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Impact of food processing on micronutrient content in biscuits and noodles collected from factories in Bangladesh and Indonesia

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Abstract

Introduction: This study aimed to quantify the impact of food processing on micronutrient content in fortified biscuits and noodles produced in Bangladesh and Indonesia.

Methods: Pre-mix, dough, final product and raw ingredient samples were collected from biscuit and noodle factories. The samples were analyzed by a laboratory to determine the micronutrient content in the samples. Statistical analysis was carried out on the laboratory results to quantify the impact of food processing on micronutrient content.

Results: The vitamin C content found in the dough samples collected from Bangladesh was very low, average 13.56 mg/kg, which was below the calculated fortification level of 457 mg/kg. Vitamin B1 content was 6.02 mg/kg below the calculated fortification level for instant noodles. The concentration of folic acid in dried noodles was 0.71 mg/kg below the calculated fortification level.

Discussion: Many of the vitamins were unstable in the dough, particularly vitamin C. The amount of vitamin C found in the final product was only about 60% of WFP's final product specification. The micronutrient content in the final product as a percentage of WFP specification varies great between factories and within factories. The retention of micronutrients was great in the factory that used the molding die versus the factory that used the cutting die.

Conclusion: Minimize the amount of time between the addition of pre-mix to the dough and the processing of the dough. Vitamin C should not be included in the premix used in biscuit fortification. WFP should provide specifications on the desired micronutrient content in the final product instead of pre-mix formulations. The contribution of micronutrients from all raw materials needs to be considered when fortifying food. WFP should consider procuring from factories that use the molding die process and not from factories that use a cutting die process to produce biscuits.

Introduction

Micronutrient deficiencies are widespread and affect large number of people in developing countries. Approximately 2 billion people worldwide suffer from some kind of micronutrient deficiency, causing a wide array of disorders and increasing the risk of death, disease and disability (1). Many studies have been conducted that aim at determining the prevalence of micronutrient malnutrition, some of which include: Vitamin A (2), iodine (3), iron (4) and zinc (5). Other groups have monitored the trends in micronutrient malnutrition (6). Each of the previous mentioned micronutrients have respective consultative groups (13-16) organized to improve understanding of the impact of specific micronutrient malnutrition, develop programs aimed at combating malnutrition, and monitor trends in prevalence of malnutrition.

The above mentioned micronutrients have received much attention due to the high rates of micronutrient malnutrition in many countries around the world. There are other forms of micronutrient malnutrition that are not wide spread, but confined to small geographic areas. These deficiencies need to be monitored so that they do not lead to a larger problem an example is selenium (9), which has been mainly studied in areas of China. Vulnerable populations, like refugees, are susceptible to health problems associated with micronutrient deficiencies such as scurvy (vitamin C) (28), beriberi (vitamin B1), pellagra (niacin) and angular stomatitis (an indicator of B vitamin deficiency, notably riboflavin) (10).

A World Food Programme (WFP) priority is to support the most vulnerable people at most critical time of their lives. In order to achieve this priority, WFP provides nutritious micronutrient rich foods for school feeding and maternal child health programs, and man-made and natural disaster relief. Thailand Burma Border Consortium (TBBC) provides fortified foods to refugees in order to combat malnutrition. Fortified food is expensive relative to basic commodities; for example wheat soy blend (WSB) costs $305/metric ton (MT), biscuits cost $720/MT compared to wheat ($160/MT) and rice ($260/MT) (18). The added cost of fortified foods compared to standard commodities largely results from food processing costs, and not the cost associated with the addition of micronutrients. It is important to WFP, TBBC and food processors to improve the understanding of fortified food quality, in order to ensure that the beneficiaries are actually benefiting from the micronutrients that were paid for.

The impacts of micronutrient malnutrition are wide ranging and the affects are social, economic and clinical. Few besides specialists are aware of the scale and severity of vitamin and mineral deficiency, or of what it means for individuals and for nations. It means the impairment of growing minds and the lowering of national IQs (20). It means wholesale damage to immune systems (21), and the death of millions of children a year (24). It means serious birth defects (22) and the deaths of young women a year during pregnancy and childbirth (25). And it means the large-scale loss of national energies, intellects, productivity, and growth (23).

The Micronutrient Initiative (MI) predicts that fortified foods will play an increasingly important role in addressing micronutrient deficiencies (19). Food fortification is utilized by TBBC and WFP to deliver micronutrients to beneficiaries. In regards to fortification, the World Bank states that “Probably no other technology available today offers as large an opportunity to improve lives and accelerate development at such low cost and in such a short time" (7). Fortified foods are included in TBBC and WFP food baskets and are particularly important in school feeding and maternal/child health programs in Asia. Various types of fortified foods that exist on the market include fortified blended foods (FBF), biscuits, noodles, and flour. Examples of FBF are wheat soy blend (WSB), corn soy blend (CSB) and Asiamix.

This study investigated the impact of food processing on micronutrient content in biscuits and noodles. The objectives of this study was to 1) quantify the micronutrient content in premix, dough and final product samples collected from biscuit and noodle factories in Bangladesh and Indonesia 2) determine the impact of baking on micronutrient content in biscuits 3) determine the impact of steaming and frying/drying on micronutrient content in noodles. The study's conclusions will be used to improve WFP and producer awareness regarding micronutrient fortification.

Samples of biscuits and noodles were collected from factories in Bangladesh and Indonesia. Pre-mix, dough, finished product and raw material samples were collected from biscuit and noodle factories. The samples were analyzed in a laboratory to determine micronutrient content and macronutrient composition. The results from the laboratory were statistically analyzed to determine the impact of food processing on micronutrient content.

Methods

Once arriving in the factories, the factory managers were briefed on the objectives of the study, on how the samples were to be collected and on what support was needed from the factory, i.e. freezer space, heat sealer, etc. The managers were informed that there should be no change in production practices during sampling. In order to encourage participation the managers were informed that the results will be communicated and explained to the factory managers. Also, the factories are easily identifiable therefore WFP verbally promises that before, after and during (1) no penalty will be drawn from the result and (2) that WFP will provide technical assistance to overcome any potential malfunctioning in the fortification process.

The production of biscuits and noodles were documented with photographs when allowed by the factory managers.

Documentation of the recipe

The factory managers were asked to provide a detailed recipe that was followed in the factories on the days of sampling. The order and quantity that the ingredients were added to the mixer was recorded when possible. The manufacturer, lot numbers, country of origin, production date and best used before dates, for the raw ingredients was recorded, when possible.

Biscuit sample collection

Biscuit samples were collected from three factories in Bangladesh, and from two factories in Indonesia.

Three samples were collected from the biscuit factories. The first sample was a 500 gram sample of the vitamin/mineral pre-mix used in the biscuit production. The vitamin/mineral pre-mix was scooped from the pre-mix supplier bag using the ladle that the factory uses to allocate the appropriate amount of pre-mix.

The second sample was a 200 gram dough sample collected from the cart that transports the dough from the mixer to the hopper where the dough was fed on to the production line. The sample was collected by placing a glove or plastic bag over a hand and scooping approximately 200 grams of dough from the cart into polypropylene bags.

The third sample was a 200 gram of biscuits collected right before packaging. The sample was collected by placing a glove or plastic bag over a hand and collecting approximately 200 grams of biscuits from packing tables in Bangladesh or from the production line right before automated packing in Indonesia.

Noodle sample collection in Indonesia only

Instant noodle samples were collect from one factory, and dried noodle samples were collected from another factory. Same methods were used to collect both types of samples.

Four samples were collected from the noodle factories. The first sample was a 500 gram sample of the vitamin/mineral pre-mix used for noodle production. The vitamin/mineral pre-mix was scooped from the pre-mix supplier bag using the ladle that the factory uses to allocate the appropriate amount of pre-mix.

The second sample was a 200 gram dough sample collected from the hopper that feeds the production line. The sample was collected by placing a glove or plastic bag over a hand and scooping 200 grams of dough from the hopper into polypropylene bags.

The third sample was 200 grams of steamed noodles collected from the production line after the noodles were steamed and before they were either fried or dried. The steamed sample was collected by placing a glove or plastic bag over a hand and randomly grabbing steamed noodles that were cut by the machine.

The fourth sample was the final product, either dried or instant noodles, collected right before packaging. The final noodle sample was collected by placing a glove over a hand and randomly grabbing blocks of noodles from the production line right before automated packing.

Biscuit and noodle samples

The samples were collected from 3 different batches. A batch of one commodity was defined as the quantity of product made from the same raw materials without changing any production parameters. An interruption of production, shift change or raw ingredient change, was used to differentiate between two batches as the possibility of different outcomes existed. In each factory, a shift change was used to differentiate between two batches, and a raw ingredient change was used to differentiate between the other batches. For example a shift change was used to differentiate between batch one and batch two, and a raw ingredient change was used to differentiate between batch two and batch three.

Within in each batch samples were collected at three different times in order to ensure that the sample represented the batch. The three 200 gram samples were blended together in the laboratory in order to make a composite sample that represented one batch.

All samples, both noodle and biscuits, were collected in polypropylene bags that were sealed using a heat sealer, and placed into another bag that was heat sealed. The only exception was in one factory were a vacuum sealer was used to seal the polypropylene bags. The samples were placed in a black plastic bag, to protect from light.

The samples were placed into a freezer (-20 C) within 30 minutes of collection. A sheet of paper was included in each bag that contained the following details: Sample number; date of sample collection; time of sample collection; baking time or baking/steaming/drying or frying time; oven temperature/steamer temperature/drier temperature or oil temperature; batch number; part of batch; and factory and location.

All samples were collected in duplicate with one sample transported to Thailand for laboratory analysis and the other samples stored in the country until the study was completed. During transportation, samples were packed into an ice box with several ice packs in order to ensure that they remained frozen. Immediately upon arrival in Bangkok, samples were transported to a freezer.

Additional samples collected in Indonesia
In Indonesia an unfortified sample was collected from each factory in exactly the same was as the fortified samples except in three of the factories the sample was collected at only one time, not at three times during a batch and the samples were collected from only one batch. The factories used the exact same recipe, but they did not add the vitamin/mineral premix to the sample.

In Indonesia samples of the wheat flour were collected from each factory.

Laboratory analysis
All the samples were analyzed by Overseas Merchandise Inspection Co., Ltd. (OMIC) in Bangkok. The laboratory methods are included in Annex 1.

The moisture and micronutrient content was determined for the pre-mix, dough and biscuit samples. The samples collected in Bangladesh were analyzed for the following micronutrients: Vitamin A; Vitamin D3; Vitamin E; Vitamin B1; Vitamin B2; Vitamin B3; Vitamin B5; Vitamin B6; Vitamin B12; Vitamin C; Folic Acid; Iron; Iodine; and Zinc. Additional macronutrient analyses were conducted on the biscuit samples that included: Protein; fat; and ash.

The moisture content and micronutrient content was determined in the pre-mix, dough and biscuit sample for samples collected from biscuit factories in Indonesia. The samples collected from biscuit factories in Indonesia were analyzed for the following micronutrients: Vitamin A; Vitamin D3; Vitamin E; Vitamin B1; Vitamin B2; Vitamin B3; Vitamin B5; Vitamin B6; Vitamin B12; Folic Acid; Iron; Zinc; Selenium; and Calcium.

The moisture content and micronutrient content was determined in the pre-mix, dough, steamed noodles and fried/dried noodles for samples collected from noodle factories in Indonesia. The samples collected from noodle factories in Indonesia were analyzed for the following micronutrients: Vitamin A; Vitamin D3; Vitamin E; Vitamin B1; Vitamin B2; Vitamin B3; Vitamin B5; Vitamin B6; Vitamin B12; Folic Acid; Iron; Zinc; Selenium; and Calcium.

The moisture content was determined in the wheat flour samples along with the content of the following micronutrients: Vitamin B1, vitamin B2, folic acid, iron, zinc and calcium.

In order to determine the micronutrient content in the samples, OMIC used in house methods adapted for the specific matrices like dough, biscuits, noodles, etc. High pressure liquid chromatography was used to isolate the following vitamins: Vitamin A; Vitamin D3; Vitamin E; Vitamin B1; Vitamin B2; Vitamin B3; Vitamin B5; Vitamin B6; Vitamin B12; Vitamin C; and Folic Acid. Atomic absorption was used to isolate the following minerals: Iron, Zinc, Calcium and Selenium. Gas chromatography was used to isolate iodine.

The macronutrient analysis was carried out by using approved Association of Official Analytical Chemist (AOAC) methods. Ash analysis followed AOAC (2002) 923.03 method. Fat analysis used AOAC (2002) 920.39 method. Moisture analysis conducted by AOAC (2002) 925.10 method. Protein analysis determined by AOAC (2002) 954.01 method.

Statistical analysis
Statistical analysis was carried out on the laboratory results. First, all the laboratory values were adjusted to represent 100% recovery. Then the micronutrient content was adjusted for moisture content so that it was reported on a dry weight basis. All values quoted in the report have been adjusted for recovery first, and then adjusted for moisture.

The micronutrient concentration contributed by the vitamin/mineral premix was calculated for each factory. The figure was determined by multiplying the laboratory's vitamin/mineral results by the pre-mix to dough ratio, which represents the content on a wet weight basis. The wet weight content was adjusted to a dry weight basis by using the average moisture content in the doughs collected from the respective factories. This calculation will be referred to as the "calculated fortification level" or "calculated fortification concentration" in the report.

The micronutrient content was presented in box plots that included median, the 25^{th}-75^{th} percentile range, non-outlier range and outliers. Using the pre-mix concentrations determined by the laboratory, the expected micronutrient content in the dough was calculated. This line was included on the box plot. The software program Statistica release 7 was used to generate the box plots.

Results

The manufacturer's specification compared to the premix results, corrected for moisture, determined by the laboratory for Unibis presented in Table 1. The corresponding table for the samples collected in Bangladesh and Indonesia reported in Annex 2 and Annex 3, respectively.

Table 1: Indonesia (Unibis): Manufacturer's specification versus micronutrient content determined by the laboratory and the percent of manufacturer's specification

Micronutrient	Pre-mix Specification (from label) mg/kg	Content of the Pre-mix (laboratory analysis) mg/kg	% label
Vitamin A	6789.00	10940.00	161
Vitamin E	36401.10	48620.00	134
Vitamin B1	11400.00	19650.00	172
Vitamin B2	7000.00	5710.00	82
Vitamin B3	84500.00	102300.00	121
Vitamin B6	8700.00	10180.00	117
Vitamin B12	11.80	10.53	89
Folic Acid	1297.00	1210.00	93
Iodine	1045.00	567.71	54
Iron	87600.00	84350.00	96
Zinc	91500.00	92540.00	101
Selenium	137.90	310.00	225

All the micronutrient content results from the laboratory analysis were reported on a wet weight basis, and the moisture content was reported too. Vitamin D3 was below the detection limit of 0.4 mg/kg, and vitamin B12 was below the detection limit of 1.5 mg/kg. Therefore these two vitamins were excluded from the annex. Recovery values as percentage of micronutrient recovery were determined for most micronutrients from the different matrices: dough; steamed noodle; fried/dried noodle; biscuit; and wheat flour. The macronutrient composition was reported as a percentage in final product. The laboratory results for Bangladesh Biscuits included in Annex 2. The laboratory results for Indonesia biscuits and noodles are included in Annex 3. The pH for the dough samples was determined by the laboratory, see table 2.

Table 2: pH for dough samples

Sample	pH
Bangladesh Biscuits	8.79
Indonesia Biscuits-Unibis	8.63
Indonesia Biscuits-Tiga Pilar	8.60
Indonesia Noodles-Olaga	6.29
Indonesia Noodles-Tiga Pilar	5.79

In order to compare micronutrient content in dough, steamed product (noodles only) and final product all values were corrected for both moisture content and laboratory recovery. A summary the results for Unibis were included in Table 3. The Bangladesh and Indonesia summaries were included in Annex 2 and Annex 3, respectively.

Table 3: Indonesia (Unibis): Calculated fortification level (premix contribution), micronutrient content in dough, micronutrient content in finished product and WFP final product specification

Micronutrient	Calculated Fortification Level mg/kg	Micronutrient Content in Dough mg/kg	Micronutrient Content in Finished Product mg/kg	WFP Final Product Specification mg/kg
Vitamin A	11.67	11.33	11.86	4.50
Vitamin E	51.87	82.54	92.98	50.00
Vitamin B1	20.97	5.48	14.05	6.00
Vitamin B2	6.09	2.51	17.54	6.00
Vitamin B3	109.15	88.33	116.91	80.00
Vitamin B6	10.86	7.06	10.32	6.00
Folic Acid	1.29	2.11	2.13	0.80
Iodine	0.61	1.17	0.93	1.00
Iron	90.00	136.66	131.08	80.00
Zinc	98.73	126.94	121.15	80.00
Calcium	324.73	692.71	680.04	2000.00
Selenium	0.34	1.88	1.16	0.12

The contributions from the raw materials was estimated by collecting samples were the premix was not added to the dough. The micronutrient content in unfortified final product, premix contribution to the fortified product ("calculated fortification level"), the unfortified product plus the premix contribution and fortified final product for the Unibis samples were compared in Figures 1-3. The graphs for the other factories in Indonesia were included in Annex 3. The calcium content was included in its own figure in Annex 5.

Figure 1: Indonesia (Unibis) vitamin E, vitamin B3, Iron and Zinc content (mg/kg) in unfortified product, contribution of premix to finished product, unfortified product plus premix contribution and fortified final product

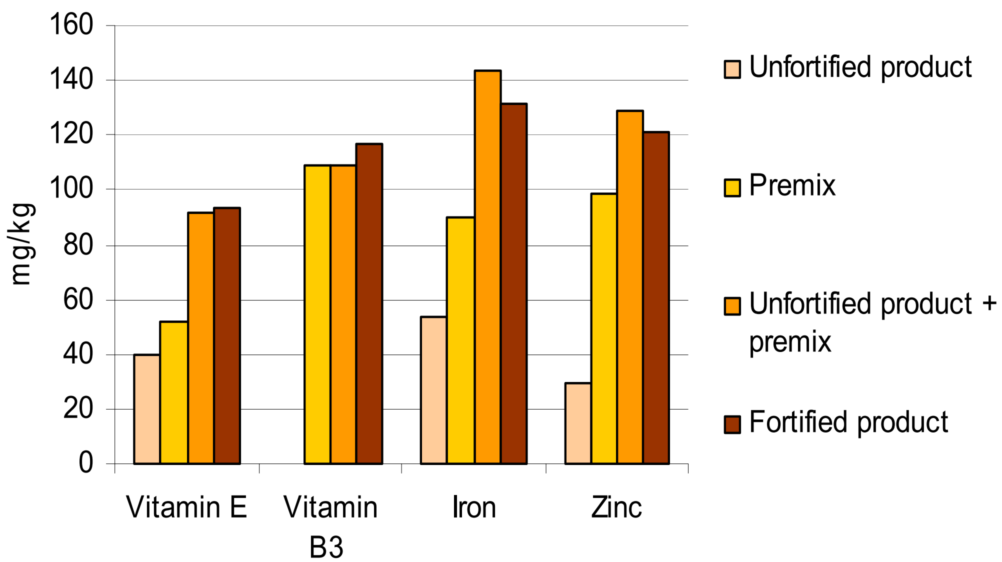


Figure 2: Indonesia (Unibis) vitamin A, vitamin B1, vitamin B2 and vitamin B6 content (mg/kg) in unfortified product, contribution of premix to finished product, unfortified product plus premix contribution and fortified final product

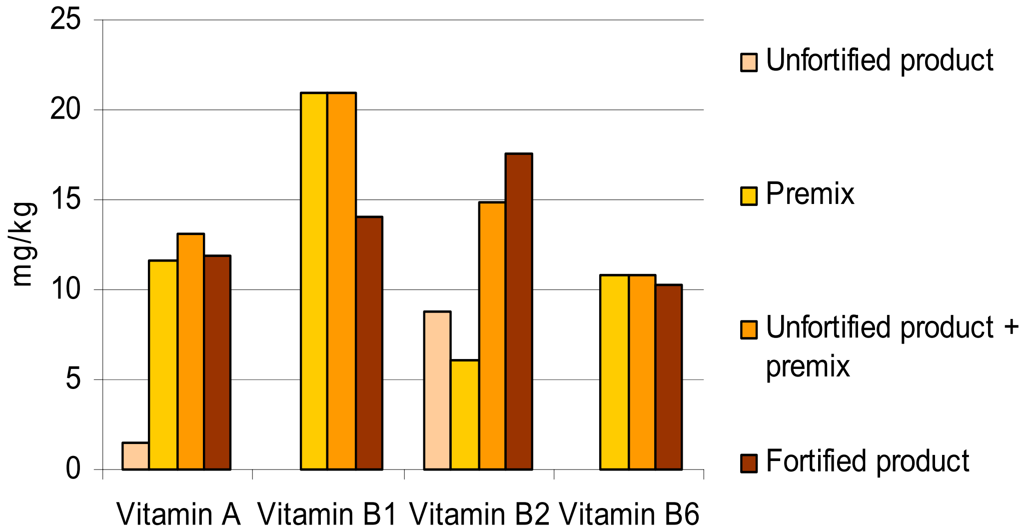
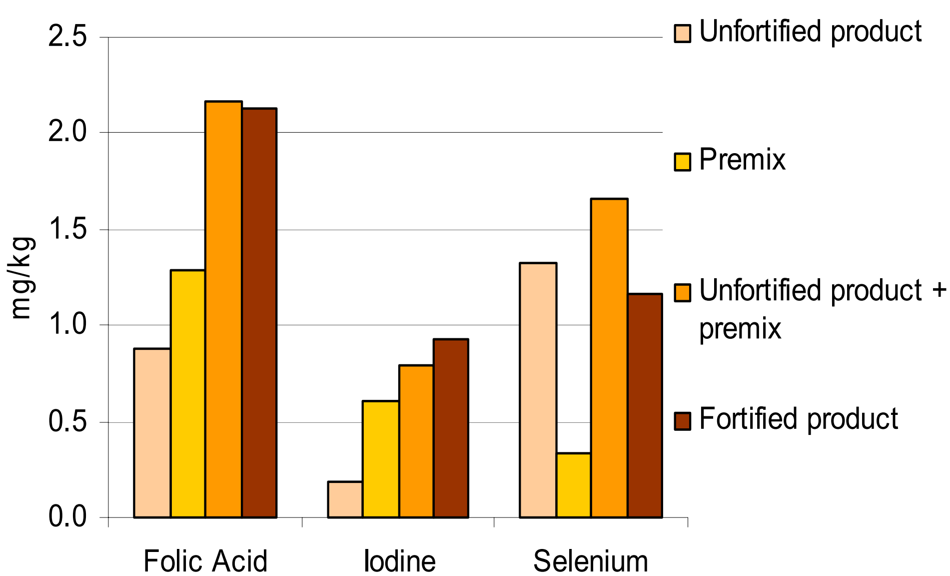


Figure 3: Indonesia (Unibis) folic acid, iodine and selenium content (mg/kg) in unfortified product, contribution of premix to finished product, unfortified product plus premix contribution and fortified final product



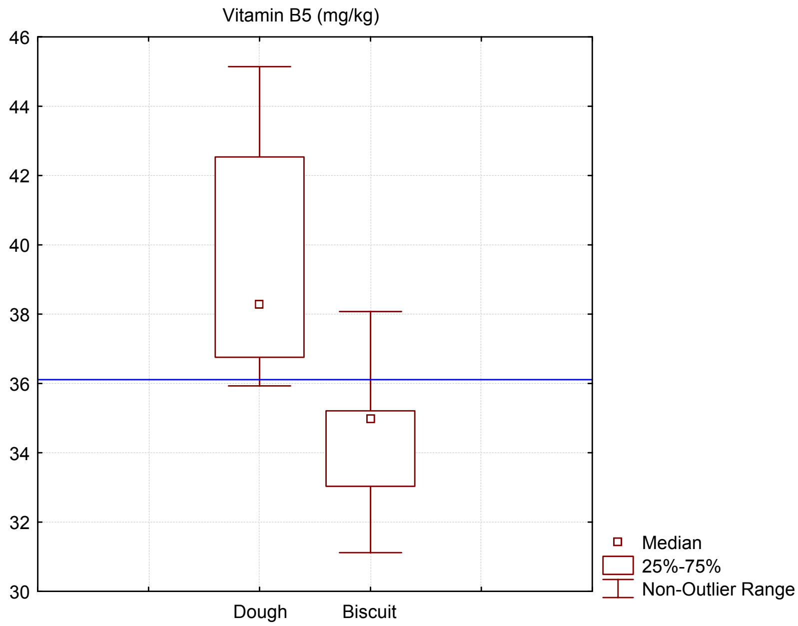
Box plots comparing micronutrient content in dough versus micronutrient content in biscuits with the calculated fortification level, represented as a line, for samples collected from Bangladesh included in Annex 4. Box plots comparing micronutrient content in dough versus micronutrient content in biscuits with the calculated fortification level, represented as a line, for samples collected from Indonesia, two factories reported separately, included in Annex 5. Box plots comparing micronutrient content in dough versus micronutrient content in steamed noodle versus micronutrient content in final noodle with the calculated fortification level, represented as a line, for samples collected from Indonesia, two factories represented individually, included in Annex 6.

Bangladesh biscuits

The vitamin C content found in the dough samples collected from Bangladesh was very low, average 13.56 mg/kg, which was well below the calculated fortification level of 457 mg/kg. Also, vitamin B1 content, average 7.03 mg/kg, in dough collected from Bangladesh was significantly lower than the calculated fortification level of 9.3 mg/kg.

Vitamin B5 was stable in dough collected from Bangladesh, see box plot 1. The average vitamin B5 concentration in the dough was 39.51 mg/kg, which was quite similar to the calculated fortification level of 36.10 mg/kg.

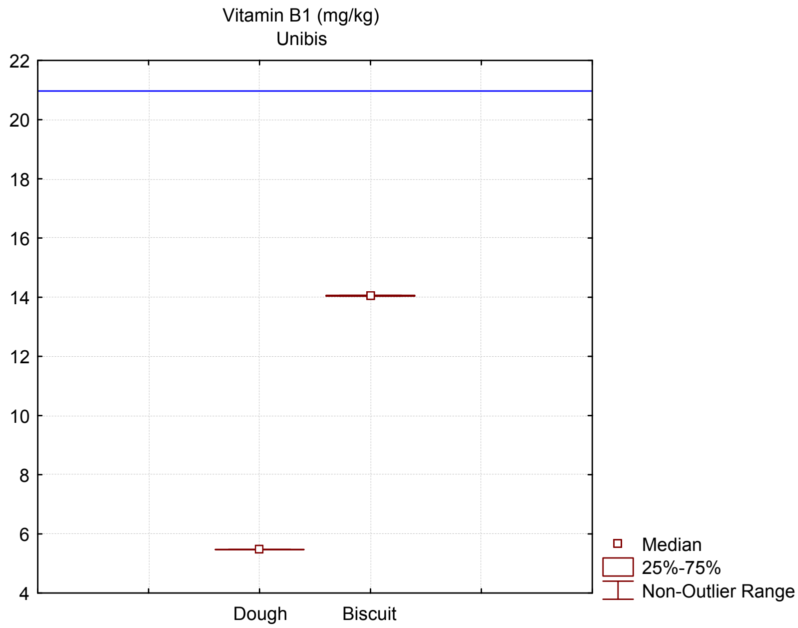
Box plot 1: Vitamin B5 content for Bangladesh biscuits



Indonesia biscuits

Vitamin B1 was detected at very low levels, 5.48 mg/kg in the dough from Unibis. The vitamin B1 content in the final product was 14.05 mg/kg, in the biscuits was lower than the calculated fortification level of 20.97 mg/kg, see box plot 2.

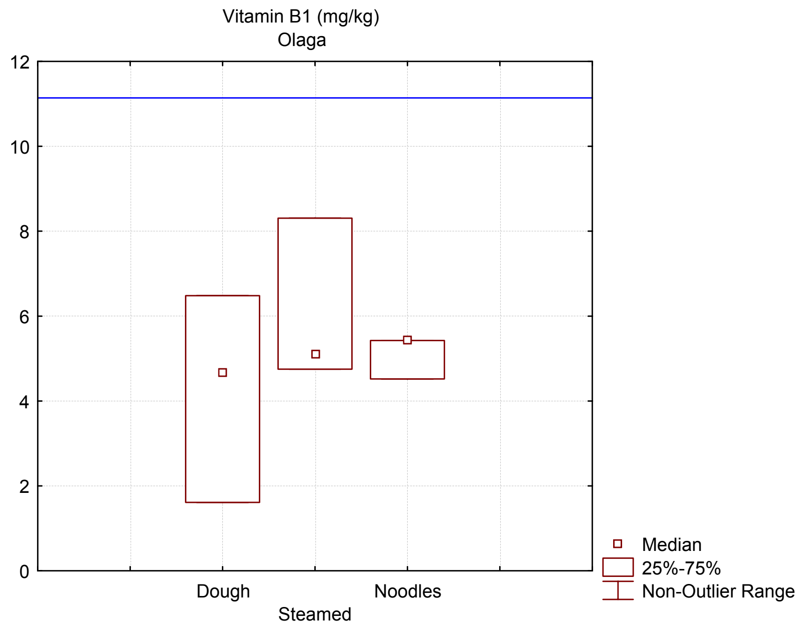
Box plot 2: Vitamin B1 content for Unibis



Indonesia instant noodles

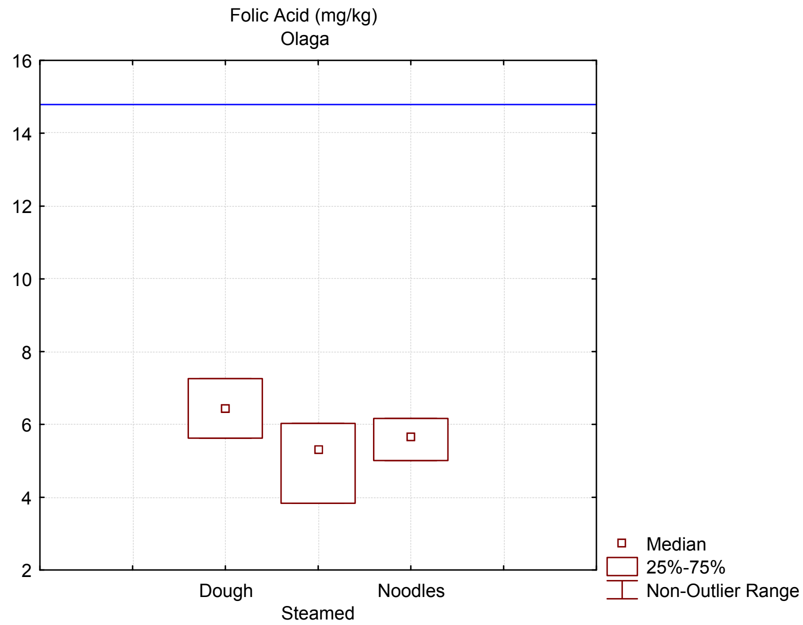
For instant noodles collected from Indonesia, vitamin B1 content was below the calculated fortification level, see box plot 3.

Box plot 3: Vitamin B1 content for instant noodles



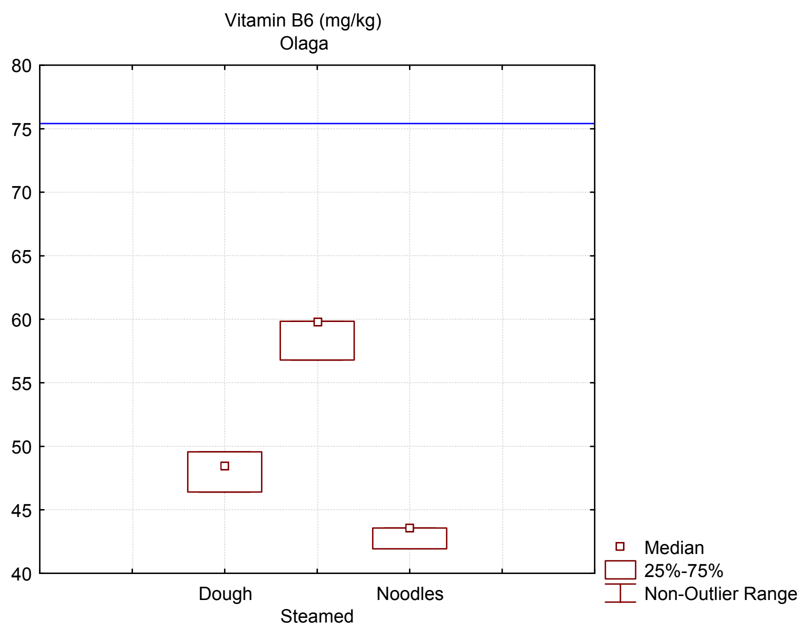
The concentration of folic acid in the final product was below the calculated fortification line, see box plot 4.

Box plot 4: Folic acid content for instant noodles



Vitamin B6 showed significant losses in the processing of instant noodles, see box plot 5.

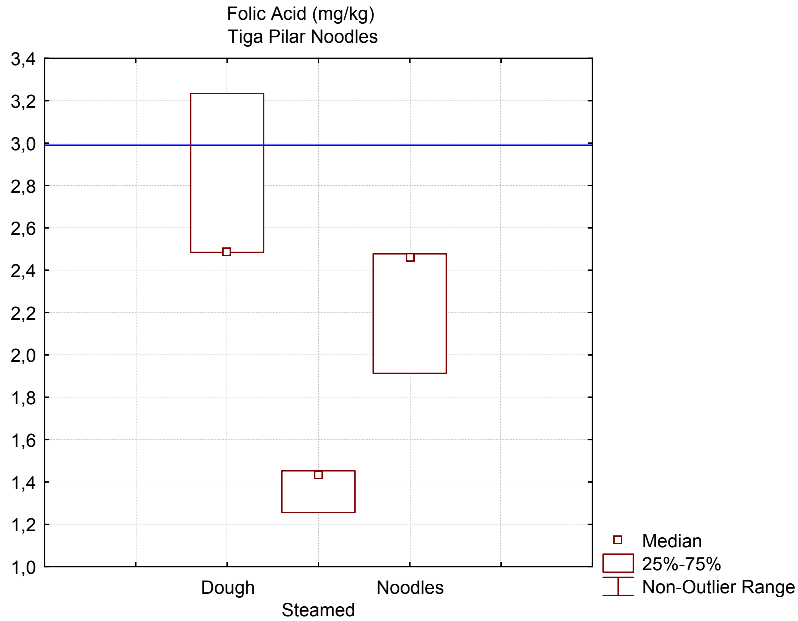
Box plot 5: Vitamin B6 content for instant noodles



Indonesia dried noodles

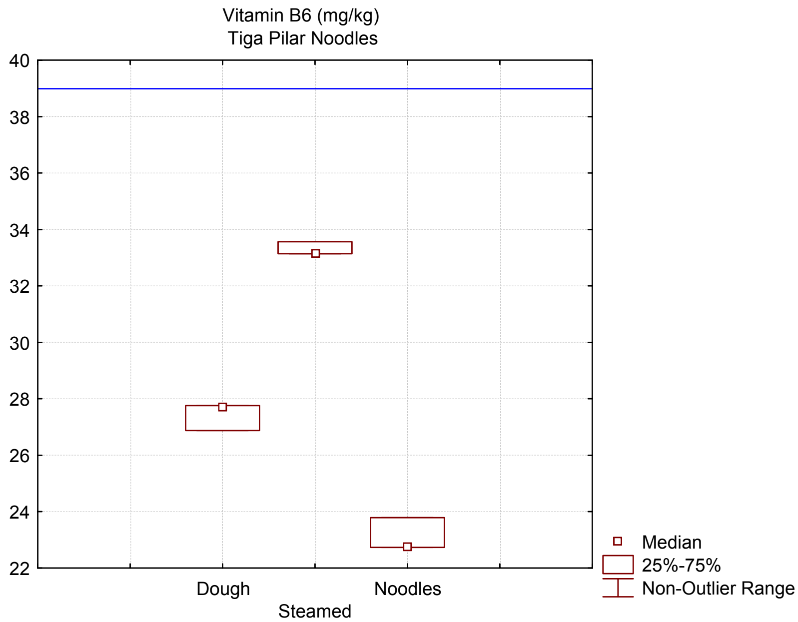
The folic acid content in the dried noodles was below the calculated fortification level, see box plot 6.

Box plot 6: Folic acid content for dried noodles



There was a loss of Vitamin B6 during the production of dried noodles in Indonesia, see box plot 7.

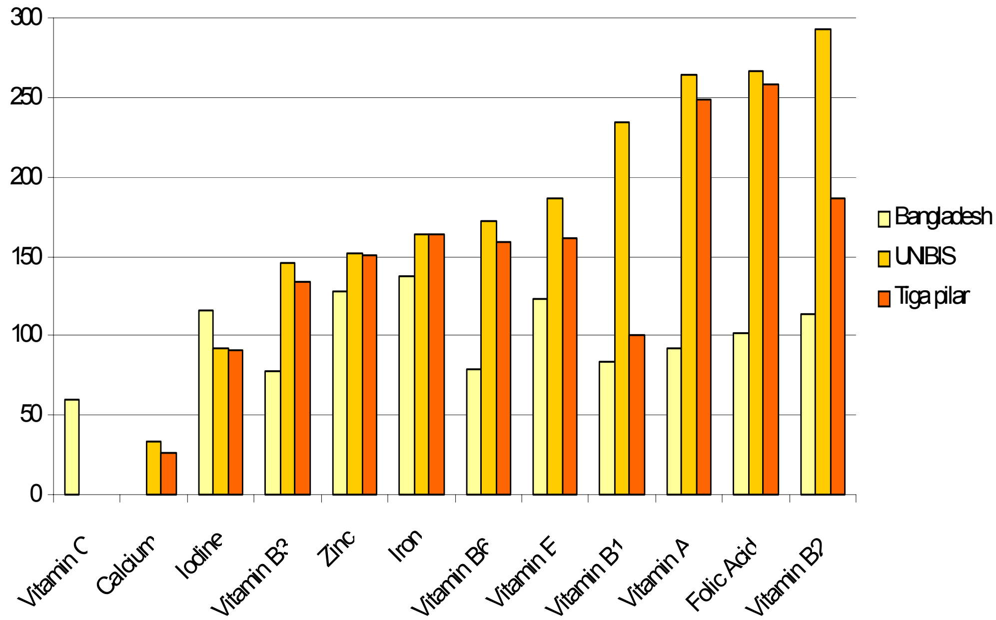
Box plot 7: Vitamin B6 content for dried noodles



WFP Spcifications

WFP supplies final product specifications to the factories on the final micronutrient content. Figure 4 shows the percent of WFP final product specifications for all biscuit fac. The percent WFP final product specifications for the other factories was included in Annex 6.

Figure 4: Percent WFP final product (biscuits) specifications



Discussion

The Micronutrient Assessment Project (MAP) conducted by Sharing United States Technology to Aid in the Improvement of Nutrition (SUSTAIN) identified problems in meeting micronutrient standards during food processing, and that losses of micronutrients occur during food preparation. The current study, "Impact of processing and preparation on micronutrient content and quality" will complement a future study "Impact of local food preparation techniques on micronutrient content and quality" to be carried out by TBBC and WFP. The two studies will further investigate issued raised by SUSTAIN and determine if progress has been made in improving fortification.

Food fortification is a complex process and many factors need to be considered when developing a fortification system, especially when multiple micronutrients are added to foods. Micronutrient-micronutrient interactions need to be considered when fortification programs are developed. Another characteristic of vitamins that need to be taken into consideration is the solubility of the vitamin. Vitamin C, B complex and folic acid are water soluble. Vitamin A, vitamin D and vitamin E are fat soluble.

This study investigated the impact of food processing on micronutrient content in biscuits and noodles. Biscuits baked at a high temperature for some time with both the temperature and time varying from factory to factory. Noodles are first steamed and then either fried or dried depending on the type of noodle be produced, instant or dried respectively.

In order to determine the impact of food processing samples were collected of the premix, dough, steamed product (noodles) and finished product. The laboratory analysis on the premix showed a range of 54-225%, see table 1, of manufacturer's specifications, provided by WFP, for the micronutrients included in the premix collected from Unibis. Sometimes the manufacturer adds an overage to account for the potential loss of micronutrients during storage and processing, which might explain the high premix concentrations. Other micronutrients may have been destroyed during transport and storage which may explain the low concentrations in the premix.

The premix is not the only source of micronutrients, the raw materials also contribute some micronutrients to the final product, see figure 1-3. The raw materials contribute vitamin B2, folic acid, iron and zinc to the finished product, but do not contribute much vitamin B3, vitamin B1 or vitamin B6 to the final product.

Micronutrients can be destroyed or lost by various mechanisms. Micronutrients are susceptible to light, oxidizing agents, reducing agents, heat, humidity, acids and alkalis. Vitamin B1 is highly sensitive to heat, and vitamin A, vitamin D and vitamin C are sensitive to heat (17). Vitamin C, vitamin B1 and vitamin B12 are sensitive to humidity (17).

The micronutrient content in the final product as a percentage of WFP specification varies great between factories and within factories. The micronutrient contribution from raw materials may not have been accounted for therefore the percentage of WFP final product specification was high. Factories may not be including the proper amount of calcium to achieve the WFP final product specification in the recipe because it is expensive to fortify at that level.

Micronutrient stability in dough

The biscuit dough was generally an alkaline environment. Vitamin C and vitamin B1 are highly sensitive to alkalis (17). The alkaline environment was one possible explanation for the near disappearance of vitamin C in biscuit dough. Vitamin C was difficult to maintain in premixes since it was susceptible to destruction by so many environmental factors (26). OMIC carried out an investigation on the stability of vitamin C in dough. The laboratory fortified a dough sample with vitamin C. Immediately after mixing the dough the vitamin C was extracted from the dough and found to be very close to the concentration that the dough was fortified at. The dough was left on the laboratory counter for one day. The laboratory tried to extract vitamin C from the dough after sitting on the counter for one day, but no vitamin C was detected.

The concentration of vitamin B5 in dough collected from Bangladesh biscuit factories was over the calculated fortification level by 3.41 mg/kg. The additional amount of vitamin B5 was likely contributed by the wheat flour and the soy flour that have micronutrient concentrations of 4.6 mg/kg and 19.8 mg/kg respectively. In Bangladesh biscuit dough, the estimated contribution of vitamin B5 by wheat flour and soy flour to the dough was estimated to be 3.45 mg/kg and 0.99 mg/kg respectively (27). Taking these contributions into consideration, the dough should contain 40.54 mg/kg, and it actually contained 39.51 mg/kg a difference of only 1.03 mg/kg. Vitamin B5 was one of the most stable vitamins in an alkaline environment (26).

Many of the vitamins were unstable in the dough, and the laboratory was not able to extract even the calculated fortification level. Further investigations need to be carried out on what led to the destruction of micronutrients in the dough samples. The destruction was possibly due to the alkaline pH or presence of microbes.

Biscuits
The biscuit factories in Indonesia used production line. In one of the factories a molding system was used were the dough was dumped into the hopper that directly fed into the die that cut the biscuits. In the other factory a cutting system wad used where the dough was run through rollers to make a sheet of dough. The sheet of dough was passed through a die that cut out the biscuits. The cutting system is a more expensive mode of production compared to the molding system. The retention of vitamin B1 and vitamin B2, refer to Annex 3, was significantly better in the biscuits produced with the molding die versus the biscuits produced by the cutting process. The retention was slightly better for the other micronutrients in biscuits produced by the molding process versus the cutting process.

The concentration of vitamin B1 in the biscuit samples collected from Indonesia was well below the calculated fortification level. Vitamin B1 was quite unstable, possibly due to the alkaline environment of the dough samples. The low levels of vitamin B1 found in the biscuits collected from Indonesia could also be caused by heat during the baking process because vitamin B1 is highly sensitive to heat (17).

In many cases the fortification level exceeds the calculated fortification level, which likely indicates contribution of micronutrients from other ingredients used to make the biscuits. The wheat flour in Indonesia is fortified with micronutrients, refer to Annex 3, and it comprises 50-60% and 74-76% of the recipe for biscuits in noodles respectively. The dried skim milk provided a significant contribution of calcium to the final product. Dried skim milk contained 13,479 mg/kg (27). The contribution of calcium from dried skim milk was approximately 470 mg/kg. The salt used in the recipes is iodized and contributes iodine to the product.

Indonesia instant noodles
Vitamin B1 content below the calculated fortification level in instant noodles indicated that destruction of vitamin B1 occurred during noodle production. The pre-mix was not the only source of vitamin B1; wheat flour also contributes vitamin B1, but was not accounted for in the calculated fortification level.

Folic acid also appeared to be quite unstable during the production of instant noodles. The pre-mix was not the only source of folic acid as the wheat flour was calculated to contribute an additional 1.23 mg/kg after adjusting for recovery and moisture. Folic acid was highly sensitive to oxidizing agents and reducing agents, and sensitive to light, acids and alkalis (17). The pH of the dough was 6.29, which may have led to some of the destruction of folic acid. The presence of Zinc, a reducing agent, may have interacted with folic acid lead to its loss.

A loss of vitamin B6 also occurred during the production of instant noodles. Vitamin B6 was sensitive to light, acids and alkalis. The acidic nature of the dough, pH 6.29, may have contributed to the loss of vitamin B6.

Indonesia dried noodles
The results indicated a loss of folic acid because the content in the final product was below the calculated fortification level. The pre-mix was not the only source of folic acid in dried noodles. The premix contributed 2.99 mg/kg, and the wheat flour

contributed an additional 1.35 mg/kg. Folic acid was highly sensitive to oxidizing agents and reducing agents, and sensitive to light, acids and alkalis (17). The pH of the dough was 5.79, which may have led to some of the destruction of folic acid. The presence of Zinc, a reducing agent, may have interacted with folic acid lead to its loss.

The results indicated a loss of vitamin B6 during production of dried noodles. Vitamin B6 was sensitive to light, acids and alkalis (17). The acidic nature of the dough, pH 5.79, may have contributed to the loss of vitamin B6.

Conclusions

The dough appeared to be an unstable environment for the following vitamins: Vitamin A, vitamin B1, vitamin B2, vitamin B3 vitamin B6 and vitamin C. WFP will need to advise producers that it is important to reduce the amount of time from when the pre-mix is added to the dough to the time the dough is processed. By minimizing this time, the producer will minimize the amount of micronutrients lost due to the instability of micronutrients in dough.

Vitamin B1, folic acid and vitamin C were highly sensitive to food processing. It will be important to adjust the overage of these vitamins to account for the loss during food processing in order to ensure that there will be the desired amount in the final product. Another option would be to explore the potential of more stable forms of the micronutrient fortificants in order to minimize the losses that occur during food processing.

Vitamin C should not be included in the pre-mix for biscuits produced in Bangladesh. The amount of vitamin C lost during food processing, about 40%, is too great considering that vitamin C accounts for nearly 50% of the pre-mix cost. Including vitamin C in the pre-mix is not cost-effective. Vitamin C is not recommended to be added to pre-mixes used to fortify biscuits (17).

When WFP develops contracts with factories to produce fortified foods for WFP, WFP should provide the factory with specifications that indicate the desired micronutrient content in the final product instead of providing the factories with a pre-mix formulation. There are too many food processing variables in each factory that make it difficult to use a specific pre-mix formulation. The producers along with the pre-mix manufactures need to produce a pre-mix formulation appropriate for the specific factory based on the conditions and processes in that factory.

When developing a fortification process, WFP and producers need to consider all the potential sources of micronutrients. The contribution of micronutrients from fortified raw ingredients needs to be accounted for when developing a fortified product. Vitamin B2, folic acid and iodine far exceed the WFP specifications for micronutrient content in the final product.

The biscuits produced with a cutting die are more expensive to produce than biscuits produced with a molding die. The retention of micronutrients was better in biscuits produced with the molding than biscuits produced with the cutting die. Therefore WFP should consider procuring from factories that use the molding die process and not from factories that use a cutting die process to produce biscuits.

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