Effects of various iron fortificants on sensory acceptability and shelf-life stability of instant noodles

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Abstract

Background. *Iron-deficiency anemia is the most common nutritional problem in Thailand and many developing countries. One of the most sustainable and cost-effective strategies for combating iron deficiency is fortification of staple foods with iron.*

Objective. *In this study, the feasibility of fortifying instant noodles with different forms of iron fortificants (ferrous sulfate [FS], ferric sodium ethylenediaminetetraacetic acid [NaFeEDTA], and encapsulated H-reduced elemental iron [EEI] was evaluated, and the fortified noodles were compared with unfortified noodles for changes in physical, chemical, and sensory qualities.*

Methods. *Wheat flour used to make instant noodles was fortified to produce a concentration of 5 mg of iron per 50-g serving of instant noodles (one-third of the Thai recommended dietary intake).*

Results. *Analytical data showed that the iron contents were close to 5 mg per serving of noodles fortified with FS, NaFeEDTA, or EEI (5.27 ± 0.10, 4.27 ± 0.07, and 5.26 ± 0.47 mg, respectively). The color quality (measured by L*, lightness, and b*, yellowness) of the raw dough sheet and of uncooked and cooked instant noodles fortified with FS was lower than that of the unfortified, but color quality was not changed by the addition of NaFeEDTA. The overall sensory acceptability scores of unfortified and fortified noodles were about 6 ("like slightly"). No metallic odor was observed. During 3 months of storage at room temperature, the iron fortificants did not affect the peroxide level, color, or sensory qualities of the product.*

Conclusions. *Iron fortification of wheat flour used to make instant noodles is feasible. NaFeEDTA is the preferred fortificant because of its nonsignificant effect on the color and sensory quality of the products.*

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Key words: Fortification, iron, iron deficiency, iron-deficiency anemia, instant noodles

Introduction

More than 2 billion people, over 30% of the world's population, suffer from deficiencies of micronutrients including iron, iodine, zinc, and vitamin A [1]. Micronutrient malnutrition, particularly iron-deficiency anemia, can result in low resistance to infection, impaired psychomotor development and cognitive function in children, and poor academic performance, as well as fatigue and poor physical endurance. Iron-deficiency anemia reduces the quality of life of all those affected. In addition to the effects listed above, iron-deficiency anemia in pregnancy can result in low birthweight [2].

Current interventions to improve or reduce micronutrient deficiency disorders focus on supplementation, dietary diversification, and food fortification [3]. Iron supplementation with pharmacological amounts of oral iron is useful for improving iron status in high-risk groups such as pregnant women and children under five. However, this method of supplementation is expensive and commonly has poor compliance because of undesirable side effects such as vomiting, constipation, epigastric discomfort, and diarrhea [4–6]. Dietary diversification focuses on teaching people how to select food items and to consume more iron-rich foods, but its use is limited because iron-rich food from animal sources is often unaffordable to low-income people [7]. One of the interventions used to prevent micronutrient malnutrition in many countries of the world is fortification, which is important as a long-term strategy and is cost effective. Fortification can reach all population groups and does not require any special investments in promotion or education [8].

A processed food, instant noodles, was selected as a suitable vehicle for fortification with micronutrients, since it is widely consumed in relatively constant amounts by people in Thailand. It is sold in a readyto-cook package and is inexpensive (about US$0.125 for a 50-g package). More than 90% of instant noodles are deep-fried. The product already has a large market (6 million package sold per day) and distribution in both urban and rural areas of Thailand. It is acceptable for consumption among people of all socioeconomic and age groups [9]. In 1994 Thailand began voluntary fortification of seasoning sachets for instant noodles with iron, iodine, and vitamin A at one-third of the recommended dietary intake (RDI) [9].

Although encapsulated reduced iron is the organoleptically inert iron compound, it is not absorbed well because it dissolves slowly and incompletely in the gastric juice during digestion [10]. Moreover, a survey of food habits in northeastern Thailand found that almost half of young children and students preferred to consume instant noodles without cooking them (unpublished data). A study by Kongkachuichai et al. in 2004 [11] showed that fortifying fresh noodles with NaFeEDTA resulted in up to 50% dialyzable iron. However, this method of fortification may not be commercially feasible because the shelf-life of fresh noodles is only 2 to 3 days [11, 12].

The first objective of this study was to develop methods of fortifying the wheat flour mass used for preparing instant noodles with various sources of iron with different solubility characteristics of solubility. The fortification process should not negatively affect the organoleptic properties of the product during storage. Thus the second objective was to evaluate the shelf-life of the product based on the changes in physical properties and sensory acceptability.

Materials and methods

Preparation of iron-fortified instant noodles

Ferrous sulfate (FS; 33% iron) was obtained from Ajax, Aubern, Australia; encapsulated H-reduced elemental iron (EEI; 70% iron, particle size 325 mesh) from Roche, Switzerland; and ferric sodium ethylenediaminetetraacetic acid (NaFeEDTA; 13% iron) from Akzo Nobel Functional Chemicals, Arnhem, Netherlands. All-purpose Kite brand wheat flour was purchased from United Flour Mill Public Co., Thailand. The formulation of instant noodles used in this study was modified from that demonstrated in the Asian noodles training course workshop, Singapore, in 2001 [13]. In brief, approximately 200 g of wheat flour was mixed with each iron fortificant for 10 minutes at a dosage to provide 5 mg of iron (one-third of the RDI [14]) per serving (one 50-g package of instant noodles). One 50-g serving of instant noodles was prepared from 43 g of wheat flour or about 61 g of wheat dough [14]. The fortified wheat flour was mixed with alkaline solution at low speed for 1 minute and then at medium speed for 4 minutes in a KitchenAid mixer. The dough was then rested for 20 minutes in a covered plastic bag. The rested dough was passed through the sheeting rollers of the noodle-making machine (ATLAS 150), cut into strips, and then steamed in a pressure steamer for 2 minutes or until starch formed gelatinization. The steamed noodle strips were then showered with soup, drained, and placed in a noodle block mold. The noodle block mold was deep-fried in palm oil at 170°C for 45 seconds, and the fried noodles were laid and cooled on a stainless-steel screen at room temperature before being stored in bags made from oriented polypropylene (OPP) and metallized cast polypropylene (MCCP). The packed noodles were kept in a plastic box and stored at room temperature until analysis. Two replicates of noodles fortified with each of the three fortificants were prepared and analyzed for evaluation of the total iron value in the noodle sample.

Evaluation of iron-fortified instant noodles

Determination of iron in the noodle sample

The iron content of the noodles was determined in triplicate with a flame atomic absorption spectrophotometer (Spectr AA-20) after digestion in concentrated nitric acid and perchloric acid at a 5:1 ratio in a hot-air oven at 100° to 120°C for 6 to 8 hours.

Test for homogeneity of the fortificants

To ensure the even distribution of the iron fortificants, four blocks of instant noodles that were sampled from each preparation batch were analyzed for total iron contents. Four preparation batches were taken from the same batch of wheat flour. The mean and SD and the percent coefficient of variation (% CV) of the iron content of the four preparation batches were calculated, and the batches were compared for statistically significant differences.

Sensory evaluation

The sensory evaluation was performed by 50 panelists who were staff members and graduate students of the Institute of Nutrition, Mahidol University at Salaya, Nakhon-Pathom, Thailand. The evaluation was performed under a daylight fluorescent lamp in an individual testing booth at the Sensory Science Laboratory of the Institute of Nutrition. The tests were performed on unfortified and iron-fortified noodles. The cooked noodles were served in a pork-flavored soup. Each sample of instant or cooked noodles was served to each panelist in random order in a white melamine bowl coded with a three-digit random number. The panelists were asked to rinse their mouths with water before testing the new sample. For instant noodle blocks, the acceptability in general appearance was measured by a 9-point hedonic scale, ranging from 1 (“dislike very much”) to 9 (“like very much”), with a neutral category of 5 ("neither like nor dislike") [15–16]. The overall acceptability, taste, and odor of fortified and unfortified cooked noodles were measured on a 9-point hedonic scale; suitability of the color, elasticity, and softness of cooked noodles was measured by a 5-point "just-about-right" scale (5 = much too dark/elastic/hard, 3 = just about right, 1 = much too light/brittle/soft); and odor intensity was measured by a 15-cm linear scale (1 cm = none, 14 cm = extremely strong). Noodles were considered acceptable overall if their mean average score was about 6 ("like slightly").

Shelf-life study

The four product batches from two replicates of iron fortification were used for a shelf-life study. Both unfortified and fortified instant noodle samples were packed in metallized plastic bags and stored at room temperature (daytime 25° to 32°C, nighttime 25°C) for 3 months. Every month, one dozen blocks of each product were sampled to determine chemical and physical properties. Color was measured by a JUKI Spectro Colorimeter (Model JS 555) and expressed in the Commission Internationale de l'Eclairage (CIE) color system (L* indicates lightness where "100" = bright and "0" = dark, a* indicates redness where "+VALUE" represents red and "–VALUE" represents green, and b* indicates yellowness where "+VALUE" represents yellow and "–VALUE" represents blue). Moisture content and water activity were measured by a water activity meter (Novasina MIK 3000), and peroxide value (PV) was determined according to the AOAC, 2000 [17].

Sensory test for shelf-life evaluation

The sensory test was performed on both instant noodles and instant noodles cooked with pork flavor soup by 27 panelists. The panelists were selected from the staff members and students of the university. The samples were presented to each panelist in a randomized complete block design. In the test sample noodles, the unfortified product was labeled as "R", and the panelists were asked to rate the degree of difference between iron-fortified noodles and the "R" sample. The "R" sample was also coded with a randomized three-digit number and tested as an internal control. Instant noodle products were evaluated for significant ($p < .05$) differences in color of fortified noodle blocks. In addition, instant noodle products were rated for intensity of rancid odor on a 15-cm linear scale (1 cm = none, 14 cm = extremely strong). The panelists also rated each kind of cooked iron fortificant product that was added to the commercial pork-flavored soup for differences in color and taste. Differences in color were rated on 9-point hedonic scale, with 1 = "much lighter than control," 5 = "similar to control," to and 9 = "much darker than control." Difference in taste was rated on a 5-point hedonic scale, with 0 = "no difference," 1 = "slight difference," 2 = "moderate difference," 3 = "large difference," and 4 = very large difference."

Food analysis

Food analysis was performed on duplicate samples. Moisture content was analyzed by drying a sample in a hot-air oven at 100 ± 5°C until a constant weight was obtained [17]. Protein and fat were determined according to AOAC, 2003 [18]. Total iron content was determined by an atomic absorption spectrophotometer after wet digestion [18].

Statistical analysis

Results are reported as means ± SD. Data were analyzed by the Statistical Package for the Social Sciences (SPSS) for Windows, version 10.0. The sensory evaluations and the means of analysis data were tested for significant differences at $p < .05$ by one-way analysis of variance (ANOVA). Scheffé's and Tukey's multiple comparison analyses were used to compare the means of each experimental group.

Results and discussion

Fortification is performed by using a mixing process to distribute an adequate amount of iron in the food vehicle; the procedure should not result in unacceptable characteristics in the food vehicle, such as discoloration and off flavor [19]. The homogeneity of the different iron fortificants in instant noodle blocks showed that there were no significant differences in total iron contents among four block pieces of all noodle samples ($p > .05$). In addition, ideally, the iron content in each block of fortified noodles should be equally distributed as 5 mg per serving, or 50 g of instant noodles [14]. The iron contents ranged from 10.54 to 10.80, 10.81 to 11.06, and 9.65 to 9.83 mg per 100 g OR 5.27 ± 0.10, 4.27 ± 0.07, and 5.26 ± 0.47 mg per serving of noodles fortified with FS, NaFeEDTA, and EEI, respectively (data not shown). Therefore, all iron-fortified noodles used in this study had close to 5 mg of iron per 50-g instant noodle block.

The percentage coefficient of variation (%CV) of EEI-fortified noodles was greater than that of the other fortificants (3.9%, 2.3%, and 2.4% for EEI, NaFeEDTA, and FS, respectively). The iron fortificant should be distributed to all parts of the food vehicle without segregation. According to the results of the analysis, all iron fortificants were evenly distributed throughout the noodle mass. However, the %CV of EEI showed a high value. This may be due to the small amount of EEI used (about 222.64 mg per kilogram of wheat flour).

However, the %CV of all fortified noodles was less than 10%, which indicates that the distribution of iron fortificants in the noodles was homogeneous.

Sensory acceptability

The sensory characteristics of the noodle samples were evaluated by 50 panelists. The test was performed using a 9-point hedonic scale and a "just-about-right" scale. According to **table 1**, the general appearance scores of iron-fortified cooked noodles were not significantly different from those of unfortified noodles ($p > .05$). The color suitability scores of fortified noodles also showed no significant differences from the unfortified noodles, except for FS-fortified instant noodles, with scores of 2 ("too light") and 3 ("just about right"), which indicated that the darker color was not observed in all cooked fortified noodles. The overall acceptability scores of iron-fortified noodles were not significantly different from those of unfortified noodles, with an average score of about 6 ("like slightly"). The average scores in terms of taste and odor were around 6 ("like slightly"). In addition, the elasticity and softness suitability scores of both fortified and unfortified noodles were about 3 ("just about right"), which indicated that both characteristics were acceptable to the panelists. No metallic odor was observed in any fortified noodles.

Color of iron-fortified instant noodles

In iron-fortified foods, change in color is the main concern because the iron compound frequently induces organoleptic changes in the food vehicle, especially in color. According to the CIE color system, the raw noodle dough sheet, instant noodles, and cooked noodles fortified with FS had significantly lower values of L* and b* and significantly higher values of a* than the unfortified products. No color changes were observed with the addition of NaFeEDTA (**table 2**).

The product that was fortified with FS had more red and yellow tone, whereas the color values of noodles fortified with NaFeEDTA were almost similar to those of the unfortified samples. The L* and b* values of EEI-fortified samples were significantly different from those of unfortified samples. These results might be due to the characteristics of FS, which is a water-soluble iron compound that has the potential to cause color changes in foods more rapidly than NaFeEDTA and EEI. The results agree with those of Theuer [20], who examined the effect of iron on the color of barley and other cereal porridges, including wheat. Addition of FS to wheat porridge caused significant changes in the L*, a*, and b* values. Moreover, the addition of FS or electrolytic iron to porridge made from normal barley resulted in an unattractive gray color when the iron was added at a high level (500 mg of iron per kilogram of flour) but did not cause a color change when it was added at a

TABLE 1. Sensory acceptability of instant and cooked noodles fortified with various forms of iron*

Sample	Instant noodles		Cooked noodles							
	General appearance**	Color suitability***	General appearance**	Color suitability***	Overall acceptability**	Taste**	Odor**	Elasticity***	Softness***	Metallic odor****
Unfortified	6.26 ± 1.56	2.52 ± 0.54^a	5.96 ± 1.09	2.66 ± 0.52	5.98 ± 1.47	5.74 ± 1.59	5.78 ± 1.52	2.96 ± 0.67	3.40 ± 0.61	0.00 ± 0.00
FS	5.74 ± 1.38	3.00 ± 0.67^b	5.72 ± 1.25	3.00 ± 0.64	5.86 ± 1.20	5.56 ± 1.30	5.60 ± 1.16	2.86 ± 0.70	3.30 ± 0.61	0.00 ± 0.00
NaFeEDTA	5.92 ± 1.29	2.62 ± 0.70^a	5.89 ± 1.25	3.12 ± 0.75	5.95 ± 1.46	5.60 ± 1.43	5.55 ± 1.45	2.86 ± 0.61	3.22 ± 0.62	0.00 ± 0.00
EEI	5.96 ± 1.48	2.62 ± 0.64^a	5.92 ± 1.23	2.82 ± 0.56	5.89 ± 1.37	5.70 ± 1.28	5.68 ± 1.22	2.86 ± 0.73	3.48 ± 0.61	0.00 ± 0.00

FS, ferrous sulfate, NaFeEDTA, ferric sodium ethylenediaminetetraacetic acid; EEI, encapsulated H-reduced elemental iron

* Results are mean ± SD values from 50 panelists. Means within the same column followed by different letters are significantly different (Tukey test; $p < .05$).

** Rated on a 9-point hedonic scale (1 = dislike very much, 5 = neither like nor dislike, 9 = like very much).

*** Rated on a 5-point just-about-right scale (1 = much too light/brittle/soft, 3 = just about right, 5 = much too dark/elastic/hard).

**** Rated on a 15-cm line scale (1 cm = none, 14 cm = extremely strong).

TABLE 2. Color values of unfortified and fortified raw noodle dough sheet, instant noodles, and cooked noodles[1]

Sample	Color value[2]	Unfortified	FS	NaFeEDTA	EEI
Raw noodle dough sheet	L*	73.34 ± 0.39^{b}	72.24 ± 0.49^{a}	72.16 ± 0.28^{a}	74.01 ± 0.62^{c}
	a*	+ 0.26 ± 0.16^{b}	+ 0.16 ± 0.01^{a}	+ 0.25 ± 0.11^{b}	+ 0.21 ± 0.05^{b}
	b*	+ 20.14 ± 0.30^{d}	+ 17.88 ± 0.26^{a}	+ 19.53 ± 0.96^{c}	+ 18.34 ± 0.32^{b}
Instant noodles	L*	78.26 ± 1.44^{b}	76.42 ± 1.98^{a}	77.42 ± 1.97^{b}	79.70 ± 0.83^{c}
	a*	+ 1.56 ± 0.53^{c}	+ 1.24 ± 0.56^{b}	+ 1.31 ± 0.36^{bc}	+ 0.92 ± 0.22^{a}
	b*	+ 26.06 ± 1.17^{b}	+ 24.95 ± 1.37^{a}	+ 26.11 ± 0.79^{b}	+ 28.99 ± 1.73^{c}
Cooked noodles	L*	72.18 ± 3.82^{b}	69.95 ± 1.04^{a}	72.01 ± 0.36^{b}	74.30 ± 0.62^{c}
	a*	+ 0.65 ± 0.32^{a}	+ 0.77 ± 0.08^{b}	+ 1.14 ± 0.17^{b}	+ 0.55 ± 0.21^{a}
	b*	+ 20.04 ± 2.05^{b}	+ 18.56 ± 0.03^{a}	+ 19.93 ± 0.80^{b}	+ 20.04 ± 1.48^{b}

FS, ferrous sulfate, NaFeEDTA, ferric sodium ethylenediaminetetraacetic acid; EEI, encapsulated H-reduced elemental iron

1. Results are means ± SD of triplicate observations. Means within the same row followed by different letters are significantly different by a parametric test ($p < .05$, Scheffé's test).
2. Color values: L* (100, bright; 0, dark); a* (+, red; –, green); b* (+, yellow; –, blue).

low level (50 mg/kg). The degree of color change was also related to the flour's content of polyphenol, which forms blue-black or dark colors when combined with iron, such as that in FS. For example, barley flour has a tendency to turn gray during manufacture since it contains large amounts of tannin (12 to 15 g/kg). Moreover, FS and ferrous fumarate are more likely to adversely affect the color of infant food made with barley, because these iron compounds are more soluble in either water or dilute acid [20]. Furthermore, the color change also depends on the enzymatic browning reaction. Wheat flour contains polyphenol oxidase, which is able to catalyze the reaction of polyphenols in flour, leading to formation of the brown color in flour products. In the presence of iron, the enzymatic browning reaction is accelerated [21]. Iron in NaFeEDTA is protected within the EDTA structure and iron in EEI is encapsulated with hydrogenated oils, and therefore the use of NaFeEDTA or EEI as fortificants might decrease the unwanted change in color of fortified foods.

Zimmermann [22] studied the effects of the dual fortification of salt with iodine and microencapsulated iron and indicated that the use of microencapsulated FS with partially hydrogenated vegetable oil reduced color changes in salt. In addition, Hurrell [23] reported that the use of encapsulated iron in infant formulas and infant cereals with hydrogenated oils has excellent potential to overcome unwanted sensory changes in fortified products. Therefore, the encapsulation of iron with coating material would seem to prevent some of the unwanted changes in iron-fortified foods, especially color changes, because the coating material, such as hydrogenated oil, provides a physical barrier between iron and the food matrix [23]. However, differences in the measured color values, as shown in **table 2**, did not affect the sensory acceptability of the fortified products to the test panelists.

Shelf-life study

The modern food industry has developed and expanded because of its ability to deliver a wide variety of high-quality food products to consumers nationwide and worldwide. Therefore, the shelf-life study provides vital information to ensure that the consumer will receive a product that retains its high quality for a significant period of time after production. In this study, the storage time was 3 months, based on the commercial turnover rate of the product in the market [9].

Water activity (A_w)

The results showed a slight change in water activity, but the change was inconsistent, perhaps due to inconsistency in the quality of the product. However, after 3 months the maximum value water activity of all the noodle products was still less than 0.3 ($A_w = 0.27$, data not shown). Doyle et al. [24] reported that the growth of any microorganisms was prohibited by an A_w value less than 0.6 (0.6 for osmophilic yeast, 0.62 for xerophilic molds, 0.71 for xerotolerant molds, 0.75 for halophilic bacteria, 0.80 for regular molds, 0.88 for most yeasts, and 0.91 for most bacteria). Therefore, the products were free of microbial growth when stored at room temperature for 3 months.

Peroxide value

The peroxide value increased during storage at the same rate in the fortified and unfortified products (5.79 to 8.07 mEq per kilogram of fat) (**table 3**). The iron in the fortificants did not appear to exert any catalytic effects on fat oxidation during the storage period. The peroxide value in all unfortified and fortified noodles was less than 10 mEq per kilogram of fat, the normal cutoff value for the rejection of products [25]. This result indicated that all fortified instant noodles had acceptable peroxide values based on industrial standards.

Sensory evaluation

Table 4 shows the sensory evaluation scores for fortified and unfortified noodles during the 3 months of storage. There were no significant differences in color between fortified and unfortified noodles, except for EEI-fortified noodles, which were rated as darker (data not shown). Particles of EEI powder were trapped in the strips of instant noodles and showed as dark spots, even in cooked noodle strands. All instant noodle products had low scores for rancid odor due to the low peroxide value (< 10 mEq/kg fat). Rho and Seib [26] found that a peroxide value of more than 50 mEq/kg in deep-fried instant noodles increased the rancid taste. A difference in the taste of the noodles fortified with FS and NaFeEDTA could be detected, but at a low degree. Therefore, all fortified products could have a shelf life of at least 3 months, the normal period between manufacture and sale of instant noodles in the market, without alteration of their sensory qualities from those of the unfortified products.

TABLE 3. Peroxide value (mEq/kg fat) of unfortified and fortified instant noodles during 3 months of storage*

Month	Unfortified	FS	NaFeEDTA	EEI
0	5.79 ± 0.71^{a}	5.24 ± 0.34^{a}	5.48 ± 0.38^{a}	5.26 ± 0.10^{a}
1	5.84 ± 0.80^{a}	5.90 ± 0.64^{a}	5.16 ± 0.06^{a}	5.00 ± 0.13^{a}
2	5.05 ± 0.02^{a}	5.54 ± 0.08^{a}	5.81 ± 0.09^{ab}	5.34 ± 0.71^{a}
3	7.29 ± 0.42^{b}	8.07 ± 0.09^{b}	7.28 ± 0.55^{b}	7.23 ± 0.11^{b}

FS, ferrous sulfate, NaFeEDTA, ferric sodium ethylenediaminetetraacetic acid; EEI, encapsulated H-reduced elemental iron

* Results are means ± SD of duplicate analyses. Means within the same column followed by different letters are significantly different by a nonparametric test for independent samples ($p < .05$, Mann-Whitney U test).

TABLE 4. Sensory qualities of unfortified and fortified instant and cooked noodles with pork-flavored soup during 3 months of storage*

Sensory quality	Month	Unfortified	FS	NaFeEDTA	EEI
Instant noodles					
Color**	0	5.18 ± 0.92^{a}	5.30 ± 1.49^{a}	5.42 ± 1.34^{a}	5.80 ± 1.56^{b}
	1	5.06 ± 1.39^{a}	5.73 ± 1.30^{b}	5.23 ± 1.08^{a}	5.56 ± 1.27^{ab}
	2	4.67 ± 0.87^{a}	5.17 ± 1.06^{a}	4.89 ± 1.76^{a}	5.89 ± 0.92^{b}
	3	4.98 ± 0.73^{a}	5.10 ± 1.01^{a}	5.21 ± 1.14^{a}	5.47 ± 1.13^{b}
Rancid odor***	0	3.59 ± 0.32^{a}	3.63 ± 0.31^{a}	3.04 ± 0.29^{a}	2.16 ± 0.23^{a}
	1	2.59 ± 0.24^{a}	3.08 ± 0.29^{a}	3.03 ± 0.25^{a}	3.16 ± 0.28^{a}
	2	2.67 ± 0.19^{a}	2.38 ± 0.17^{a}	3.09 ± 0.24^{a}	2.50 ± 0.17^{a}
	3	1.62 ± 0.09^{a}	1.58 ± 0.10^{a}	2.62 ± 0.28^{b}	1.95 ± 0.16^{ab}
Cooked noodles					
Color**	0	4.96 ± 1.01^{a}	5.30 ± 1.68^{a}	5.49 ± 1.40^{a}	5.42 ± 1.01^{a}
	1	4.87 ± 0.91^{a}	5.27 ± 1.37^{a}	5.23 ± 1.20^{a}	5.04 ± 1.19^{a}
	2	4.83 ± 0.82^{a}	4.85 ± 1.41^{a}	4.93 ± 0.99^{a}	4.69 ± 0.86^{a}
	3	4.88 ± 0.73^{a}	5.13 ± 1.34^{a}	4.88 ± 0.98^{a}	5.00 ± 0.91^{a}
Taste****	0	0.78 ± 0.08^{a}	1.50 ± 0.12^{b}	1.43 ± 0.12^{b}	1.14 ± 0.09^{ab}
	1	0.75 ± 0.09^{ab}	1.15 ± 0.09^{b}	0.94 ± 0.09^{ab}	0.69 ± 0.08^{a}
	2	0.52 ± 0.07^{a}	1.19 ± 0.08^{b}	1.13 ± 0.08^{b}	0.69 ± 0.08^{a}
	3	0.58 ± 0.08^{a}	1.27 ± 0.09^{b}	1.15 ± 0.09^{b}	0.83 ± 0.09^{ab}

FS, ferrous sulfate, NaFeEDTA, ferric sodium ethylenediaminetetraacetic acid; EEI, encapsulated H-reduced elemental iron

* Results are means ± SD of duplicate scores from 27 panelists at 0, 1, 2, and 3 months. Means within the same row followed by different letters are significantly different by a parametric test ($p < .05$, Tukey's test).

** Color was rated on a 9-point scale of difference from unfortified (control) noodles (1 = much lighter than control, 5 = similar to control, 9 = much darker than control).

*** Rancid odor was rated on a 15-cm line scale (1 cm = none, 14 cm = extremely strong).

**** Taste was rated on a 5-point scale of difference from unfortified (control) noodles (0 = no difference, 1 = slight difference, 2 = moderate difference, 3 = large difference, 4 = very large difference).

Food analysis of instant noodles

The nutrient composition of the fortified instant noodles was comparable to that of commercial instant noodles, which provide about 5.5 g of protein, 9.1 g of fat, 32 g of carbohydrate, and 233 kcal of energy per package, except for the iron contents, which could fulfill up to 33% of the daily requirement.

Conclusions

By using the fortificants ferrous sulfate (FS), ferric sodium ethylenediaminetetraacetic acid (NaFeEDTA), and encapsulated H-reduced elemental iron (EEI), it was feasible to fortify instant noodles to provide one-third of the Thai RDI for iron per 50-g serving. The addition of any of the three fortificants to noodles did not change their sensory properties or shelf-life stability as compared with the unfortified noodles. NaFeEDTA produced the least differences in color and flavor of the fortified product as compared with the unfortified product. All fortified instant noodles were well accepted by the consumers. During 3 months of storage at room temperature, the iron fortificants did not adversely affect the peroxide value, color, or sensory quality of the noodles as compared with unfortified noodles. The bioavailability of each iron fortificant in the noodles needs to be further studied.

Acknowledgments

The authors thank Mahidol University for financial support.

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