Review Article

Instant noodles made with fortified wheat flour to improve micronutrient intake in Asia: a review of simulation, nutrient retention and sensory studies

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Background and Objectives: Consumption of foods made with wheat flour, particularly instant noodles, is increasing in Asia. Given this trend, fortifying wheat flour with vitamins and minerals may improve micronutrient intake in the region. The objective of this review was to understand what is known about fortifying wheat flour used to make instant noodles. **Methods and Study Design:** A literature review of seven databases was performed using the search terms "noodle" and ("Asian" or "instant"). Grey literature was requested through a food fortification listserv. Articles were title screened first for relevance and duplicity, with exclusion criteria applied during the second round of abstract-level screening. This review considered studies examining simulation, retention, sensory, bioavailability, efficacy, and effectiveness of instant noodles made with fortified wheat flour. **Results:** Fourteen relevant documents were reviewed for simulation (n=1), retention (n=11), and sensory studies (n=3). The documents revealed that instant noodles produced from fortified wheat flour have potential to improve nutrient intakes, have high retention of most nutrients, and provoke no or minimal changes in sensory characteristics. **Conclusions:** The available literature indicates that using fortified wheat flour for instant noodle production results in retention of the added nutrients, except thiamin, with no significant sensory change to the final product. Given the rising consumption of instant noodles, production of this item with fortified wheat flour has potential to improve nutrient intakes in Asia. This review provides a resource for the design of a wheat flour fortification program in countries where a large proportion of wheat flour is consumed as instant noodles.

Key Words: instant noodles, fortification, wheat flour, Asia, micronutrient

INTRODUCTION

The negative health effects of nutrient deficiencies in Asia are particularly concerning as this region is home to over half of the world's total population (more than 3.8 billion people)[1] with a high burden of nutrition-related diseases.[2]

To address nutritional deficiencies and prevent their sequelae, staple foods and condiments may be fortified based on the dietary practices and nutritional needs of a country's population. For example, countries have dramatically decreased the population prevalence of iodine deficiency by fortifying salt with iodine.[3] Twenty countries in Asia have mandatory national or sub-national legislation for salt iodization.[4] Among households in South Asia and East Asia and the Pacific, 71% and 91%, respectively, are consuming adequately iodized salt,[5] making salt the only large scale fortification program in Asia.

Wheat flour fortification is a well-accepted practice globally to reduce the risk of anemia caused by nutritional deficiencies[6] and neural tube defects caused by insufficient folic acid.[7] However, wheat flour fortification has yet to become routine practice in Asia even though wheat-based foods are the second most commonly consumed staple food after rice in most countries.[8] Currently, only six countries in Asia have legislation for mandatory wheat flour fortification. Indonesia mandated flour fortification in 2001, the Philippines in 2000, Fiji in 2009, the Solomon Islands in 2010, Nepal in 2012, and Viet Nam in 2016.[9] A common reason given by governments for not fortifying wheat flour in Asia is that wheat consumption is too low and, as such, the health impact of fortification is presumed to be low (Karen Codling, Executive Officer for Asia, Food Fortification Initiative, personal communication). How- ever, wheat availability (a proxy indicator for wheat consumption) is substantial and increasing in

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many Asian countries.[10] In Asia, a large proportion of wheat flour is consumed as noodles. For instance, 70% of Indonesia's wheat flour is used in noodle production,[11] and 34% to 38% of Indonesia's total flour is consumed in the form of instant noodles,[12] while all types of noodles account for 21% of wheat flour products in Malaysia (Elmar Nau, General Manager, Prestasi Flour Mill, Malaysia, personal communication). Instant noodles are the fastest growing sector of the noodle industry and increasingly contribute to energy and nutrient intake of people in many Asian countries.[13]

Instant noodles are made from wheat flour (primarily) and/or rice flour and/or other flours by the use of a pregelatinization process and dehydration. They are generally fried[14] to decrease their cooking time. Instant noodles are often packaged with a seasoning sachet for flavor or in a cup with powdered soup base sprinkled over it.[15]

Rising consumption of wheat-based instant noodles in Asia

Consumption of wheat flour based instant noodles is rising as indicated by an increasing global demand from 92,220 million servings in 2009 to 105,590 million servings in 2013.[16] This represents a rise of 3% per year, with most servings sold in China, Indonesia, Japan, Viet Nam, and India.[16] The rising popularity of instant noodles is part of a regional trend in changing food demands. This trend is characterized by decreased consumption of rice, increased consumption of wheat products, and increased popularity of convenience foods.[17] Instant noodles are one of the specific wheat flour products in which demand steadily increased in nearly every Asian country over 2008-2013 (Table 1). Since instant noodles comprise a significant proportion of wheat flour products,[18] fortification of flour used for their production presents an opportunity to improve nutrient intake among consumers, particularly given the increasing demand for instant noodles.

Data from Indonesia illustrate the demand for instant noodles. A survey (n=3,612 households) in Indonesia performed in 1996-1997 showed that instant noodles were consumed in nearly every household surveyed.[19] A more recent National Health Survey conducted in Indonesia found that 10.1% people over 10 years ate instant noodles every day and 51%, 49.5% and 48% of children 10-14 years, 15-19 years and young adults aged 20-24 years, respectively, ate instant or fresh noodles at least 3-6 times per week.[20] This survey indicated that although noodle consumption declined with age, 22.5% of people over 65 years ate noodles at least 3-6 times per week. Only 15.7% of people over 65 years reported never eating noodles.[20] Euromonitor data, quoted by Rabobank, confirms that "Noodle consumption is now an integral part of the Indonesian diet and appeals to all income classes. The volume for the noodle industry grew at an annual growth rate of 3.5% between 2008 and 2013 with noodle consumption high at close to 80 packets per person per year".[18] Korea has the highest daily per capita consumption of instant noodles with 6 packs per month.[16] The Korean National Health and Nutrition Examination Survey found that 18.1 g of instant noodles were consumed per day per capita nationwide. This makes instant noodles the second largest food type after steamed rice that contributes to overall energy intake of individuals.[21]

Similarly, a study of 60 Vietnamese primary schoolchildren in two communes of Phu Tho province reported that instant noodles were consumed at least once a week by 50% of the children with a mean of 2.9 portions/week.[22] The parents of the children stated that some of the positive attributes of instant noodles were that they are easy and quick to prepare, they alleviate their children's hunger, and that children like to eat them.

The parents' responses echo other reasons noted for the increasing popularity of instant noodles. One book described instant noodles as "supercheap" which appeals to low-income populations.[23] In addition, the seasoning packet can be easily modified, making instant noodles adaptable to local preferences.[23] With their long shelf life and fast cooking time, instant noodles are also convenient.[24] The book's authors concluded that a way to help those who rely on instant noodles is to make the product more nutritious by using fortified flour, reducing the sodium and fat content, and increasing the fiber.[23]

Objectives

It is hypothesized that capitalizing on the increasing consumption of foods made with wheat flour, in particular instant noodles in Asia, fortifying wheat flour could improve nutrient intake in the region. The objective of this review is to understand what is known about the feasibility and acceptability of fortifying wheat flour for instant noodle production. Given increased demand for instant noodles, this could represent an important means of improving micronutrient intake in Asia. The review did not include an in-depth discussion of the sodium, fat or fiber contribution of instant noodles.

A framework for fortification programs

One framework for the design of food fortification programs posits that several components of scientific evidence are needed to ensure effectiveness.[25] Careful planning and evidence-based decisions must take place in close collaboration with nutrition scientists. Every country does not need unique studies for each component of the framework, however, as decisions can be based on scientific evidence from other countries and internationally recognized guidelines. A country only needs to conduct its own study to address the framework's components if its use of the potential food vehicle is unique and no other study is relevant.

The framework proposes that the burden of micronutrient deficiencies and dietary patterns of a population must be known to select appropriate food vehicles, necessary fortificants, and the amount of each fortificant to add.[25] Population-specific simulation studies can be performed to estimate the impact of fortification levels on nutrient intake adequacy and safety. Retention, sensory, and bioavailability studies further evaluate fortification's acceptability and appropriateness. Retention studies determine the availability of the selected fortificants after processing, storing and cooking the food vehicle. Sensory studies assess potential organoleptic changes of the food vehicle following fortification. Bioavailability studies evaluate absorption of the micronutrients. In addition, efficacy trials indicate whether the intervention being considered

Table 1. Global demand for instant noodles in million packs per country per year, as estimated by the World Instant Noodle Association,[16] with country-specific prevalences of anemia in non-pregnant women[74] and stunting in children less than 5 years of age[75]

Country / Region	2008	2009	2010	2011	2012	2013	Increase 2008-2013 (%)	Anemia prevalence in non-pregnant women	Stunting prevalence in children 0-59 months
China / Hong Kong	42,530	40,860	42,300	42,470	44,030	46,220	8	19 (China)	9.4 (China)
Indonesia	13,700	13,930	14,400	14,530	14,750	14,900	8	22	36.4
Japan	5,100	5,340	5,290	5,510	5,410	5,520	8	22	7.1
Viet Nam	4,070	4,300	4,820	4,900	5,060	5,200	22	14	19.4
India	1,480	2,280	2,940	3,530	4,360	4,980	70	48	38.7
Republic of Korea	3,340	3,480	3,410	3,590	3,520	3,630	8	25	2.5
Thailand	2,170	2,350	2,710	2,880	2,960	3,020	28	24	16.3
Philippines	2,500	2,550	2,700	2,840	2,720	2,720	8	25	30.3
Malaysia	1,210	1,200	1,220	1,320	1,300	1,350	10	20	17.2
Taiwan	1,110	1,070	1,020	1,010	1,010	980	-13	-	-
Nepal	510	590	730	820	890	1,020	50	36	37.4
Myanmar	210	210	240	240	300	340	38	30	35.1
Cambodia	240	240	330	260	260	240	0	43	32.4
Bangladesh	150	60	90	100	160	220	32	23	36.1
Singapore	110	120	120	130	130	130	15	22	4.4

shows impact in controlled settings. Effectiveness studies evaluate the public-health impact of the fortification program following large-scale implementation.

The framework's criteria for wheat flour fortification have been addressed by international public and private researchers. This is documented in World Health Organization (WHO) guidelines for fortifying wheat flour[26] and corresponding supplement.[27] The WHO guidelines are stratified by the wheat availability or intake level in each country, as shown in Table 2. However, the process of preparing instant noodles with pregelatinization, dehydration, and frying makes this product unlike breads and other foods commonly made with wheat flour. Consequently this review attempts to apply the framework's components specifically to instant noodles made with a proven fortified food vehicle (e.g. wheat flour). This review will address the following components of the framework as they relate to instant noodles: simulation, retention, sensory, bioavailability, efficacy, and effectiveness.

MATERIALS AND METHODS

A literature review was performed using the search terms of "noodle" and ("Asian" or "instant") in seven databases: PubMed, EMBASE/Ovid, CAB abstracts, Web of Science, CINAHL, POPLINE, and AGRICOLA. The initial search resulted in 435 articles. Articles were excluded if they did not include information about instant noodles, they discussed macronutrient fortification only, or they investigated fortification via seasoning packets rather than fortification of the wheat flour used to make the noodles. After reviewing the titles for relevance and excluding duplicates, 94 articles remained. After reading the abstracts and applying the exclusion criteria, 45 remained. Further review of the full texts resulted in 11 studies meeting the inclusion criteria. Additionally, a request for grey literature through the Food Fortification Initiative mailing list resulted in 19 new articles, three of which met the aforementioned inclusion criteria.

The final 14 documents were divided into the following sections for the framework assessment: simulation studies (n=1), retention studies (n=11), sensory studies (n=3), bioavailability studies (n=0), efficacy trials (n=0), and effectiveness trials (n=0).

RESULTS

Appropriate fortificants are micronutrients that, when added to the food vehicle, cause few sensory changes, are bioavailable, do not negatively affect the absorption or metabolism of other micronutrients, and are affordable for consumers.[28] In the reviewed documents, the following nutrients were added to wheat flour used to make instant noodles: iron in the form of NaFeEDTA,[22,29-32] ferrous sulfate,[29] ferrous fumarate,[31,32] electrolytic iron,[32] encapsulated elemental iron,[29] and encapsulated ferrous fumarate,[32] as well as folic acid,[31-37] vitamin B-12 (cyanocobalamin),[31] vitamin A palmitate,[31] zinc oxide,[31] thiamin,[31,38-40] riboflavin,[31,41] and pyridoxine.[42] Fortificant's suitability for wheat-based instant noodles is described below.

Simulation of the impact of fortification levels on nutrient intake adequacy and safety

Simulation studies serve as a theoretical basis for fortification programs.[25] These studies analyze food consumption data of populations to calculate the potential contribution of fortified foods to Recommended Nutrient Intakes (RNI). To accomplish this, researchers model different fortification levels for selected micronutrients. These data can help countries determine the appropriate quantity of fortificants to use based on the dietary habits and nutritional needs of their populations.

Only one simulation study was found that assessed the dietary impact of instant noodles made with fortified

Table 2. World Health Organization 2009 recommendations on wheat and maize flour fortification on average levels of nutrients to consider adding to fortified wheat flour based on extraction, fortificant compound, and estimated per capita flour availability[26]

Nutrient	Flour extraction rate	Compound	Level of nutrient to be added in parts per million (ppm) by estimated average per capita wheat flour availability†			
			<75 g/day‡	75-149 g/day	150-300 g/day	>300 g/day
Iron	Low	NaFeEDTA	40	40	20	15
		Ferrous sulfate	60	60	30	20
		Ferrous fumarate	60	60	30	20
		Electrolytic iron	NR§	NR§	60	40
	High	NaFeEDTA	40	40	20	15
Folic acid	Low or High	Folic acid	5.0	2.6	1.3	1.0
Vitamin B-12	Low or High	Cyanocobalamin	0.04	0.02	0.01	0.008
Vitamin A	Low or High	Vitamin A palmitate	5.9	3	1.5	1
Zinc¶	Low	Zinc oxide	95	55	40	30
	High	Zinc oxide	100	100	80	70

†These estimated levels consider only wheat flour as main fortification vehicle in a public health program. If other mass-fortification programs with other food vehicles are implemented effectively, these suggested fortification levels may need to be adjusted downwards as needed.

‡Estimated per capita consumption of <75 g/day does not allow for addition of sufficient level of fortificant to cover micronutrients needs for women of childbearing age. Fortification of additional food vehicles and other interventions should be considered.

§NR: not recommended because very high levels of electrolytic iron needed could negatively affect sensory properties of fortified flour.

¶These amounts of zinc fortification assume 5 mg zinc intake and no additional phytate intake from other dietary sources.

wheat flour. Spohrer et al used market consumption data and product ingredient information to simulate the potential contribution of ferrous fumarate to the daily RNI for iron from a typical Indonesian diet.[43] They determined that a typical 75-g pack of Indonesian instant noodles made with flour fortified with ferrous fumarate at the current Indonesian standard of 50 parts per million (ppm) of iron[44] should deliver 2.8-3.2 mg of iron, assuming a loss of 0-5% from processing, storage, and cooking with a 10% bioavailability. The simulation concluded that consumption of one 75-g pack of instant noodles made with flour fortified with 50 ppm of iron as ferrous fumarate could provide 45-51% of the daily iron RNI for children 4-6 y of age, 10-11% for women of reproductive age, and 6% for pregnant women. Spohrer et al concluded that based on the widespread consumption of instant noodles, especially in lower socioeconomic populations, fortification of commonly consumed processed foods such as instant noodles "could be an increasingly important strategy to improve the delivery of micronutrients".[43]

Retention of fortificants

For a fortification program to be effective, fortificants should be stable throughout product packaging, transport, storage, and cooking. Losses from production, storage, and cooking instant noodles varied by nutrient.

Three studies investigated the retention (or losses) of nutrients after production of instant noodles. Two studies assessed folic acid losses during the manufacturing process from dough preparation through frying of instant noodles. Hau Fung Cheung and colleagues[36] assessed folic acid during four main stages of instant fried noodle manufacturing: mixing, sheeting and cutting, steaming, and frying. Folic acid was stable at all four stages, with recovery of folic acid ranging from 96.0-104.8%. No significant losses of folic acid were noted by the end of the production process. Welch[37] measured total folate in instant noodles after cutting, steaming and frying them. Total folate was not statistically different in the fried noodle than in the wheat flour. One study assessed iron losses after instant noodle production. Le and colleagues[30] found that although production of instant noodles includes deep-frying in oil at high temperatures (140-160°C), iron content (added in the form of NaFeEDTA) was not affected.

One study assessed iron retention in instant noodles made from fortified wheat flour, after extended periods of storage. No or minimal losses of iron, added as either electrolytic, ferrous fumarate, encapsulated ferrous fumarate or NaFeEDTA, were found in laboratory-prepared instant noodles after storage of up to 42 weeks at 25°C, 30°C, 35°C, and 40°C.[32] The maximum loss recorded after storage of instant noodles made with fortified flour was 10% loss in iron added as ferrous fumarate after storage for 26 weeks at 35°C. Losses of iron added as electrolytic, encapsulated ferrous fumarate or NaFeEDTA or in different storage conditions (e.g. at 40°C for 18 weeks) was less than 10%. In another study however, about 70% of the NaFeEDTA was found to have dissolved out of the noodles into the soup used for cooking within 5 minutes of preparation.[30] This suggests if the soup is not consumed with the instant noodles, much of the added iron content may not be consumed. No additional studies were identified that assessed iron retention in cooked instant noodles.

Seven studies evaluated the losses of folate, riboflavin, pyridoxine, and thiamin in instant noodles samples after cooking to assess the amount of nutrient that might be ingested by consumers (Table 3). Less than 15% of folate and riboflavin were lost after cooking; this included non-fortified commercial samples[34] and fortified, laboratory-prepared samples of instant noodles.[33,41] For fortified, laboratory-prepared samples of instant noodles, 23% of pyridoxine was lost after cooking.[42] For thiamin, fortified, laboratory-prepared samples of instant noodles experienced 45-55% losses after cooking.[39.40] For fortified and non-fortified commercial samples of instant noodles, thiamin losses were higher: 66-80%.[38]

Effect of fortificants on sensory qualities of food

For a food vehicle to be suitable for fortification, its taste and appearance should not be changed by the added fortificants.[28] To determine the presence of any sensory changes due to fortification of instant noodles, Van den Wijngaart and Codling reported organoleptic trials carried out in Malaysia and the Philippines comparing cooked and uncooked instant noodles made from fortified and unfortified wheat flour.[31] Kongkachuichai et al[29] reported similar trials completed in Thailand comparing noodles made from fortified and unfortified wheat flour; cooked and uncooked noodles were assessed. The Food Innovation and Resource Centre of the Singapore Polytechnic[32] reported sensory trials carried out with noodles made from unfortified wheat flour or flour fortified with four

Table 3. Summary of relevant studies estimating nutrient losses after cooking instant noodles

Author	Nutrient assessed	Noodles tested	Fortification of noodles	Nutrient losses after cooking (%)
Bui & Small 2007[34]	Folate	Commercial samples	Non-fortified	4-6
Bui & Small 2007[33]	Folate	Laboratory prepared	Fortified†	12
Bui & Small 2009[41]	Riboflavin	Laboratory prepared	Fortified†	13
Bui & Small 2012[42]	Pyridoxine	Laboratory prepared	Fortified†	23.1
Bui & Small 2007[38]	Thiamin	Commercial samples	Some fortified†; some non-fortified	66-80‡
Bui & Small 2007[39]	Thiamin	Laboratory prepared	Fortified†	54.2
Bui & Small 2008[40]	Thiamin	Laboratory prepared	Fortified†	~45
Le et al 2007[30]	Iron as NaFeEDTA	Commercial samples	Fortified†	~70

†The sample was fortified with the nutrient noted in the "Nutrient assessed" column.
‡ Losses were not stratified by fortification status.

different kinds of iron compounds. Results for cooked noodles, mimicking what consumers would eat, were reviewed.

In the Malaysian and Filipino studies,[31] the wheat flour used to make the instant noodles was fortified with two forms of iron (NaFeEDTA and ferrous fumarate) as well as folic acid, vitamin B-12, vitamin A, zinc, thiamin and riboflavin. Compounds and the fortification level were chosen according to WHO recommendations.[26] For fortified and unfortified cooked instant noodles in Malaysia and for fortified cooked instant noodles in Philippines, research teams compared texture, color and sensory attributes. Results were not statistically compared.

In Malaysia, the following three flour samples were used: unfortified flour, flour fortified with NaFeEDTA, and flour fortified with ferrous fumarate.[31] The texture of instant noodles made with all three flour samples, as evaluated by a sensory panel and measured by a Texture Analyzer, was similar and deemed acceptable. Similarly, the measured color of all instant noodles was considered acceptable; although, the noodles made with fortified flour had a lower brightness score than the noodles made with unfortified flour.

In evaluations by a sensory panel in Malaysia,[31] no differences were observed in noodles made with any of the three flour samples. This included no differences with regard to brightness, yellowness, overall surface appearance, firmness, elasticity, smoothness, and overall texture characteristics. Nor were there noticeable differences in taste, flavor and mouth feel.[45] In the Philippines, noodles made with both fortified flours were of a similar firmness; the color of noodles made with NaFeEDTA-fortified flour was slightly darker than the color of ferrous fumarate-fortified noodles.[31]

Kongkachuichai et al tested the sensory qualities of instant noodles made with unfortified wheat flour and noodles made from wheat flour fortified with different forms of iron (ferrous sulfate, NaFeEDTA, and hydrogen-reduced elemental iron) at a concentration of 5 mg per 50-g serving of instant noodles.[29] Changes in physical, chemical, and sensory qualities were compared. For instant noodles cooked in pork-flavored soup, all of the noodles made with fortified flour had statistically similar results to those made with unfortified flour. All noodles showed no differences in eight sensory attributes: general appearance, color suitability, overall acceptability, taste, odor, elasticity, softness and metallic odor. Some differences in color values were noted. Cooked instant noodles made with ferrous sulfate-fortified flour yielded statistically different lightness (L*) and chromaticity (a* and b*) color values compared with non-fortified, cooked instant noodles. Fortification with elemental iron affected L* color values, and fortification with NaFeEDTA influenced a* values in cooked instant noodles, as compared with non-fortified, cooked instant noodles. None of the three iron compounds affected the color quality (per a sensory panel) of fresh and stored (for 1, 2 or 3 months) cooked instant noodles compared with non-fortified cooked instant noodles. Ferrous sulfate and NaFeEDTA fortification of flour affected the taste of fresh and stored (for 2 or 3 months) cooked instant noodles compared with non-fortified cooked instant noodles.

A study of fortification's impact on instant noodles' sensory qualities over time was conducted in Singapore.[32] Non-fortified wheat flour and wheat flour fortified with iron as electrolytic iron, ferrous fumarate, encapsulated ferrous fumarate or NaFeEDTA were used to make instant noodles. Iron was added at 60 mg/kg, based on WHO recommendations for populations where wheat flour availability is less than 150 g/person/day;[26] however to keep the amount of iron the same in all samples of fortified flour, the WHO recommendations for the amount of iron to be added as NaFeEDTA were exceeded. Control noodles (both fortified and non-fortified) were stored at low temperature (3-4°C) and humidity (50-60%) prior to cooking. Test noodles (both fortified and non-fortified) were stored at four different temperatures (25°C, 30°C, 35°C, 40°C) and high humidity (75-80%) for 0-40 weeks. At 3-5 week intervals throughout the storage period, samples of noodles were removed from storage, cooked and tested for physical and sensory attributes. For physical analysis, pH, color, moisture level, peroxide value and free fatty acid levels were measured. For the sensory evaluation, appearance, texture and flavor were assessed by an untrained panel. Specifically, the noodles were cooked and panelists were asked to compare stored samples (fortified and unfortified) with control samples (fortified and unfortified) stored in low temperatures and to assign these scores to the stored noodles: 0, same as control; -1, very slightly poorer than control; -2, slightly poorer than control; -3, moderately poorer than control; -4, very much poorer than control; -5, extremely poorer than control; -6, unacceptable.

The physical analysis found that noodles prepared with electrolytic iron and stored at 30°C and high humidity were statistically darker (based on L* values) than non-fortified noodles.[31] Similarly, noodles prepared with NaFeEDTA and stored at 30° or 40°C and high humidity, were statistically darker than non-fortified noodles, though as noted the amount of NaFeEDTA used in the wheat flour was greater than WHO recommendations.[26] For chromaticity a* and b* values, there were no significant differences between the fortified and non-fortified noodles. There were also no significant differences in pH or moisture content between the fortified and non-fortified noodles at all temperatures. Measurement of peroxide values and free fatty acids, which are measures of rancidity, yielded significant differences between non-fortified noodles and those fortified with electrolytic iron and NaFeEDTA at 40°C but not at lower temperatures after 35 weeks of storage.

The sensory evaluation tests recorded a decline in all parameters (appearance, texture and flavor) with time, including in non-fortified noodles.[32] For fortified noodles stored at 30°C and high humidity between 0 and 40 weeks, panelists rated all noodles' appearance and texture between 0 and -1, suggesting minimal change in appearance and texture over time. For fortified noodles stored at 40°C and high humidity between 0 and 18 weeks, appearance was also rated between 0 and -1 for electrolytic, ferrous fumarate and encapsulated ferrous fumarate fortificants. For NaFeEDTA-fortified noodles, appearance scores more rapidly decreased over time, suggesting greater deterioration than the other fortified noodles when stored at 40°C and high humidity. Storage also caused deterioration in flavor over time, including in non-fortified noodles; all noodles, including non-fortified noodles, scored between -2 and -4 after 35 weeks of storage at 30°C. Noodles fortified with NaFeEDTA had the lowest flavor scores while noodles fortified with ferrous fumarate had similar flavor scores to non-fortified noodles.

Additionally the study concluded that the shelf life of instant noodles exceeds 12 months when stored at 30°C or less.[32] Shelf life was assessed on the basis of flavor and included noodles made with flour fortified with all types of iron, except NaFeEDTA. At higher temperatures, no instant noodles, including non-fortified noodles, had a shelf life of more than 12 months.

In summary, fortification of wheat flour with iron and other nutrients minimally influenced sensory attributes of instant noodles made from the flour and did not decrease the shelf life except when stored above 30°C for more than 12 months.

Bioavailability of nutrients added to wheat flour used to make instant noodles

Bioavailability studies demonstrate the biological plausibility of using specific food vehicles and fortificants in specific populations.[25] No studies were identified in the literature review that assessed the bioavailability of specific micronutrients in humans after consumption of instant noodles made with fortified wheat flour.

Efficacy trials of fortified wheat-based instant noodles

Efficacy trials with experimentally controlled populations, generally occurring in an ideal setting with near perfect compliance, measure the effect of fortification on nutritional outcomes.[25] No efficacy trials using fortified wheat flour to make instant noodles were found during this literature review.

Effectiveness trials of fortified wheat-based instant noodles

In contrast to efficacy trials, effectiveness studies demonstrate an improvement in the health of a population in a real world setting.[25] To date, no studies have been done to show whether instant noodles made with fortified flour improve health outcomes on a population level.

DISCUSSION

The increasing demand for instant noodles in Asia presents an important opportunity for wheat flour fortification to address nutritional deficiencies. This review provides a resource for the design of a wheat flour fortification program in countries where a large proportion of wheat flour is consumed as instant noodles, as it compiles the available scientific evidence base and highlights knowledge gaps. The simulation study suggests that fortification of wheat flour used for instant noodle production may be an important strategy for improving dietary micronutrient intake, especially among vulnerable populations. The retention studies repeatedly show that for folate, riboflavin and pyridoxine added to instant noodles, more than 75% of the nutrients are retained throughout processing and cooking while almost all iron is retained after production and storage. This is in contrast to thiamin, where losses after cooking range from 45-80%. This review also identifies studies demonstrating that the organoleptic properties of instant noodles may be affected by fortification, but to a limited and acceptable extent, including after storage in normal storage conditions (less than 12 months at 30°C).

Instant noodles typically have high fat (15-22%) and salt (1-3%) content.[46] Instant noodles made with unfortified flour provide carbohydrate but are low in fiber, vitamins and minerals. Instant noodle producers have been making efforts to reduce fat and sodium content and increase micronutrient and fiber content.[47]

A study compared food and nutrient intake in Korean adults that consumed instant noodles with those who did not consume instant noodles. The study found that adults who consumed instant noodles had significantly higher intakes of energy, fat, sodium, thiamin, and riboflavin and significantly lower intakes of calcium, phosphorus, iron, potassium, vitamin A, niacin, and vitamin C when compared to those in the non instant noodle consuming group. The sodium intake of the instant noodle consumers was >6.4 g/day, which was 3.2 times higher than the recommended Korean intake; instant noodles contributed approximately 30% of the total sodium intake. Although the instant noodle consumers consumed significantly higher amounts of fat and calories, no significant difference in body mass index was observed between the two groups.[47]

The higher consumption of thiamin and riboflavin was attributed to the fact that flour used to make instant noodles in Korea is fortified with thiamin and riboflavin.[48] Park et al. found that instant noodles contributed 41.7% and 34.6% of the total consumption of thiamine and riboflavin, respectively.[48]

To reach national-scale coverage of the benefits of fortification, the best foods to fortify are centrally processed foods that are widely eaten, including by the poorest populations.[49] Sometimes this means fortifying foods that are not deemed healthy. For example, salt intake is associated with high blood pressure and cardiovascular disease, yet it is the optimal vehicle for increasing iodine intake.[50] WHO has concluded that salt iodization and salt reduction are compatible because the concentration of iodine in salt can easily be adjusted to meet policies aimed at reducing the consumption of salt to prevent cardiovascular disease.[51] In the same way, fortification of wheat flour used to make instant noodles can make an important contribution to increasing micronutrient intakes as instant noodles are widely eaten. Efforts to make instant noodles with fortified flour should be accompanied by advocacy to instant noodle producers to further reduce the sodium and fat content of their products.

This review highlights certain gaps in the literature regarding fortification of wheat flour used to produce instant noodles in Asian countries. First, consumption data are needed for all wheat flour products in Asia, particularly instant noodles. While manufacturers of instant noodles report an increasing demand for their product in recent years, instant noodles are most likely not consumed equally across the population. Studies suggest that these food items are more likely to be consumed by lower and middle income individuals and those in search of quick, convenient solutions for a meal.[17,23] Prior to implementing wheat flour fortification, it is important to estimate the consumption of wheat-based foods, including instant noodles, to more effectively design the intervention.[28]

Second, although this review identifies simulation data on the potential benefits of instant noodles made with fortified wheat flour in Indonesia, we do not know the potential impact of wheat flour fortification in other Asian countries. Given the heterogeneity of the region, simulation studies in other countries will aid in more fully understanding the potential impact of wheat flour fortification. Household Income and Expenditure Surveys (HIES) may be able to provide apparent intake information[52,53] and the Intake Modeling, Assessment and Planning Program (IMAPP) software can aid with this simulation.[54]

The findings of retention after packaging, transport, storage, and cooking fortified instant noodles are promising for iron, folate, riboflavin and pyridoxine as less than a quarter of iron, folate, riboflavin and pyridoxine were lost after cooking, and iron was retained after noodle production and long periods of storage. One study suggests that iron, added as NaFeEDTA to noodles, may be dissolved into the cooking water or soup.[30] However, iron losses from cooking wheat flour-based foods such as spaghetti, noodles and macaroni, were <15%[55] and virtually nill from baking leavened and unleavened bread from fortified flour.[56] Additionally, iron losses were negligible from storing fortified flour for up to 45 days at 20-25°C and 50-60% relative humidity[56] and from storing at 29-38°C fortified whole wheat flour and naan made from fortified flour for up to 60 days.[57]

Thiamin losses after cooking fortified noodles were high with the greatest losses (66-80%) observed in commercial samples. These losses are higher than the thiamin losses observed in other wheat-flour containing foods. Specifically, thiamin losses for cooking instant noodles were higher than those experienced from cooking pasta (34-59%)[58,59] and from baking bread (0-18%).[60-62] Similarly, pyridoxine losses after instant noodle preparation were higher than losses noted in baking (~0%).[61] In contrast, riboflavin losses after cooking instant noodles were lower than those noted for cooking pasta (41-55%)[58,63] and baking bread (0-16%).[60,61] Finally, folic acid losses from baking or boiling bread were <25%[61,64-66] and comparable with folic acid losses from cooking instant noodles.

Bioavailability (or the body's ability to absorb the nutrient) was considered in setting WHO guidelines for wheat flour fortification,[67] but this review did not identify any studies on bioavailability of fortificants specifically from instant noodles made with fortified wheat flour. Therefore it is not possible to fully understand the potential impact of fortifying flour used for instant noodles to address micronutrient deficiencies. It should be noted that bioavailability is not the same for all iron compounds. Electrolytic iron is the least bioavailable[68] and is not recommended where the availability of wheat flour is less than 150 grams per person per day, even if electrolytic iron meets other criteria for fortification.[68] As most countries in Asia have wheat flour availability below this threshold, electrolytic iron is not recommended for wheat flour fortification in Asia. However, multiple studies with other wheat based products have consistently shown that NaFeEDTA, ferrous sulfate, and ferrous fumarate each have high bioavailability; they are therefore recommended for wheat flour fortification, even if consumption is less than 150 grams per person per day.[26,68] Similarly, folic acid has been found to be even more bioavailable than folate naturally found in food.[69] Therefore, it can be reasonably assumed that instant noodles made with wheat flour fortified with NaFeEDTA, ferrous sulfate, ferrous fumarate and/or folic acid would produce impactful results.

While this review did not find any efficacy or effectiveness trials analyzing instant noodles specifically, similar trials have demonstrated that large scale wheat-flour fortification, in general, leads to improved nutritional status and health outcomes. Fortifying wheat flour with folic acid improves serum folate levels[70] and reduces the birth prevalence of neural tube defects.[7,71] This has been widely demonstrated in all countries that have evaluated the impact of fortifying with folic acid.[72] Effectiveness trials have shown that adding iron to wheat flour, alone or in combination with maize flour, improves iron status in women of childbearing age.[73]

One limitation of this study is that it only addressed the potential to increase micronutrient intake in Asia by fortifying wheat flour used to make instant noodles. The paper did not consider the macronutrient content of instant noodles and their potential contribution to the nutritional status of the population.

Conclusion

Before any food is fortified with vitamins and minerals to improve the nutrient intake of a population, several factors should be considered:[25] potential for impact, nutrient retention and bioavailability, sensory changes, efficacy and effectiveness. Each country does not need to conduct unique studies for each issue but rather can rely on applicable global or regional evidence and guidelines. If evidence shows that these criteria are met, then large-scale food fortification may be an effective way to increase nutrient intake among the population. Based on this review, instant noodles produced from fortified wheat flour have the potential to increase nutrient intakes; have high levels of retention after production, storage, and cooking for reported nutrients with the exception of thiamin; and do not provoke important changes in sensory characteristics, even after storage.

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