oxide has good bioavailability and does not have any effect on color, taste, and Vitamin A stability while used together. Further, it is commercially cheap. Zinc sulfate also can be another option although it is more expensive and might have negative effect on Vitamin A stability.

Calcium and Vitamin D

Dietary deficiency of calcium in both the rural and urban India compounded with Vitamin D deficiency leads to a serious health concern, particularly among the women and children of different age groups [37-40]. In one study, it was shown that out of total surveyed patients identified with disorders of bone and mineral metabolism 52% was accounted for nutritional bone disease presumably due to dietary deficiency of calcium and Vitamin D [41]. The major role of calcium is the formation of bones and teeth by virtue of its phosphorus salt. Apart from this, calcium also plays crucial roles in cell signaling, nerve impulse transmission, muscle contraction, etc. Absorption of calcium is relatively inefficient; moreover, the presence of phytate and oxalate significantly hinders calcium absorption [42,43]. Thus, intake of calcium-dense food always does not ensure calcium absorption by the body. Absorption of calcium occurs primarily through two processes, active transport across the cell, mainly in the duodenum and the upper jejunum and passive transport by small intestine, mainly in the ileum and very little in the large intestine [44-46]. However, Vitamin D influences in the process of active transport and enhances the absorption of calcium. In the liver,

Table 3: Clinical trials carried out in India to examine role of food fortification on the nutritional level

Location	Study design	Outcome	Reference
Rice fortification			
Bangalore, Karnataka	Double-blind, randomized, controlled 7-month MGFP 6–13-year-old schoolchildren (n=184)	Increase iron store reduce the prevalence of iron deficiency	[63]
Bangalore, Karnataka	Double-blind, randomized, controlled 4-month ferric pyrophosphate 5–13-year-old iron-deficient children (n=184)	Reduce prevalence of iron deficiency	[64]
Maheshtala, South 24 Parganas district, West Bengal	Double-blind, randomized, controlled 6-month ferrous fumarate, retinyl acetate, folic acid 3–5.5-year-old pre-school children (n=516)	Increase iron store Reduce the prevalence of iron deficiency and anemia	[65]
Ranga Reddy district, Andhra Pradesh	Double-bind, randomized, controlled 8-month micronized ferric pyrophosphate 5–11-year-old schoolchildren (n=140)	Improve iron store reduce iron deficiency	[66]
Bangalore, Karnataka	Double-blind, randomized, controlled 6-month MGFP 6–12-year-old schoolchildren (n=258)	Small reduction in anemia prevalence improve Vitamin B12 status and physical performance	[67]
Gajapati and Rayagada district, Orissa	Fortified rice distributed by Government of Orissa 6–14-year-old schoolchildren (n=1899 for Gajapati; n=1920 for Rayagada)	Decrease in anemia	[68]
Wheat fortification			
Bangalore, Karnataka	Double-blind 7-month NaFeEDTA 6–15-year-old iron-depleted children (n-401)	Improve iron store reduce iron deficiency	[69]
Salt fortification			
Anekal taluk, Bangalore urban district, Karnataka	Double-blind fortified salt in two arms (MGFP and encapsulated ferrous fumarate) 5–15-year-old children (n=458)	Decrease the prevalence of anemia	[70]
Panighata tea estate, Darjeeling district, West Bengal	Double-blind, randomized, controlled 9-month double-fortified (potassium iodate and microencapsulated ferrous fumarate) 18–55-year-old female	Improve hemoglobin, ferritin, soluble transferrin receptor, body iron	[71]
Laddoo (cereal-legume snack) fortification			
India	Randomized, controlled calcium and Vitamin D 2–3-year-old boy (n=64)	Increase TBLH BMC	[72]
Milk fortification			
NCR, India	Randomized, controlled Vitamin D 10–14-year-old children	Improve 25 OHD level	[73]

MGFP: Micronized ground ferric pyrophosphate, NCR: Near capital region, TBLH BMC: Total body less head bone mineral content

Vitamin D is transformed into 25-hydroxyvitamin D (25OHD) which is further converted to the active hormonal form 1,25-dihydroxyvitamin D (calcitriol) in the kidney. Calcitriol plays a crucial role in the expression of gene encoding calcium-binding protein, causing synthesis of the protein, and thereby regulating the migration of calcium across the intestinal cells [46]. Moreover, calcitriol also increases the membrane permeability and activates Ca-ATPase, thus facilitating higher calcium absorption. Apart from sunlight, the common sources of Vitamin D include fish, fish liver oil, and egg yolk which is beyond the affording capacity in many sections of people due to poverty. Still, a large section of Indian population exists outside of daily affordability of milk and milk products, although demand is increasing. According to the current regulation, calcium is absent in the list of mandatory fortification, but Vitamin D is mandatory for oil and milk fortification. Although a limited number of trials carried out in India, most trials with food fortification with Vitamin D showed improved Vitamin D status, i.e., increasing level of $25OHD_3$ of the population. However, several studies involve intervention with food fortified with Vitamin D and calcium.

Folate and Vitamin B_{12}

Mandatory flour (cereal grain products) fortification with folic acid was first authorized in the United States in 1996 and fully implemented in 1998. Since then at least 53 countries made regulations for mandatory fortification of wheat flour with folic acid [47]. The primary goal of folic acid fortification is to prevent NTDs pregnancies and birth by improving folate status in the body [48,49]. Benefits of folic acid fortification were

demonstrated by 19 to over 50% reduction of NTDs [50-52]. As the consequence folate status of the entire population has been shifted to a state of sufficiency or even excess which could come up few adverse events. As a result of long term consumption of folate fortified foods there is a chance for elevation of un-metabolized folic acid. The elevated unmetabolized folic acid results reduced natural killer cell cytotoxicity. Several shreds of evidence suggest high folic acid intake exacerbate the adverse effects of Vitamin B_{12} deficiency. High serum folate and Vitamin B_{12} deficiency together result in increased risk of both anemia, cognitive impairment [53], and significantly higher plasma homocysteine [54]. Although a little old but alarming statistics was represented by McLean *et al*. [55] which stated that based on data from the World Health Organization of 2005 the prevalence of Vitamin B_{12} deficiency in Indian adults accounted 50%.

Vitamin B_{12} or cyanocobalamin plays a critical role in synthesizing of s-adenosyl L-methionine which is the major methyl group donor in the methylation reactions and also helps in synthesizing of cysteine (transsulfuration). Together folate and cobalamin are essential for the normal development and function of the central nervous system and this indicates that a fraction of NTD during pregnancies is associated with low Vitamin B_{12} plays a significant role in instituting a mandatory rule for flour fortification with Vitamin B_{12} in the United States. Foods of animal origin are often a good resource of Vitamin B_{12} and due to a restriction of non-vegetarian diet among a sizable of Indian population, low Vitamin B_{12} and hyperhomocysteinemia are common. Unlike folate, the absorption of Vitamin B_{12} is tightly regulated. Thus, the question remains important whether sufferings associated with Vitamin B_{12} deficiency is due to inadequate intake of the vitamin or the malabsorption of the vitamin. This question requires further studies.

Vitamin A

Vitamin A deficiency continues to be one of the major public health concerns in India [56,57]. High prevalence of Vitamin A deficiency among the pre-school children is presumably due to maternal Vitamin A deficiency, decreased breastfeeding, and poor weaning practice [58,59]. Thus, Vitamin A fortification has been mandatory for milk and oil to eradicate the deficiency. Primarily, edible oil used in India is sourced from groundnut, rapeseed or mustard, soybean, and sunflower seed. In addition to that sesame oil and in southern part coconut oil have been used. Furthermore, India is the top importer of palm oil. The peroxidation capacity of the cooking oil has been found as a barrier to ensure the stability of Vitamin A (retinyl palmitate, the common ingredients used for fortification) [60]. A study revealed an increase in Vitamin A decay once the peroxide level was more than 2 mEq of active oxygen per kilogram [61]. Moreover, it is also worth mentioning that often the same oil has been used several times, i.e., under thermal treatment (frying/cooking) and it could potentially loss the Vitamin A. Furthermore, depletion of Vitamin A in the vegetable oil is subjected to storing time and high temperature [62].

Although grains are not in the list of mandatory fortification with Vitamin A in India, it is in industrial practice in many countries. Vitamin A palmitate (retinyl palmitate) stabilized with antioxidants such as butylated hydroxytoluene (BHT) and BHT is most used for cereal fortification including rice while because of storage stability issue Vitamin A acetate (retinyl acetate) is not used [20]. β-carotene, provitamin of Vitamin A also being is being added for rice fortification in some cases.

CONCLUSION

In spite of having an implementation of several policies and strategies, nutrition deficiency is still a serious problem in India as well as many different parts of the world. Food fortification mandate can be expected a potential tool in this context. So far, the trials conducted with fortified foods in India mostly were found having positive results to improve the nutritional status of the subjects included in the study. However, most of the trials were designed focused primarily children. Adults and especially vulnerable section of people such as pregnant and lactating women, elderly population, as well as population of different socioeconomic categories are required also to be focused in time to design the trial of fortified food. A regular review and monitoring are also utmost essential to understand the efficacy of the fortification. Besides, it is also important to keep eye on the micronutrient profiling of the population because excess of micronutrients also undesirable as it is associated with health problems as already discusses above. Awareness among people should be raised in regard to nutrition and health.

AUTHORS' CONTRIBUTION

AS helped in collection of data and information, AP supervised AS, and SG formulated and wrote the manuscript.

CONFLICTS OF INTEREST

The authors do not have any conflicts of interest.

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