Will fortification of staple foods make a difference to the dietary intake of South African children?

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Abstract

Objectives: To evaluate the estimated dietary intake of children at population level who consume fortified staple foods.

Methods: In this study, a secondary data analysis of the database of the National Food Consumption Survey (NFCS; 1999) on dietary data of a nationally representative sample of children (n = 2 200) in South Africa was performed. Prior to 2003 there was no mandatory fortification of staple foods, with the exception of iodine added to salt. Mandatory fortification of maize and wheat flour was introduced in October 2003. Micronutrient values of fortified wheat and maize food sources were determined by chemical analyses of these foods. These values were then interpolated in the original staple food nutrient analysis determined in the primary analysis of the NFCS database.

Findings: The findings of the present study indicated that the addition of micronutrients to staple foods made a significant difference to the intake of vitamin A, thiamine, niacin, vitamin B_6, folic acid and iron. These improvements were particularly important in rural areas where children have the lowest mean dietary micronutrient intake.

Conclusions: Based on the results of the secondary data analysis of the national dietary data together with the chemical analyses of fortified foods, it would appear that fortification of two of the most commonly eaten staple foods in the country will significantly improve the micronutrient intake of children under nine years of age and will improve the overall micronutrient density of their diets. It is recommended that appropriate educational messages on the fortification of staple foods in the country should be utilised to improve children's dietary intake at population level, provided such messages facilitate the consumption of the fortified staples by children.

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Introduction

A number of dietary surveys have been undertaken in South Africa, both before and after democratisation in 1994.[1-5] These studies have repeatedly shown, albeit to differing extent, that certain nutritional disorders are rife and that young children are particularly vulnerable to nutritional insults. In brief, the most common dietary inadequacies documented include a low energy intake resulting in a high prevalence of stunting[6] (national level = 21.6%); a low fat intake[7] particularly of essential fatty acids; and an inadequate intake of specific micronutrients (iron and vitamin A[8] [also shown biochemically] calcium, zinc, vitamin C, niacin, folic acid, vitamin B_6 and riboflavin).[1-6] Such dietary deficits have always appeared to occur with a higher frequency in rural areas.[9]

In 1999, the first National Food Consumption Survey (NFCS) was undertaken in South Africa on one- to nine-year-old children.[6] One of the main objectives of this study was to determine, on a population basis, the nutrients that were most commonly deficient in these children's diets, and secondly to identify the most commonly consumed foods by children at both pre- and early school level. The NFCS confirmed at the national level the findings of earlier isolated dietary studies, namely that the dietary intake of calcium, iron, zinc, vitamins A, D, C and E, riboflavin, niacin, vitamin B_6 and folic acid were below two-thirds of the Recommended Dietary Allowances (RDAs) used at that time.[10] The reason for such dietary inadequacies[6] was attributed to the monotonous nature of the diet. In this regard, the most commonly consumed foods identified by the NFCS were maize, sugar, tea, and bread, which are known, on their own, to be inadequate sources of micronutrients to meet daily requirements. The two most commonly used staple foods identified by the NFCS were maize meal and bread.[11]

A number of options are available to health policy makers when making decisions regarding the improvement of the dietary intake of children at a national level. In the short term, such decisions have included supplementation with either oral supplements such as iron and vitamin A[12] or the provision of enriched complementary foods or beverages such as milk powder, and staple foods rich in energy.[13,14] School feeding has also been a favoured method to reach older children.[15,16] Longer-term recommended solutions include dietary diversification and fortification of food.[17] Fortification of staple foods with selected micronutrients is an option that has been introduced in many developed and developing countries with varying degrees of success.[18,19] However, food fortification benefits the target population effectively only if the correct foods are fortified and in the appropriate doses. In South Africa, school feeding[20] and vitamin A supplementation[21] have been used for some years with varying degrees of success. However, targeting of the needy segments of the population has remained rather elusive. Hence the Department of Health elected to enact mandatory fortification to ensure better coverage and improved dietary micronutrient intake of the population at large.

Since maize meal and bread were shown to be the most commonly consumed staples in the country,[6] it was decided to use these foods as the vehicles for fortification. Hence vitamin A, iron, zinc, folic acid, thiamine, niacin, vitamin B_6 and riboflavin have been added to maize meal and wheat flour in South Africa since October 2003 (Tables Ia–Ib).[22] This was considered to be a sustainable and relatively inexpensive way to address the documented inadequate intake of vitamins and minerals without changing the traditional food consumption patterns. The effectiveness of this mandatory fortification legislation in the amounts supplied to the average South African child has not so far been evaluated. Although ideally one would evaluate such effectiveness by determining the concentrations of the relevant micronutrients in the blood of those consuming fortified food products at the national level, a simpler and less expensive approach is to analyse dietary micronutrient intake pre- and post-fortification using existing dietary data, which is the aim of the present study.

Table Ia: Fortificant mix for wheat flour (white and brown bread flour) as stipulated by the South African government regulations[22]

Fortificants and diluent	Micronutrient requirements (per 1 kg flour)	Fortificant requirements (per 1 kg flour)	Fortification mix (g/kg)
Vitamin A palmitate[a] (Activity: 75 000 µgRE[b]/g)	1786 µgRE	23.8095 mg	119.0475 g
Thiamine mononitrate (Activity: 78% min)	1.9444 mg	2.4929 mg	12.4644 g
Riboflavin	1.7778 mg	1.7778 mg	8.8889 g
Nicotinamide/niacinamide	23.6842 mg	23.6842 mg	118.4210 g
Pyridoxine HCl (Activity: 81% min)	2.6316 mg	3.2489 mg	16.2443 g
Folic acid (Activity: 90.5% min)	1.4286 mg	1.5786 mg	7.8927 g
Electrolytic iron[c] (Activity: 98% min)	35.00 mg	35.7143 mg	178.5714 g
Zinc oxide (Activity: 80% min)	15.00 mg	18.7500 mg	93.7500 g
Diluent	-	To complete 200 mg	To complete 1 000 g

a. Protected, stabilised Vitamin A palmitate containing 75 000 µg RE activity per gram
b. Retinol equivalents (RE) = 1 µg retinol = 3.33 IU (International Units) vitamin A
c. Elemental iron powder where more than 95% passes through a 325 mesh (<45 micron particle size) made by an electrolytic process

Table Ib: Fortificant mix for maize meal (super, special, sifted, unsifted) as stipulated by the South African government regulations[22]

Fortificants and diluent	Micronutrient requirements (Per 1 kg meal)	Fortificant requirements (Per 1 kg meal)	Fortification mix (g/kg)
Vitamin A palmitate[a] (Activity: 75 000 µgRE[b]/g)	2085 µgRE	27.8000 mg	139.0000 g
Thiamine mononitrate (Activity: 78% min)	2.1875 mg	2.8045 mg	14.0224 g
Riboflavin	1.6875 mg	1.6875 mg	8.4375 g
Nicotinamide/niacinamide	25.000 mg	25.0000 mg	125.0000 g
Pyridoxine HCl (Activity: 81% min)	3.1250 mg	3.8580 mg	19.2901 g
Folic acid (Activity: 90.5% min)	2.0000 mg	2.2099 mg	11.0497 g
Electrolytic iron[c] (Activity: 98% min)	35.0000 mg	35.7143 mg	178.6714 g
Zinc oxide (Activity: 80% min)	15.00 mg	18.7500 mg	93.7500 g
Diluent	-	To complete 200 mg	To complete 1 000 g

a. Protected, stabilised Vitamin A palmitate containing 75 000 µg RE activity per gram
b. Retinol equivalents (RE) = 1 µg retinol = 3.33 IU (International Units) vitamin A
c. Elemental iron powder where more than 95% passes through a 325 mesh (<45 micron particle size) made by an electrolytic process

Methods

Study sample

The survey population comprised children aged one to nine years (12–108 months) in South Africa and comprised a nationally representative sample (n = 2 200, randomly selected, weighted for provincial representation). A detailed description of the sampling has been described elsewhere.[23]

Dietary intake

Dietary data was collected by 24-hour recall. This method has been used in the majority of population-based studies.[24-26] The 24-hour recall was conducted with the caregiver of each child by trained interviewers who visited the homes of the participants. Dietary aids comprising household utensils and wax food models were used to determine portion sizes. A training video was developed and utilised to standardise field workers nationally.[6] Relative validity was determined by comparison of the 24-hour recall data with that obtained from the same participants with a quantitative food frequency questionnaire. Furthermore, three 24-hour recalls were repeated in 10% of the sample population. The full details of the dietary methodology employed have been described elsewhere.[6,11]

Data analysis

In order to determine the nutrient quality of the children's diets, a Nutrient Adequacy Ratio (NAR) was calculated for each nutrient. NAR was calculated as the ratio of the intake of a nutrient divided by the Recommended Nutrient Intake (RNI) for a given nutrient using the WHO/FAO recommended intakes,[27] which are set at two standard deviations above the average nutrient requirements. In the case of iron and zinc, the category for moderate bioavailability was used. The Mean Adequacy Ratio (MAR) was calculated as the measure of the adequacy of each child's overall diet. MAR was calculated as the sum of each NAR (truncated at 1) divided by the number of micronutrients of which the intake is inadequate, irrespective of whether such micronutrients were included in the food fortification legislation or not. For both NAR and MAR a value of 1.0 (or 100%) is the ideal, since it means that the intake is the same as the requirement.

The documented micronutrient intakes of the children[6] were re-calculated by substituting the nutrient values for maize meal porridge and bread of the non-fortified products (Table II) with values of the chemically analysed fortified samples of maize meal porridge and fortified white and brown bread currently available on the market.[28,29] The amount of these foods consumed by each child (per capita consumption) was also calculated.[6]

Results

The low levels of the specified nutrients prior to the 2003 food fortification legislation, as reported by the NFCS (Table III), indicate that the lowest mean nutrient intake and NAR values were for folic acid and vitamin B_6 levels, particularly in seven- to eight-year-old children, who had NAR values of 54.5% and 68.6% respectively. Some nutrients such as vitamin B_6, thiamine and riboflavin had mean NAR values above 100% in the one- to three-year-olds but these values fell below 100% in the older children. Zinc was the only nutrient with mean values above 100%. Nevertheless, the MAR was below the level recommended.

Table II: Mean values (per 100 g) as chemically determined by the South African industry for cooked maize meal porridge and bread[28,29]

Nutrients	Maize: unfortified[a]	Maize: fortified[a]	White bread: unfortified[b]	White bread: fortified[b]	Brown bread: unfortified[b]	Brown bread: fortified[b]
Iron (mg)	0.2	1.3	1.2	3.6	1.5	3.8
Zinc (mg)	0.22	0.63	1.0	1.7	1.4	2.2
Vitamin A (RE)	0	34	0	83.4	0	73.4
Thiamine (mg)	0.08	0.13	0.15	0.28	0.16	0.28
Riboflavin (mg)	0.01	0.05	0.04	0.16	0.06	0.15
Niacin (mg)	0.2	1.2	1.2	3.1	2.6	4.6
Vitamin B6 (mg)	0.01	0.12	0.07	0.24	0.14	0.30
Folic acid (µg)	3.0	46.0	97.0	81.7	42.0	82.0

a- Reference 28
b- Reference 29

Table III: Mean micronutrient intakes and NRI, NAR (%) and MAR (%) values of South African children's diet by age group as derived by secondary dietary analysis of the National Food Consumption Survey, 1999[6]

	1–3 years (n = 795)				4–6 years (n = 861)				7–8 years (n = 544)				RNI[a]
Nutrients	**Mean**	**SD[b]**	**95% LCI[c]**	**95% UCI[d]**	**Mean**	**SD**	**95% LCI**	**95% UCI**	**Mean**	**SD**	**95% LCI**	**95% UCI**	
Dietary Intake													
Iron (mg)	4.88	0.12	4.64	5.13	6.47	0.17	6.14	6.80	6.98	0.27	6.44	7.51	6–9
Zinc (mg)	4.25	0.08	4.08	4.41	5.30	0.11	5.08	5.53	5.78	0.20	5.39	6.17	4.1–5.6
Folate (µg)	97.4	2.70	92.07	102.7	145.5	4.94	136	155.3	163.4	7.01	149	177	160–300
Niacin (mg)	5.65	0.14	5.37	5.92	7.71	0.23	7.25	8.18	8.50	0.36	7.80	9.21	6–12
Riboflavin (mg)	0.70	0.02	0.65	0.74	0.77	0.03	0.71	0.84	0.80	0.05	0.71	0.90	0.5–0.9
Thiamine (mg)	0.59	0.01	0.57	0.61	0.72	0.01	0.70	0.75	0.78	0.02	0.74	0.82	0.5–0.9
Vitamin A (RE)	369.7	21.0	328.1	411.2	436.1	41.2	355	517.6	451.9	63.7	326	578.0	400–500
Vitamin B_6 (mg)	0.50	0.01	0.48	0.53	0.65	0.02	0.61	0.69	0.69	0.03	0.62	0.75	1.0
NARe %													
Iron	81.4	2.06	77.3	85.5	107.8	2.76	102	113.3	77.5	2.98	71.6	83.4	100
Zinc	103.6	2.00	99.6	107.5	104.0	2.25	99.6	108.5	103.2	3.48	96.3	110.1	100
Folate	60.9	1.69	57.5	64.2	72.8	2.47	67.9	77.6	54.5	2.33	49.8	59.1	100
Niacin	94.1	2.34	89.5	98.7	96.4	2.91	90.7	102.2	70.8	2.98	65.0	76.7	100
Riboflavin	139.2	4.92	129.5	148.9	128.6	5.59	118	139.7	89.4	5.09	79.4	99.5	100
Thiamine	118.4	2.29	113.9	122.9	120.6	2.24	116	125.1	86.8	2.40	82.1	91.6	100
Vitamin A	92.4	5.25	82.0	102.8	96.9	9.15	78.8	115.0	90.4	12.7	65.1	115.6	100
Vitamin B_6	100.1	2.53	95.1	105.1	108.2	3.34	101	114.8	68.6	3.1	62.4	74.7	100
MAR[f] %													
Percentage	64.74	0.80	63.16	66.32	65.8	0.92	64.0	67.6	57.3	1.31	54.7	59.9	100

[a]-RNI = Recommended Nutrient Intake (27); [b]-SD = Standard deviation; [c]-LCI = lower confidence interval; [d]-UCI = upper confidence interval
[e]-NAR = Nutrient Adequacy Ratio: The intake/RNI x 100%; [f]-MAR = Mean Adequacy Ratio (sum of RNIs/nr of nutrients)

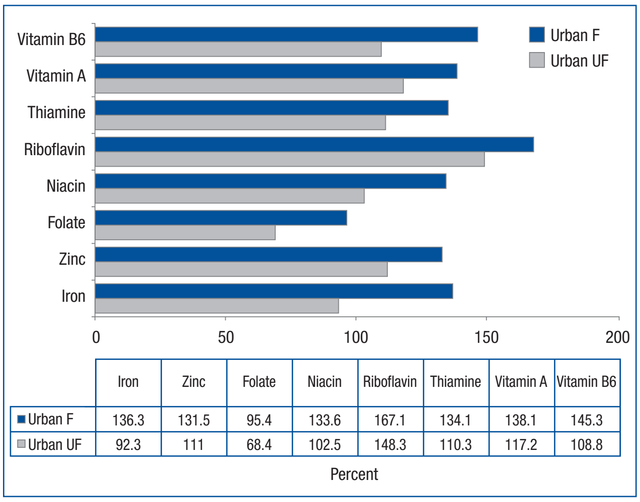
In relation to urban/rural comparisons (Table IV), urban mean nutrient intake and NAR values were overall higher than those of rural children. All mean NAR values of the urban children, with exception of folic acid (68.4%) and iron (92.3%), were above 100% of recommendations. By contrast, in children living in rural areas only the mean NAR value for thiamine was above 100% of recommendations. Although food fortification made a significant ($p < 0.05$) difference in both mean nutrient intakes and NAR values among rural children (Table IV; Figures 1 and 2), the MAR remained significantly lower when compared with the MAR (fortified) of children living in urban areas. In essence, food fortification made a large difference to mean NAR values in rural areas with all values, except for vitamin A (93.5%), increasing to above 100% of the recommended level. For some nutrients, the mean rural NAR values increased to above those found in urban areas (rural vs urban: thiamine (145% vs 134%), folic acid (118.3% vs 95.4%) and iron (151.4% vs 136.3%)). These changes could more than likely be attributed to the much higher percentage of children who consumed maize porridge (88.9% vs 66.8%) and in larger quantities (437.3 g vs 263.6 g) when compared with urban children (Figure 3). Urban children, by contrast, had a higher mean intake of white bread when compared with rural children (35.3 g vs 17.1 g), which was also consumed in much smaller quantities.

Table IV: Mean micronutrient intakes of South African children with fortified maize and bread substituted for the equivalent previously unfortified products by area of residence

	Urban unfortified	Urban fortified	Rural unfortified	Rural fortified	All unfortified	All fortified
Nutrients	N = 1218		N = 982		N = 2200	
Dietary Intake						
Vitamin A (RE)	520.7	614.6	286.1	415.7	416.0	525.8
Thiamine (mg)	0.68	0.83	0.70	0.90	0.69	0.86
Riboflavin (mg)	0.91	1.03	0.56	0.71	0.75	0.89
Niacin (mg)	8.21	10.74	5.86	9.49	7.16	10.18
Vitamin B_6 (mg)	0.69	0.92	0.50	0.86	0.60	0.90
Folate (µg)	141.4	196.0	121.5	242.2	132.5	216.6
Iron (mg)	6.09	9.03	5.93	10.10	6.02	9.50
Zinc (mg)	5.40	6.41	4.60	6.07	5.04	6.26
NAR (%; 100% is the recommended)[a]						
Vitamin A	117.2	138.1	64.5	93.5***	93.7	118.2
Thiamine	110.3	134.1	112.9	145.0**	111.5	139.0
Riboflavin	148.3	167.1	91.1	115.8***	122.8	144.2
Niacin	102.5	133.6	72.9	118.5***	89.3	126.9
Vitamin B_6	108.8	145.3	78.9	135.8**	95.5	141.1
Folate	68.4	95.4	58.4	118.3***	63.9	105.6
Iron	92.3	136.3	88.8	151.4***	90.8	143.1
Zinc	111.0	131.5	94.6	124.9*	103.7	128.6
MAR (%; 100% is the recommended)[b]						
Percentage	**67.7**	**75.7**	**57.9**	**70.3*** **	**63.3**	**73.3**

*p<0.05 independent t-test, difference between urban and rural after fortification
**p<0.01 independent t-test, difference between urban and rural after fortification
***p<0.0001 independent t-test, difference between urban and rural after fortification
[a] NAR = Nutrient Adequacy Ratio: The intake/RNI x 100%
[b] MAR = Mean Adequacy Ratio (sum of RNIs/nr of nutrients)

Figure 1: Mean nutrient adequacy ratios of children in urban areas of South Africa before (UF) and after food fortification (F) of staple foods according to the South African government regulations[22]



The mean MAR (%) for the children's overall diets remained below 100% of the recommendation, irrespective of the fortification status of the food products (Figure 4), since there were still additional nutrients that remained inadequate in the diet because they had not been included in the legislated fortification mix (calcium, vitamin C, D and E) but were found to be deficient in the NFCS survey.[6] The MAR of the children's diets, however, with respect to micronutrient intake, increased by about 10% overall in both urban and rural areas (Figure 4).

Figure 2: Mean nutrient adequacy ratios of children in rural areas of South Africa before (UF) and after food fortification (F) of staple foods according to the South African government regulations[22]

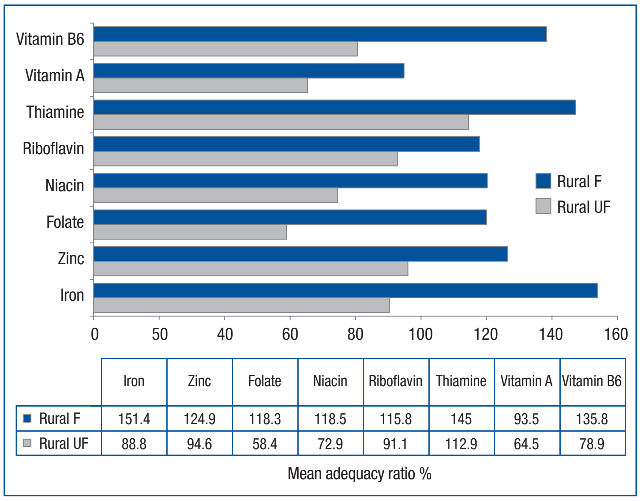


Figure 3: Average consumption (g per child per day) of fortified maize porridge and bread made from wheat flour among South African children by area of residence

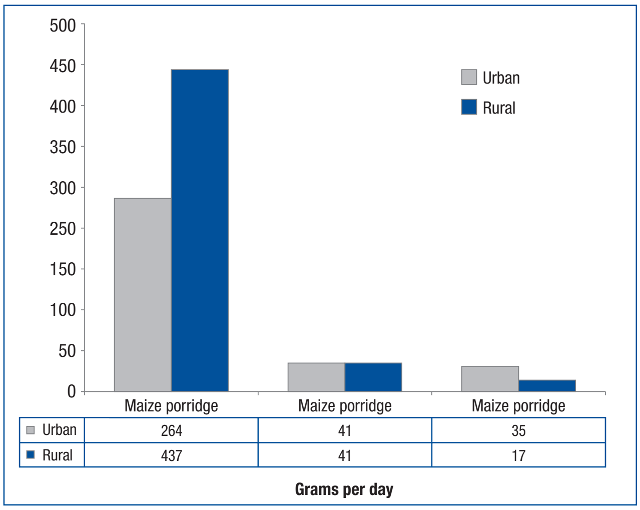
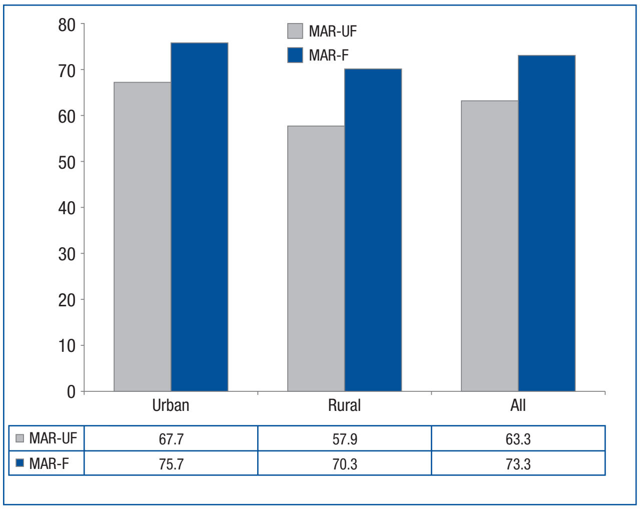


Figure 4: Mean Adequacy Ratios (MAR %) for micronutrient intake of the diet of urban and rural children with fortified and unfortified maize and wheat products UF = unfortified; F = Fortified



Discussion

The findings of this study indicate that, at the usual dietary intake, the NAR and MAR levels of the current fortification strategy mandated by the Department of Health do make a significant difference to the quality of the diet of all children but particularly to that of children living in rural areas. This of course is of great importance since the most vulnerable group of children who consume diets of the poorest nutrient density have been reported to live in rural areas.[6] Such children have also been documented to have the highest mean prevalence of stunting (26.5% in rural vs 16.7% in urban areas), the most common nutritional disorder in the country.[6]

Evidence from other countries that have successfully implemented national fortification programmes indicates that certain important requirements need to be satisfied in order to ensure long-term sustainability of such programmes.[30-33] Perhaps the most important of these requirements in the South African context is access to and affordability of the fortified foods, a consideration that should be high on the priority list of the overall micronutrient strategy of the Department of Health. Furthermore, the success of such programmes also depends on the need of continued dialogue between the various sectors that have to collaborate closely on issues relating to the production, promotion, distribution and consumption of fortified foods. Food fortification also needs to be supported by adequate monitoring and evaluation, food regulations, labelling and quality assurance.

In South Africa the process of mandatory fortification has been efficiently and effectively managed and most of the mentioned factors have been closely adhered to. A special task team comprising Department of Health officials, NGOs, academics and representatives of the largest maize and wheat flour (bread) producers planned the development and implementation procedures, also based on the outcomes of the NFCS.[34] The food industry role-players were closely involved and carried most of the costs related to the introduction of the staple foods fortification, such as the buying of specialised equipment and the purchasing and testing of fortificants. These procedures allowed for a smooth and effective introduction of the mandatory process. Furthermore, procedures were introduced for the effective monitoring of the fortification process at manufacturing and consumer levels.[34]

In conclusion and based on the results of this secondary analysis of the NFCS dietary data together with the data on the chemical analyses of foods used in this study, as provided by the industry, it would appear that fortification of the two most commonly eaten staple foods is likely to significantly improve the micronutrient intake of children under nine years of age. It is, therefore, recommended that fortification should be utilised to its full potential to improve children's dietary intake at population level and to ensure access to and affordability of the fortified staples so that they are consumed by all children in the country. Of course the time required for these beneficial changes in dietary micronutrient intake, brought about by the legislation on the fortification of food staples, to be reflected in an improvement of the blood concentrations of such micronutrients at the population level, remains to be determined.

References

1. Langenhoven ML, Steyn K, Van Eck M, Gouws E. Nutrient intake in the coloured population of the Cape Peninsula. Ecology of Food and Nutrition 1988;22:97–106.
2. Steyn NP, Pettifor JM, Van der Westhuizen J, Van Niekerk L. Nutritional status of schoolchildren in the Richtersveld. South African Journal of Food Science and Nutrition 1990;2(3):52–6.
3. Badenhorst CJ, Steyn NP, Jooste PL, Nel JH, Kruger M, Oelofse A, Barnard C. Nutritional status of Pedi schoolchildren aged 6–14 years in two rural areas of Lebowa: A comprehensive nutritional survey of dietary intake, anthropometric, biochemical, hematological and clinical measurements. |South African Journal of Food Science and Nutrition 1993;5(4):112–9.
4. Bourne LT, Langenhoven ML, Steyn K, Jooste PL, Laubscher JA, Bourne DE. Nutritional status of 3–6-year-old African children in the Cape Peninsula. East African Medical Journal 1994;71:695–702.
5. Dannhauser A, Joubert G, Nel M. Nutritional status of preschool children in the Bloemfontein district. South African Journal of Food Science and Nutrition 1996;8(1):14–22.
6. Labadarios D, Steyn NP, Maunder E, MacIntire U, Swart R, Gericke G, Huskisson J, Dannhauser A, Vorster HH, Nesamvuni EA. The National Food Consumption Survey (NFCS): Children aged 1–9 years, South Africa, 1999. Pretoria: Department of Health; 2000.
7. Tichelaar HY, Steyn NP, Badenhorst CJ, et al. Epidemiological evidence of impaired fatty acid status of undernourished rural primary school children in Lebowa. South African Journal of Food Science and Nutrition 1994;6(2):60–5.
8. South African Vitamin A Consultative Group (SAVACG). Children aged 6–71 months in South Africa, 1994: Their anthropometric, vitamin A, iron and immunization coverage status. Stellenbosch: Stellenbosch University; 1995.
9. Vorster HH, Oosthuizen W, Jerling JC, Frederick J, Veldman J, Burger HM. The nutritional status of South Africans: A review of the literature from 1975–1996. Durban: Health Systems Trust; 1997.
10. Food and Nutrition Board NAS-NRC, USA. Recommended Dietary Allowances revised. Journal of the American Dietetic Association 1989;89:1748–52.
11. Steyn NP, Maunder EM, Labadarios D, Nel JH. Foods and beverages that make a significant contribution to macro- and micronutrient intakes of children in South Africa: Do they meet the food-based dietary guidelines? South African Journal of Clinical Nutrition 2006;19(2):66–76.
12. Zimmerman MB, Biebinger R, Rohner F, Dib A, Zeder C, Hurrell RF, Chaouki N. Vitamin A supplementation in children with poor vitamin A and iron status increases erythropoietin and haemoglobin concentrations without changing total body iron. American Journal of Clinical Nutrition 2006;84(3):580–6.
13. Mannar MV. Successful food-based programmes, supplementation and fortification. Journal of Pediatric Gastroenterology Nutrition 2006;43 (Suppl 3):S47–53.
14. Tontisirin K , Nantel G, Bhattacharjee L. Food-based strategies to meet the challenges of micronutrient malnutrition in the developing world. Proceedings of the Nutrition Society 2002;61(2):243–50.
15. Simeon DT. School feeding in Jamaica: A review of its evaluation. American Journal of Clinical Nutrition 1998;67(4):790S–794S.
16. Van Stuijvenberg ME. Using the school feeding system as a vehicle for micronutrient fortification: Experience from South Africa. Food and Nutrition Bulletin 2005;26(2 Suppl 2): S213–9.
17. Latham MC, Ash D, Ndossi G, Mehansho H, Tatala S. Micronutrient dietary supplements: A new fourth approach. Archives of Latinoamerican Nutrition 2001;51(1 Suppl 1):37–41.
18. Nutrition Service of the World Food Program. Micronutrient fortification: WFP experiences and ways forward. Food and Nutrition Bulletin 2006;27(1):67–75.
19. Faber M, Kvalsvig JD, Lombard CJ, Benade AJ. Effect of a fortified maize-meal porridge on anaemia, micronutrient status, and motor development of infants. American Journal of Clinical Nutrition 2005;82(5):1032–9.
20. Steyn NP, Labadarios D. Review of nutrition policy implementation. In: South African Health Review 2002: Durban: Health System Trust, 2003; Internet: http://www.hst.org.za
21. Labadarios D, Steyn NP, Ngijma C, Daldla N. Review of the South African nutrition policy 1994–2002 and targets for 2007: Achievements and challenges. Nutrition 2005;21:100–8.
22. Government Notice: Department of Health. Foodstuffs, Cosmetics and Disinfectants Act, No. R 2003. (Act No. 54 of 1972). Regulations relating to the fortification of certain foodstuffs. Pretoria: Department of Health; 2003.
23. Steyn NP, Labadarios D, Nel J, Lombard C, Maunder E. Secondary anthropometric data analyses of the National Food Consumption Survey in South Africa: The double burden. Nutrition 2005;21:4–13.
24. Blanton CA, Moshfegh AJ, Baer DJ, Kretsch MJ. The USDA automated multiple-pass method accurately estimates group total energy and nutrient intake. Journal of Nutrition 2006;136(10):2594–9.
25. Fox MK, Reidy K, Novak T, Ziegler P. Sources of energy and nutrients in the diets of infants and toddlers. Journal of the American Dietetic Association 2006;106(1 Suppl 1):S28–42.
26. Mackerras D, Rutishauser I. 24-hour national dietary survey data: How do we interpret them most effectively? Public Health Nutrition 2005;8(6):657–65.
27. FAO/WHO. Human Vitamin and Mineral Requirements. Report of a joint FAO/WHO expert consultation. Rome; 2002.
28. Wolmarans, P, Danster N, Chetty J. Energy and nutrient composition of South African maize meal. Technical report. Tygerberg: Nutritional Intervention Research Unit, South African Medical Research Council; 2005.
29. Vorster N. SASKO unpublished data on bread analyses. Paarl; 2003.
30. Mannar MG, Sankar R. Micronutrient fortification of foods: Rationale, application and impact. Indian Journal of Pediatrics 2004;71(11):997–1002.
31. Darnton-Hill I, Nalubola R. Fortification strategies to meet micronutrient needs: Successes and failures. Proceedings of the Nutrition Society 2002;61(2):231–41.
32. Mannar MG, Van Ameringen M. Role of public-private partnership in micronutrient food fortification. Food and Nutrition Bulletin 2003;24 (4 Suppl):S151–4.
33. Fletcher RJ, Bell IP, Lambert JP. Public health aspects of food fortification: A question of balance. Proceedings of the Nutrition Society 2004;63(4):605–14.
34. Labadarios D, Steyn NP, Maunder E, MacIntyre U, Gericke G, Swart R, Huskisson J, Dannhauser A, Vorster HH, Nesamvuni AE, Nel JH. The National Food Consumption Survey (NFCS): South Africa, 1999. Public Health Nutrition 2005;8(5):533–43.