Potential of Iron Fortification Complex Compounds against Soybean Food for Anemia Problem Solution in Indonesia

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***Abstract*—The problems of anemia, especially in Indonesia is still high due to the lack of nutrient daily intake of iron. One effective strategy to reduce the problem is through the iron fortification of soy foods. The addition of iron complex compounds in soy foods can add nutritional value by increased iron that can reduce the potential of anemia. Various iron supplementations performed on soy-based foods such as tempeh, tofu, and soy milk. This article reviews presentations on iron fortification programs of soy foods. The percentage of iron fortification in tempeh, tofu and soy milk can achieve a great value that is respectively 80-90%, 50-60% and 55-60%. With a variety of treatments to food fortification iron to make iron soy can improve the nutritional value of soy food and have the potential to meet the needs of iron, thereby reducing anemia.**

***Index Terms*—iron deficiency, fortification, iron fortification, soy foods**

I. Introduction

Anemia is common problem in developing countries, especially in Indonesia. Iron Deficiency Anemia (IDA) is the general case of Anemia in Indonesia. IDA is a condition in which a lack of iron in the blood, especially in the complex hemoglobin that makes the patient weak due to lack of oxygen captured by hemoglobin [1]. Based on primary health research data of Ministry of Health Republic of Indonesia in 2013, the rate of anemia in Indonesia reached 21.7% of the total population of Indonesia [2]. IDA occurs in children, pregnant women, and the elderly.

Attempts have been made to address the problem of IDA by using drugs containing iron compounds as a supplement to increase blood hemoglobin levels. The use of such a supplement drug can be effective in the short term only, it unable to meet the needs of the iron intake if consumption of the supplements is stopped. Therefore, it needs another effective way which is through food fortification. Fortification, which has been carried out on the material is fortified cereal, wheat flour and soy sauce, brown rice [3].

Soy-based foods such as tofu, tempeh and soy milk widely consumed by Indonesian people. There is a huge potential for tempeh and tofu in iron fortification program, to increase the iron intake without iron supplements.

A. Soybean

Soybean or soya beans (Glycine max) are a type of legume, native to eastern Asia. They are an important component of Asian diets and have been consumed for thousands of years. Various derivatives of soy products are available, including soy flour, soy protein, tofu, soy milk, soy sauce, and soybean oil. Soybean and its derivates represent an excellent source of high quality protein, with low content of saturated fat and a great amount of dietary fiber and bioactive components like the isoflavones [4]. Soybeans contain with rich and complete nutrients like antioxidants and phytonutrients that provide health benefits. The absorption of iron by humans from soybeans has been reported to be better than that from a number of other foods of plant origin and some countries like China are supplementing soybean based foods with iron to prevent anemia [5].

B. Soy Milk

Soy milk is nutritious drink made from soybeans. The traditional soymilk production method consists basically soaking the beans, wet grinding (cold water grinding), filtering and cooking, which results in a final product that resembles cow milk in appearance being commercialized either in sterilized or pasteurized form, with or without flavoring addition, which is better to attenuate the soy taste, and is unpleasant to the Western population [6]. Soy milk is high in essential fatty acids, proteins, fiber, vitamins and minerals. The nutrients that naturally present in the soybean provide energy and keep the body functioning at its optimum level. Among soybean derivatives is the soymilk, an important alternative for human nutrition, based on water-soluble hydrolyzed soy protein extract, for those who are lactose intolerant or places where bovine milk is expensive or unavailable [7]. In this way, soy milk could be a suitable vehicle for iron fortification to reduce anemia in Indonesia.

C. Tempeh

Tempeh is one of processed soybean food by fermentation using the fungus Rhizopus oligosporus. Tempeh has a better flavor than raw soybeans, as well as the content of dissolved solids is also higher, which

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contain vitamin B12, minerals such as Ca and Fe, contains no cholesterol and is relatively free from toxic chemicals. During the fermentation process there is a simple process of forming compounds of more complex compounds that are more soluble, so tempeh that contain various nutrients that high can be easily digested by the body (Table I). Tempeh has a white color, dense texture, and flavor. The white color is due to fungal mycelia growing on the surface of soy beans and dense terkstur caused fungal mycelia that connects between the seeds of soybean and distinctive taste because of the degradation of components in soybeans during the fermentation process.

TABLE I. NUTRIENT DATA FOR: TEMPEH

Nutrient	Unit	Value per cup (166.0 g)
Energy	kcal	319
Protein	g	33.68
Total lipid (fat)	g	17.93
Carbohydrate, by difference	g	12.68
Calcium, Ca	mg	184
Iron, Fe	mg	4.48
Magnesium, Mg	mg	134
Phosphorus, P	mg	442
Potassium, K	mg	684
Sodium, Na	mg	15
Zinc, Zn	mg	1.89
Vitamin C, total ascorbic acid	mg	0
Thiamin	mg	0.129
Riboflavin	mg	0.594
Niacin	mg	4.382
Vitamin B-6	mg	0.357
Folate, DFE	µg	40
Vitamin B-12	µg	0.13
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	0
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Fatty acids, total saturated	g	4.215
Fatty acids, total		
Monounsaturated	g	5.32
Fatty acids, total		
Polyunsaturated	g	7.138
Fatty acids, total trans	g	0
Cholesterol	mg	0
Amino Acids		
Water	g	99.02

Source: USDA National Nutrient Database for Standard, 2016

D. Tofu

Tofu is a popular food in Asian countries and its consumption is recently increasing in Western countries [8]. Tofu is a soy protein product, with homogeneous composition, cream-colour and mild flavour, which is produced by the coagulation of heated soymilk. Tofu has been considered as a particularly nutritious product because it contains about 1% of dietary fiber, has a very low energetic value and does not contain cholesterol. Furthermore, it also contains high levels of isoflavones, vitamins and minerals, which contribute to both the health benefits and the nutritional value of the tofu [9] (Table II).

TABLE II. NUTRIENT DATA FOR: TOFU

Nutrient	Unit	Value per slice (84 g)
Protein & Amino Acids		
Protein	g	4.0
Carbohydrates		
Total Carbohydrate	g	2.4
Dietary Fiber	g	0.1
Sugars	g	1.1
Fats & Fatty Acid		
Total Fat	g	2.3
Saturated Fat	g	0.3
Monounsaturated Fat	g	0.4
Polyunsaturated Fat	g	1.3
Vitamins		
Vitamin A	IU	0.0
Vitamin C	mg	0.0
Vitamin D		~
Vitamin E		~
Vitamin K		~
Thiamin	mg	0.1
Riboflavin	mg	0.0
Niacin	mg	0.3
Vitamin B6	mg	0.0
Folate	~	~
Pantothenic Acid	~	~
Choline	~	
Betaine	~	
Minerals		
Calcium	mg	26.0
Iron	mg	0.7
Magnesium	mg	24.4
Phosphorus	mg	52.1
Potassium	mg	151
Sodium	mg	4.2
Zinc	mg	0.4
Copper	mg	0.2
Manganese	~	~
Selenium	~	~
Fluoride	~	~
Sterols		
Cholesterol	mg	0.0
Water	g	74.8

Source: USDA National Nutrient Database for Standard, 2016

II. DISCUSSION

A. Iron Fortification in Soybean

A fortification enhancer compound nutrient to soy is one of the food fortifications of soy. In Indonesia, soybean can be processed into food such as tofu, tempeh,

soy milk and other soy products processed materials [10]. Soybean become one of the fortified due to high nutritional content, as in protein and carbohydrates [11]. Soybeans also relatively affordable and widely consumed by the public, hence it is good to increase nutrient fortification in soy.

In the process of fortification of soy the important thing is phytic acid content. Phytic acids are chelate compounds in plants that are capable of binding to metal minerals such as iron. Therefore it is considered as an anti-nutrition phytic acid in food [12]. However, despite the phytic acid will hinder the process of fortifying minerals; phytic acid is a natural antioxidant. In addition to being antioxidants, phytic acid also can lower cholesterol and lead poisoning antidote [13].

What the researchers do to reduce phytic acid interference against the absorption of iron in soybeans is to use chelate compounds. Chelate compounds which are widely used for fortification is EDTA, fumarate, and glycinate [14]. Ascorbate can also be used as chelate compounds that affect the bioavailability of iron so the iron absorption increased [15]. Chelate compounds will protect the iron ion to be added to soy thereby reducing the possibility of phytic acid attack against the iron ions which can reduce the effectiveness of the absorption of iron ions.

B. Iron Fortification in Tempeh

Tempeh fortification with iron has been pretty much done. Some researchers make the process of fortification iron in soybean by several methods. Yuniarti *et al.* reported that it has successfully fortification of iron in food soybean tempeh one of them is by using a variation fortifying material $FeSO_4.7H_2O$; Ferrous bis glycinate; and a mixture of Na-glycinate + $FeSO_4.7H_2O$ [16]. By using fortification iron fortification is the verdict percent each by 74%; 86% and 56%. Darlan while doing research using $FeSO_4.7H_2O$ as fortifying material; $FeSO_4.7H_2O$ + Na_2H_2EDTA; and NaFeEDTA get the value of fortification in 10 grams of tempeh each 70-150 mg; 65-125 mg; and 25-45 mg of fortifying material [17].

Sudargo, *et al.* reported that he has been testing fortification iron in tempeh and also conducts organoleptic testing and in vitro in Wistar rats. In the study Sudargo, *et al.* said that there was no significant change in the organoleptic test between non fortifications tempeh with iron fortification tempeh. But also there is a significant increase hemoglobin levels in Wistar rats after feed by iron fortification tempeh. Sudargo, *et al.* discovered conditions that may increase serum ferritin tempeh on the blood of Wistar rats [18]. It shows that the presence of fortifying substances in Tempeh has the potential to increase the iron levels in the blood and can be expected to be one of the solutions for IDA.

Astuti, *et al.* doing research using the tempeh fortification of iron and vitamin A as well as doing the cooking tempeh fortification results to determine whether there are significant changes to the nutritional value of tempeh fortified [19]. The study came to the conclusion that the fortification tempeh are not change significantly after a heating process in cooking. Levels of protein, fat, water, carbohydrates and minerals in tempeh fortification did not experience a significant reduction after a cooking process.

C. Iron Fortification in Tofu

Fortification iron is also performed in tofu because tofu is a soy-based food with high nutrients such as protein. Tofu can experience particularly iron fortification process to increase the nutritional value. One study conducted by Masuda with ferritin extract from tofu is capable of being an iron fortifying material with good bioavailability. Ferritin has good stability during the heating process, and has a large content of iron atoms that may be a good potential fortifying substance for food. Masuda had a view that ferritin is not only derived from soybeans, but also can be obtained from other plants that contain ferritin [20].

Yuniarti *et al.* fortified tofu with $FeSO_4.7H_2O$; Ferrous bisglisinat; and a mixture of Na-glycinate + $FeSO_4.7H_2O$ got the results of the fortification percent respectively: 51%; 55% and 46%. Tofu has phytic acid levels lower than tempeh and soy milk. It is caused when the manufacturing process involves heating and removal solution which can contain phytic acid.

D. Fortification in Soy Milk

Another based-soy foodstuff that contain good nutrient for human are soy milk. Soy milk are foodstuffs that becomes an alternative to cow's milk, because of the nutrients are similar to cow's milk, which is contain high proteins and vitamins. However, the soy milk has lower of mineral such as calcium and iron than cow's milk [21]. Due to a lower content of mineral than cow's milk, the researcher do fortify to soy milk to enrich the nutrient, especially the minerals such as calcium and iron.

Phytic acid which is owned by soy milk are higher than tempeh and tofu. It is because the process of making soy milk does not go through the fermentation process and only utilize soy bean grinding process and heating from soybean extract. Therefore, the process of fortification iron to soy milk will have a value lower fortification effectiveness of tempeh and tofu due to have a higher phytic acid.

The research that conducted by Fauziyati using substance $FeSO_4$ and $FeSO_4$ + glycine in soy milk, which gained the maximum results in substance $FeSO_4$ + glycine than $FeSO_4$, because of glycine would blocking phytic acid to interact with ions of iron-free [22].

E. Comparison Results Iron Fortified Foods

Before the soybeans food base, researches of the food fortification have been done in soy sauce and flour. Komari and Hermana do fortification process by using Ferrous Sulfate and Ferrous fumarate on soy sauce and wheat flour [23]. The effectiveness value of iron obtained from wheat flour with Ferrous Sulfate ranged between 86-95%, while ferrous fumarate ranges from 90-91%. In the fortification of soy sauce with some variations in the types of soy sauce effectiveness iron values obtained using Ferrous Sulfate with grades ranging from 66-82%. Although it has great value sufficient effectiveness as the

fortification of soy ingredients, but there is a difference in the amount of consumption of wheat flour and soy sauce to tempeh.

Based on the average consumption of soy sauce data in Indonesia in the year of 2002 - 2013 is 0.63kg / capita / year, while the consumption of tofu and tempeh are 7.26kg / capita / year and 7.57kg / capita / year (Foods Consumption bulletin, 2014) [24]. The data shows the consumption of tofu and tempeh are higher than soy sauce and flour, therefore the effectiveness of anemia reduction through food fortification has bigger impact on the using of tofu and tempeh.

F. Efficacy of Iron Fortification Compared to Iron Supplementation

The effect of iron fortification is generally assumed to be less than iron supplementation. Huong Thi Le *et al.* 2006 conducted a research of the efficacy of iron fortification compared to iron supplementation among Vietnamese schoolchildren**.** Vietnam condition similar to Indonesia, anaemia is also a significant public health problem in Vietnam. Results from their study show that in anaemic schoolchildren, iron fortification was 58% (based on change in haemoglobin level), 80% (based on SF level), and 69% (based on body iron) less effective than iron supplementation. The efficacy of iron fortification based on reduction of prevalence of anemia, and on the change in hemoglobin level, is about half of the maximum impact of supplementation [25]. But it could be beneficial in the long term, and there is consideration about supplementation in malaria endemic areas.

Study from Gera *et al. Effect of iron-fortified foods on hematologic and biological outcomes: systematic review of randomized controlled trials*. Data from 60 trials showed that iron fortification of foods resulted in a significant increase in hemoglobin (0.42 g/dL; 95% CI: 0.28, 0.56; $P < 0.001$) and serum ferritin (1.36 µg/L; 95% CI: 1.23, 1.52; $P < 0.001$), a reduced risk of anemia (RR: 0.59; 95% CI: 0.48, 0.71; $P < 0.001$) and iron deficiency (RR: 0.48; 95% CI: 0.38, 0.62; $P < 0.001$), improvement in other indicators of iron nutriture, and no effect on serum zinc concentrations, infections, physical growth, and mental and motor development [26]. Consumption of iron-fortified foods results in an improvement in hemoglobin, serum ferritin, and iron nutriture and a reduced risk of remaining anemic and iron deficient.

Rob Baltussen *et al.*, also show on their research that iron fortification has the lowest cost-effectiveness ratio and is from the economic point of view most attractive. Thereof, food fortification is often suggested as one of the most effective and sustainable strategies for increasing iron intake in the general population. To be concerned in the fortification processes is choosing a suitable food vehicle. The important factors in the selection are to choose the food that consumed regularly and in predictable amounts, and affordable by the target population; also the quality could be effectively controlled when implemented on a large-scale [27].

Soy-based foods such as tofu, tempeh and soy milk are widely consumed food by Indonesian people. Based on data from the Central Bureau of Statistics the average consumption per capita tempeh for a week in 2014 amounted to 0.133kg, while for Tofu is 0.136kg (CBS, 2014), then there is potential for tempeh and tofu in iron fortification program. Thus, Indonesian people can increase the iron intake without consuming iron supplements. The program is effective in reducing anemia during the dose consumed is high enough, but not effective when taken in low doses.

G. Studies of Iron Fortification in Foods

Fortification of foods at the community level is also still at the experimental stage. These are recent systematic reviews of the researches on iron-fortified foods.

No.	Fortification Substance	Researchers	Result
1	Fortification in Tempeh	Yuniarti *et al.*, 2013	Tempeh added by $FeSO_4.7H_2O$; Ferrous bis-glycinate; and mixture of Na-glysinate + $FeSO_4.7H_2O$. The result of iron fortification are 74%; 86% and 56%.
2		Sudargo, *et al.*, 2015	Organoleptic test and in vitro testing on wistar rats in Tempeh that have been fortified. The result there is a significant increase hemoglobin levels in Wistar rats after being given tempeh fortification and increase serum ferritin in the blood of Wistar rats
3		Astuti, *et al.* 2014	Fortification tempeh using iron and vitamin A and doing cooking experimental of the tempeh. The fortification tempeh are not change significantly after a heating process in cooking. Levels of protein, fat, water, carbohydrates and minerals in tempeh fortification did not experience a significant reduction after a cooking process.
4		Darlan Azhar, 2012	Fortification tempeh using $FeSO_4.7H_2O$; $FeSO_4.7H_2O$ + Na_2H_2EDTA; and NaFeEDTA. In 10 gram each tempeh contain 70-150 mg; 65 – 125 mg; and 25 – 45 mg of iron
5	Fortification in Tofu	Yuniarti *et al.*	Iron fortification in tofu, using $FeSO_4.7H_2O$; Ferrous bisglycinate; and mixture of Na-glycinate + $FeSO_4.7H_2O$ (Yunarti *et al.* 2013). And the result, the each tofu contains 51%; 55% and 46% of iron
6	Fortification in Soy Milk	Fauziyati, 2011	Soy milk added by $FeSO_4$ and $FeSO_4$ + glycine in soy milk, and which gained the maximum result in substance $FeSO_4$ +Glycine

III. CONCLUSION

Iron Deficiency Anemia (IDA) is a condition when someone has insufficient amount of iron to meet the

needs of his body. Food fortification is often suggested as one of the most effective and sustainable strategies for increasing iron intake in the general population to meet the daily needs of iron. Researchers have done many studies on iron fortification of the soy-based foods. Studies have shown that iron fortification of soy foods have a significant effect on the increase of the iron content in the human body. The effectiveness of iron in soy foods such as tempeh, tofu and soy each has a value of effectiveness fortification are respectively 80-90%, 50-60%, and 55-60%. Increasing the amount of iron in the soy foods has the potential to be a solution to meet the needs of iron per day, they are expected to reduce the number of patients with iron deficiency anemia.

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