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Iron and Zinc Fortified Food Products: Interaction, Acceptability and Bioavailability

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ABSTRACT

This review aims to compile interaction, bioavailability of iron and zinc, and sensory acceptability of fortified food products. It was found that high level of iron fortificant may be interfered on zinc absorption in some food products. In general, iron and zinc bioavailability increased after fortified contemporary these fortificants into food products. Consumer acceptability of fortified products with iron and zinc did not show any significant negative properties and consumer did accept these products when these compounds were used in the proper food and right amount.
KEYWORDS: Iron, Zinc, Interaction, Acceptability, Bioavailability

INTRODUCTION

Iron and zinc deficiency, a common nutritional disorder, is a significant factor in health problem in over the world particularly in the developing and low-income countries [1]. More than two billion population worldwide are not only suffered with the deficiency but the productivity, ability and economy also significantly retard.

Iron, a trace element and essential mineral for human growth, is mainly found in hemoglobin and myoglobin [2], which plays as an important role in variety of biochemical processes [3]. Deficiency of iron strongly relates to anemia, mental disorder and immunity problems [4], children cognitive ability, poor pregnancy quality and lower working capacity in adults [5]. Iron deficiency mainly caused by low intake of heme iron and vitamin C. In fact, poor absorption of iron relates to high phytate, phenolic compounds containing in daily food and period of life when iron requirement is significantly high such as fetus or child age and the monthly discharge of blood of unpregnant women as well as heavy blood losses due to an accident or operation [1]. However, the excess iron intake also can cause an acute toxicity for example lethargy, vomiting, abdominal pain, blade stools and signs of shock, metabolic acidosis, liver damage and coagulation. In addition, toxicity of over dose of iron consumption is common in adult rather than children [6].

Zinc, an essential element for human body as iron, is a good reducing agent. It can easily form complex with other compounds including carbonates, phosphates, sulfates, oxalates and phytates. An important function of zinc is an essential cofactor of more than 70 enzymes [7]. Zinc deficiency is listed in the top five risk factors of disease and death in developing countries [8]. Zinc deficiency caused dermatitis, growth retarding, diarrhea, mental disturbances and recurrent infections [1]. This deficiency generally relates to diet consumption with low in zinc or high in phytates leading to the occurrence of malabsorption disorders, and impaired utilization of zinc and genetic diseases. In contrast, high dose of zinc also can adverse effect on human body. The acute zinc poisoning such as nausea, vomiting, diarrhea, fever, and lethargy may due to upper limit of amount of zinc consumption [9].

Food fortification is a process of addition of essential components such as trace elements, vitamins, protein and so on into food, even though, they normally either contains or absent in the food. And the aim of dealing with element fortification is to prevent, reduce and correct the deficiencies within the population or population group [1]. In recent years, micronutrient fortification into staple foods has been proven to be a simple and effective way to increase micronutrients in daily meals [10]. Therefore, the objective of this present review is to produce an

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overview of scientific data on interaction, acceptability and bioavailability of contemporary fortified food products with iron and zinc.

INTERACTION OF IRON AND ZINC IN HUMANS

There are two underlying interaction types of trace element occur in the biological systems [11]. Firstly, two or more elements absorb in the same pathway, in which case one element has high concentration interfere with the absorption of other element in the systems [12]. Secondly, the interaction occurs because one of trace element is deficient that affects the metabolism of another one [13]. From both of types, the first interaction type is mostly important since one of elements was fortified, which can make an adverse effect on the employment of other trace elements [14]. While the second interaction type should also be inspected because of the deficiency of one trace element may have a pronounced effect on the outcome of the study and affect to the assessment of the study also. As the study of Cohen *et al*. on the growing rat, the copper-deficiency anemia resulted in iron-deficiency anemia because the essential component of ceruloplasmin is coper, when the copper is deficient the ferroxidase activity decreased dramatically, which prevents the mobility of iron from stores and its incorporation into hemoglobin [13].

Iron and zinc interaction in human measured by Solomons *et al*. were reported that after oral ingestion iron interfered with zinc uptake at high level [15]. Plasma uptake in human body was reduced when increasing the ratio iron to zinc in water more than 2:1 compared with 1:1. However, it was found that interaction between iron and zinc in the meals may differ from water system [16]. The difference of iron and zinc in the water and the meals may due to binding property of some foods components, which is the presence or absence of ligand binding of iron and zinc. For example, the addition of histidine as a dietary ligand to the water, which can chelate with zinc causing zinc absorbed via pathway that was not affected by the concentration of iron in human gut system. However, when there are no ligand binding iron and zinc would be an important competitor of common binding sites at the mucosal surface particularly when one compound is too high leading to percentage uptake of another [14]. The evidence for this situation was reported by observation of Yip *et al*. who stated there was no interaction between iron and zinc in the infants treated with iron drop (30 mg) and zinc (30 mg) compared with the infants given placebo for 3 months [17].

Effects of heme and nonheme iron on the zinc absorption via Coca-Cola beverage carrier in human was reported by Solomons *et al*. [15]. There was no significant difference between male and female, however, at ratio 1:1 of nonheme iron (ferrous sulfate) to inorganic zinc (zinc sulfate) showed that plasma zinc decreased significantly compared to zinc alone after 1 hour post-ingestion. While the plasma zinc depressed after 1, 2, and 3 hour at Fe:Zn ratio 2:1, and 1, 2, 3, 4 hour at Fe:Zn ratio 3:1. In contrast, the absorption of zinc was not significantly different at ratio 3:1 of heme iron (heme chloride) to inorganic zinc (zinc sulfate). This report explained that because the human body can manage the absorption and excretion of zinc to conserve zinc homeostatic [18]. However, at certain high level of iron, the negative effect on the absorption of zinc was found due to the competition of the nonspecific pathway [16, 19]. Iron and zinc interaction in human influence on the absorption of iron and zinc in human body is summarized in Table 1.

Table 1. Summary of studies about the effect of iron and zinc interaction in human subject[1] (cont.)

Iron (mg)	Zinc (mg)	Fe:Zn	Carrier	Effect	Reference
25	25	1:1	Cola	D	[15]
50	25	2:1	Cola	D	[15
75	25	3:1	Cola	D	[15]
100	54	1.9:1	Oysters	NE	[15]
50	25	2:1	Cola	D	[29]
47	22.5	2:1	Water	D	[30]
100	50	2:1	Water	D	[31]
51	6	10:1	Water	D	[32]
26	6.2	5:1	Water, heme	D	[32]
17	4	5:1	Turkey	NE	[32]
34	4	10:1	Turkey	NE	[32]

2.2	2.6	1:1	Water	NE	[16]
5.6	2.6	2.5:1	Water	NE	[16]
56	2.6	25:1	Water	D	[16]
2.2	2.6	1:1	Rice and meat	NE	[16]
5.6	2.6	2.5:1	Rice and meat	NE	[16]
56	2.6	25:1	Rice and meat	D	[16]
2.5[2]	1.87[2]	1.3:1	Infant formula	NE	[33]
10.2[2]	1.88[2]	5.4:1	Infant formula	NE	[33]
47	22	2.4:1	Water	NE	[34]
24	27	1:1	Water	D	[34]
24	68	1:2.5	Water	D	[34]
3	15	1:5	Water	D	[35]
3	45	1:15	Water	D	[35]
3	15	1:5	Hamburger	NE	[35]
10.3	0.44	23.3:1	Weaning cereal	NE	[36]
25.3	0.44	57.4:1	Weaning cereal	NE	[36]
4.5	0.51	8.8:1	Bread rolls	NE	[36]
5.5	0.54	10.2:1	Infant formula	NE	[36]

[1] D: decreased zinc absorption; NE: no effect on zinc absorption.
[2] Iron and zinc expressed as mg/L.
Source: [37].

SENSORY ACCEPTABILITY OF IRON AND ZINC FORTIFIED PRODUCTS

A consumer preference is the major item concerning in food fortification. The millet flours fortified with iron and zinc salt, and EDTA at levels equimolar were performed and the result showed no change in the organoleptic properties between the raw and cooked products [20]. In 2002, Lopez De Romana *et al*. reported that consumer did accept all noodles and bread fortified with iron and zinc salts, while noodles fortified with iron and ZnO had a slightly lower degree of liking score compared with noodles fortified with only iron or iron plus $ZnSO_4$ [21]. In addition, the fortificants added to cassava flour in the dough preparation such as NaFeEDTA and $ZnSO_4$ did not show any significant negative effect to the sensory properties of chips [22]. However, colour of the fortified cassava flour chip was iron dependent [23]. Khoshgoftarmanesh *et al*. reported that fortification of iron (60 mg/kg) and zinc (30 mg/kg) would enhance the mineral deficiency but sensory acceptability of products was reduced [24]. Khabbazi breads fortified with iron had lower score in colour, taste and overall attributes compared with control, unfortified iron [24]. However, the Khabbazi breads fortified with zinc did not have any negative sensory effect even compared with the control one [24].

Iron and zinc salt were fortified into fresh buffalo's milk to produce Domiati cheese [25], and the result of organoleptic properties showed that all fortified cheese samples at level 40 mg/kg fortificants did not have any negative effect on cheese quality even when compared with control samples. However, fortification with higher level of iron and zinc salts (> 40 mg/kg) had the lower score of flavour because of rusty or oxide or metallic taste.

BIOAVAILABILITY OF IRON AND ZINC FORTIFIED PRODUCTS

Bioavailability is defined as the amount nutrients in food that be digested absorbed and utilized by metabolic pathways [26]. In fact, the absorption mechanism of chemical transportation in human body are similar [27]. Avalos Mishaan *et al*. studied the bioavailability of iron and zinc from a multiple micronutrient-fortified beverage in children aged 6 to 9 years. And the report showed that an increasing iron uptake from fortified beverage with 1 mg/200 mL ^{58}Fe and 0.4 mg/200 mL ^{70}Zn was 9.6 ± 6.8% when consumed with a piece of bread and butter and increased to be 11.6 ± 6.9% when the same beverage containing 4 mg/200 mL ^{57}Fe plus 2 mg/200 mL ^{67}Zn (2 mg)/200 mL was served without meal. While zinc absorption from consumption of the fortified beverage with and without meal was similar as 24.5 ± 10.7% and 22.8 ± 7.6%, respectively. The results pointed out that the fortified beverage with both iron and zinc could be consumed with or without a small meal. However, some scientific data reported that food containing phytates or phenol might inhibit iron and zinc absorption [28].

Tripathi *et al*. also studied the fortified iron and zinc salt with EDTA as co-fortificant to finger millet flour and sorghum flour [20]. The result showed that native bio-accessible zinc content in millet and sorghum flour was 0.22 mg and 0.39 mg/100 g, respectively, then reached to 0.83 mg and 1.63 mg/100 g when these flours fortified with zinc at 5 mg/100 g of flours. In addition, an initial bio-accessible iron content was 0.33 mg and 0.37 mg/100 g, respectively then increased to 2.39 mg and 2.63 mg/100 g after fortification of iron at 6 mg/100 g of flours. However, the bio-accessible iron and zinc content declined in fortified and unfortified flours during 60-day storage. As can be seen from the result, the fortification of iron and zinc salt with EDTA as co-fortificant could be increased significantly in the bio-accessibility of both iron and zinc fortificant.

CONCLUSION

Iron and zinc are essential micronutrient for health of human. Zinc absorption from food decreased when fortified with iron. However, in some food systems the bioavailability of iron and zinc was higher when compared with unfortified products. Iron and zinc did not significantly change the sensory properties if proper amount was used.

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