Public Health Nutrition: 8(5), 461–467 DOI: 10.1079/PHN2005782

Fortification of maize meal improved the nutritional status of 1–3-year-old African children

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Submitted 5 May 2005: Accepted 12 May 2005

Abstract

Objective: To evaluate the effectiveness of a vitamin-fortified maize meal to improve the nutritional status of 1–3-year-old malnourished African children.
Design: A randomised parallel intervention study was used in which 21 experimental children and their families received maize meal fortified with vitamin A, thiamine, riboflavin and pyridoxine, while 23 control children and their families received unfortified maize meal. The maize meal was provided for 12 months to replace the maize meal habitually consumed by these households.
Methods: Sixty undernourished African children with height-for-age or weight-for-age below the 5th percentile of the National Center for Health Statistics' criteria and aged 1–3 years were randomly assigned to an experimental or control group. Baseline measurements included demographic, socio-economic and dietary data, as well as height, weight, haemoglobin, haematocrit, serum retinol and retinol-binding protein (RBP). Anthropometric, blood and serum variables were measured again after 12 months of intervention. Complete baseline measurements were available for 44 children and end data for only 36. Changes in these variables from baseline to end within and between groups were assessed for significance with paired *t*-tests, *t*-tests and analysis of variances using the SPSS program, controlling for expected weight gain in this age group over 12 months. Relationships between changes in variables were examined by calculating correlation coefficients.
Results: The children in the experimental group had a significantly ($P \leq 0.05$) higher increase in body weight than control children (4.6 kg vs. 2.0 kg) and both groups had significant ($P \leq 0.05$) but similar increases in height. The children in the experimental group showed non-significant increases in haemoglobin and serum retinol, while the control children had a significant ($P = 0.007$) decrease in RBP. The change in serum retinol showed a significant correlation with baseline retinol ($P = 0.014$), RBP ($P = 0.007$) and weight ($P = 0.029$), as well as with changes in haemoglobin ($P = 0.029$).
Conclusion: Despite a small sample size, this study showed positive effects of a vitamin-fortified maize meal on weight gain and some variables of vitamin A status in 1–3-year-old African children. The study confirmed the relationship between vitamin A and iron status. The results suggest that fortification of maize meal would be an effective strategy to address micronutrient deficiencies in small children in South Africa.

Keywords
Fortification
Undernutrition
Anthropometry
Maize meal
Vitamin A
Haemoglobin
South Africa
Children

Undernutrition and micronutrient deficiencies and their serious adverse effects on child development remain a problem in developing countries[1]. In South Africa, two national studies[2,3] indicated unacceptably high levels of chronic malnutrition (stunting) and several vitamin and mineral deficiencies. In a national study on pre-school children in which biochemical variables were measured, conducted by the South African Vitamin A Consultative Group (SAVACG)[2], anthropometric, vitamin A and iron status of children aged 6 to 71 months were assessed. Thirty-three per cent of the children were found to have marginal vitamin A deficiency and 21.1% were found to be anaemic. Iron deficiency was found in 12.1% of urban children compared with 8.3% of rural children. Stunting was found in 22.9% of children, with the highest prevalence amongst those residing in rural and informal

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housing areas. Based on these findings, it can be estimated that 1 520 000 pre-school children in South Africa are undernourished due to chronic undernutrition[2].

Recently, similar results to those of the SAVACG study were found by the National Food Consumption Survey (2000)[3]. The results of the survey indicated that 22% of South African children aged 1–9 years were stunted; 9% were underweight; and 3% were wasted[3]. This motivated the South African Department of Health to implement mandatory fortification programmes, which started with the iodisation of salt, followed by extensive micronutrient fortification of the staples: maize meal and bread flour. The decision to choose fortification, the choice of staple food vehicles, the type of micronutrients and levels of fortification were based on a scientific process in which all relevant factors were considered (M de Hoop, personal communication, South African Department of Health Fortification Programme). However, the effect of fortified maize meal on the nutritional status of undernourished children is not known.

In the present paper, we report the effect on nutritional status of a vitamin-fortified maize meal consumed for 12 months by undernourished children aged 1–3 years.

Methods

Setting

The participating households or families all resided in Oukasie, Brits, in the North West Province. Oukasie was established in 1928 and comprises formal and informal houses. It is fully served by the Brits City Council in terms of water, sewerage and emergency services. It has one clinic, one formal crèche, two primary schools and one secondary school. The Oukasie Development Trust plays a central role in organising community activities in Oukasie, and assisted in the logistic arrangements of this study.

Study design

The study design was a randomised, parallel, single-blind intervention (families were blinded) of 12 months duration. Sixty undernourished 1–3-year-old children and their households were randomly allocated to either an experimental or control group. The households (families) in the experimental group received a vitamin-fortified maize meal and those in the control group unfortified maize meal. Between 25 and 50 kg (depending on usual monthly consumption) of maize meal flour was provided to the families per month to replace all maize meal consumed by these households. This was based on an estimation of a daily consumption of at least 150 g raw meal by the 1–3-year-old children and a minimum of 200 g raw meal by individuals aged 15 years and older[4]. Demographics, socio-economic data and child-care practices of the households, as well as dietary intakes of the participating children, were measured at baseline.

The nutritional status of these children (weight, height, haemoglobin, haematocrit, serum retinol and serum retinol-binding protein (RBP)) was assessed at baseline and at the end of the 12-month intervention.

Fortification and distribution of the maize meal

A premix for fortification of the maize meal was prepared and donated by the Vitamin Division of Roche Products (Pty) Ltd (Isando, South Africa) and sent to a milling company (Maizecor, South Africa) to be added to the maize meal, using a volumetric feeder, at the end of the milling process. To each 150 g of raw maize meal, 1700 IU vitamin A, 0.61 mg thiamine, 0.62 mg riboflavin and 0.56 mg pyridoxine were added. Samples of the fortified maize meal were tested and verified for these fortificants by Roche Products (Pty) Ltd.

The maize meal had an estimated shelf-life of approximately 4 months and was delivered in three batches for temporary storage at the Oukasie Community Hall. The meal was packed in 25 kg bags, and was differentiated by the colour of the thread used to close the bags (white for unfortified and yellow for fortified). Fieldworkers monitored if the households were using the maize meal issued for the study through surprise house visits. The fieldworkers had to collect the maize meal from the community hall, accompanied by the head of the household or a representative, and were also required to return the old bag used the previous month.

The effect of cooking the maize meal on the stability of added vitamin A was tested in the Roche laboratories in Isando. Two preparation methods usually used by the mothers in the community were used. In the first, 1500 ml water with 2 g salt was brought to the boil. Then 500 g maize meal was added gradually and whisked to prevent formation of lumps. The porridge was left to simmer for 30 min with occasional stirring. In the second method 336 g maize meal was added to 750 ml water with 1 g salt in a pot and brought to the boil while stirring. The lid of the pot was put on and the porridge left to steam-cook for another 30 min. In the first method, 71% of the added vitamin A was retained, and in the second, only 55%.

Sample selection

Using the crèche and clinic as entry points into the community, all 1–3-year-old children at the crèches and the well-baby clinic were screened and the first 60 undernourished children who had weight-for-age or height-for-age below the 5th percentile of the National Center for Health Statistics (NCHS) reference[5] identified. The parents/guardians of these children were contacted and recruited to voluntarily participate in the study. The 100 children previously participating in a similar feeding trial, as well as those with any physical or mental disability (not on disability grant), those with severe forms of undernutrition (marasmus and kwashiorkor), those participating in the Protein–Energy Malnutrition programme and children of mothers who recently relocated to the area, were excluded. The 60 identified households/families were randomly assigned to an experimental or control group.

However, full baseline data were available for only 44 children (21 in the experimental and 23 in the control group) and end data after 12 months for only 36 children (16 in the experimental and 20 in the control group). The unavailability of full data was due to the difficulty of obtaining adequate blood from small children. It meant that children from whom adequate blood could not be drawn were dropped. This resulted in the high drop-out rate and the lower numbers affected the power of the study.

Experimental methods

Demographics, socio-economic, hygiene and child-care practice data were collected using standardised and validated questionnaires by trained fieldworkers during face-to-face interviews with the mother or other caregiver of each participating child, under the leadership of a Masters student (Ms P Tladinyane).

Anthropometric measurements (weight and height) were performed using a calibrated electronic balance and a stadiometer, to the nearest 0.1 kg and 0.1 cm, respectively. The children wore only underwear and the mean of two measurements taken was calculated. For children younger than 2 years, recumbent length was measured.

Blood samples were collected from participating children by a registered nurse, from the anterior cubital vein, using sterile disposable syringes and a 23-gauge butterfly system. For measurements in the field laboratory of haematocrit (capillary centrifuge method) and haemoglobin (cyanomethaemoglobin calorimetric method), blood was drawn into tubes containing ethylenediaminetetraacetic acid. Serum samples were prepared and immediately frozen in the field. These samples were transferred to Potchefstroom and stored at -84°C until batch analysis for retinol and RBP at the end of the study. Serum retinol was determined by a high-performance liquid chromatography method and serum RBP with the modified relative dose–response method in the Department of Chemical Pathology, University of Pretoria.

Compliance

It was not possible under these free-living conditions to measure exact intakes of maize porridge by these children. However, the families/households were closely monitored by paid fieldworkers to ensure sufficient supplies and regular consumption of maize meal. These fieldworkers were selected from the community through a democratic process and trained to monitor their allocated households, as well as to implement the questionnaires. Fieldworkers who participated in other studies in the North West Province (THUSA, THUSABANA and the National Food Consumption Survey) assisted in the training. The fieldworkers of the present study were paid R90.00 per day.

Ethical considerations

The parent or guardian of each participating child signed an informed consent form. Participation was voluntary and participants were allowed to withdraw from the study at any time. The Ethics Committee of the Potchefstroom University for Christian Higher Education approved the study (ethics no. VGE 7M 8/98) and the community leaders, via the Oukasie Development Trust, gave permission for the study.

Statistical analyses

All data were electronically captured and cleaned. Changes in nutritional status variables within and between groups were compared using paired *t*-tests, analysis of variance and independent *t*-tests with the SPSS program (SPSS Inc., Chicago, IL, USA). The significance of changes in both groups was compared controlling for the expected weight increases in children of this age over a 12-month period (an estimated 2.4 kg)[5]. The relationships between these changes as well as the influence of baseline variables on these changes were assessed with Spearman rank correlations, controlling for the appropriate variables.

Results

The demographic, socio-economic, child-care practices and dietary intake data have been reported by Tladinyane[6] and are not shown herein. Briefly, the children were from a poor socio-economic background with 63% from female-headed households. All children regularly consumed maize porridge, either as soft porridge with milk or stiff porridge with a relish, two to four times a day. The 12–18-month-old children were occasionally breast-fed.

The data in Tables 1, 2 and 3 are given for all children available for measurements at baseline and end, as well as separately for children available at both periods. Statistical analyses were performed on the latter.

Table 1 shows that, for those children for whom both baseline and end data were available, the experimental group gained 4.6 kg in weight compared with 2.0 kg in the control group. Both these increases were significant. However, it can be expected that children of this age will gain approximately 2.4 kg over 12 months. The additional 2.2 kg gained by the experimental group was statistically significant. Table 1 further shows that both groups showed a significant, but similar gain in height.

Table 2 indicates that the small increases in mean haemoglobin values of the experimental group and the decreases in the control group were not significant. However, the decreases in haematocrit of both groups were significant, with the control group having a significantly greater change.

Table 1 Changes in anthropometry during the intervention

	Experimental group		Control group	
Variable	Baseline	End	Baseline	End
All participating children	$n = 21$	$n = 16$	$n = 23$	$n = 20$
Weight (kg)				
Mean	9.9	14.9	10.5	13.8
SD	1.9	2.4	2.7	2.4
95% CI	9.0–10.7	13.7–16.3	9.3–11.7	12.7–14.9
Height (cm)				
Mean	76.2	87.9	76.1	90.0
SD	6.0	5.0	8.6	8.5
95% CI	73.4–78.9	85.2–90.6	72.4–79.8	86.0–94.0
Children participating at both baseline and end	$n = 16$	$n = 16$	$n = 20$	$n = 20$
Weight (kg)				
Mean	9.9*‡	14.5*‡	11.9†	13.9†
SD	2.1	2.5	2.9	2.6
95% CI	8.6–11.3	12.9–16.1	9.6–14.2	11.9–15.9
Height (cm)	$n = 16$	$n = 16$	$n = 16$	$n = 16$
Mean	76.2*	87.1*	77.7†	88.5†
SD	7.2	5.5	7.5	4.4
95% CI	71.5–80.7	83.6–90.6	72.0–83.5	85.2–91.9

SD – standard deviation; CI – confidence interval.
*,† Means are significantly different within groups (paired *t*-test): $P \leq 0.005$.
‡ After correcting for expected weight increase of 2.4 kg, the change was significantly different in the experimental compared with the control group: $P \leq 0.05$.

Table 3 shows that the experimental group had an increase of 0.11 μmol l^{-1} in serum retinol levels while the control group had an increase of 0.03 μmol l^{-1} (when children who had both baseline and end data are compared). None of these increases within groups as well as the changes between groups were significant. Table 3 also shows that the serum RBP decrease in the control group was significant within the group. The change in serum RBP of the control group was also significant when compared with the slight decrease in the experimental group.

Table 4 depicts the percentage of children from each group who were in the different categories of vitamin A status, based on serum retinol levels. During the

Table 2 Changes in haematology during the intervention

	Experimental group		Control group	
Variable	Baseline	End	Baseline	End
All participating children	$n = 21$	$n = 16$	$n = 23$	$n = 20$
Haemoglobin (g dl^{-1})				
Mean	11.2	11.4	11.1	10.8
SD	1.5	2.2	1.4	2.4
95% CI	10.6–11.8	10.2–12.7	10.5–11.7	9.7–11.9
Haematocrit (%)				
Mean	39.9	37.1	42.2	35.6
SD	5.8	2.6	5.2	4.0
95% CI	37.5–42.4	35.7–38.5	39.7–44.8	33.7–37.6
Children participating at both baseline and end	$n = 16$	$n = 16$	$n = 20$	$n = 20$
Haemoglobin (g dl^{-1})				
Mean	11.2	11.4	10.7	10.5
SD	1.2	2.2	1.7	2.4
95% CI	10.4–11.9	10.2–12.7	9.4–12.1	9.3–11.8
Haematocrit (%)				
Mean	40.1*	37.5*	43.6†‡	34.7†‡
SD	6.4	2.8	5.0	2.8
95% CI	36.0–44.1	35.8–39.3	39.7–47.4	32.5–36.8

SD – standard deviation; CI – confidence interval.
* Means are significantly different (paired *t*-test): $P = 0.05$.
† Means are significantly different (paired *t*-test): $P = 0.001$.
‡ The change in haematocrit of the control group was significantly greater than in experimental group (analysis of variance): $P = 0.059$.

Table 3 Changes in vitamin A status during the intervention

Variable	Experimental group		Control group	
	Baseline	End	Baseline	End
All participating children	$n = 21$	$n = 16$	$n = 23$	$n = 20$
Serum retinal (μmol l^{-1})				
Mean	1.19	1.30	1.26	1.35
SD	0.44	0.35	0.37	0.49
95% CI	1.01–1.38	1.11–1.49	1.11–1.42	1.09–1.61
Serum RBP (mg dl^{-1})				
Mean	1.73	1.72	2.08	1.51
SD	0.57	0.56	0.94	0.41
95% CI	1.47–1.98	1.44–2.01	1.68–2.48	1.29–1.72
Children participating at both baseline and end	$n = 16$	$n = 16$	$n = 20$	$n = 20$
Serum retinal (μmol l^{-1})				
Mean	1.19	1.30	1.28	1.31
SD	0.48	0.35	0.38	0.47
95% CI	0.85–1.36	1.11–1.49	1.09–1.45	1.03–1.84
Serum RBP (mg dl^{-1})				
Mean	1.73	1.71	2.26†‡	1.47†‡
SD	0.57	0.67	1.13	0.42
95% CI	1.36–2.09	1.27–2.13	1.39–3.13	1.14–1.80

SD – standard deviation; CI – confidence interval; RPB – retinol-binding protein.
† Means are significant different (paired *t*-test): $P = 0.007$.
‡ The change in RBP of the control group was significantly different from that in the experimental group (analysis of variance): $P = 0.032$.

intervention more children in the experimental group moved from the adequate to normal category, while the percentages in the control group decreased in the normal and increased in the adequate categories.

Table 5 shows that the changes in serum retinol were significantly influenced by baseline values of weight, retinol and RBP, while Table 6 indicates that these changes in serum retinol had significant negative correlations with retinol at baseline and weight changes. The change in retinol also showed a significant positive correlation with the change in haemoglobin. Table 5 further indicates that the changes in RBP had significant negative correlations with retinol at baseline and change in height.

Discussion

The design of the study allowed examination of the effects of the fortification of maize meal with four vitamins on the growth and nutritional status of 1–3-year-old children. Both groups showed the expected increases in weight and height over the 12 months[5]. The additional 2.2 kg gained by children in the experimental group suggests that the vitamin fortification could have been responsible. It was, however, a shortcoming in this study that body composition was not measured. It would have provided important data on whether the additional weight gain was adipose tissue only or lean body mass.

Table 4 Percentage of children in vitamin A status categories at baseline and end of intervention

Vitamin A status category*	Experimental group		Control group	
	Baseline	End	Baseline	End
Marginal deficient (0.35–0.7 μmol l^{-1})	7	7	0	0
Adequate (0.7–1.05 μmol l^{-1})	60	33	29	47
Normal ($>$1.05 μmol l^{-1})	33	60	71	53

* Based on serum retinol values as indicated.

These children were undernourished at baseline. According to the mean weight values and if the mean age increased from 2 to 3 years, the experimental children moved from under the 5th NCHS[5] percentile to the 50th percentile. There is some controversy in the literature on the effects of fortification on growth. Oelofse[7] and Fawzi *et al.*[8] found no effects of additional micronutrients on growth, while West *et al.*[9] could demonstrate a significant effect in children who were severely vitamin A-deficient. The observations in this study were that baseline weight, serum retinol and RPB significantly inversely influenced changes in serum retinol. It was also observed that there was a significant negative correlation between change in height and RBP change. These two observations suggest that those children who were more undernourished with a lower nutritional status had better responses to the intervention than those with 'better' nutritional status. It is therefore prudent to conclude that fortification of maize meal could influence the growth of 1–3-year-old children, especially when they are undernourished.

The effects of the intervention on haemoglobin were small and non-significant. The decreases seen in haematocrit are difficult to interpret, because little is known about the effects of micronutrients on haematocrit levels. The significant decreases observed in both groups suggest that it could have been a time effect. Haematocrit

Table 5 Relationship between changes in blood and serum variables and the influence of baseline variables on the change in variables from baseline to end

	Dependent variable: change in serum retinal				
Source	Type III sum squares	Degrees of freedom	Mean square	*F*-value	*P*-value
Corrected model	2.963*	6	0.494	4.881	0.004
Intercept	0.016	1	0.016	0.159	0.695
Weight baseline	1.353	1	1.353	13.372	0.002
Serum RBP baseline	0.924	1	0.924	9.129	0.007
Serum retinol baseline	1.924	1	1.347	13.312	0.002
Gender	0.075	1	0.075	0.745	0.399
Haematocrit	0.114	1	0.114	1.127	0.302
Group	0.357	1	0.357	3.532	0.076
Error	1.922	19	0.101		
Total	5.185	26			
Corrected total	4.886	25			

RBP – retinol-binding protein.
* $R^2 = 0.607$; adjusted $R^2 = 0.482$.

levels of newborns are high and decrease slowly with time[10]. However, the significant correlation found between changes in serum retinol and changes in haemoglobin ($r = +0.399$, $P = 0.029$; Table 6) suggests that the vitamin fortification of maize meal may also influence iron metabolism and status. There is currently great interest in the interaction of vitamin A with iron metabolism[11] and our results support existing data on this interaction.

The small changes in serum retinol and RBP were disappointing. However, it seems that the fortified maize meal did improve vitamin A status, because 27% of the children in the experimental group moved to the normal category while 18% of the children in the control group deteriorated from normal to adequate categories after the intervention. This decline in the control children's vitamin A status is confirmed by the statistically significant decrease in RBP of these children. It seems that the fortified maize prevented this decline because no change in the experimental group was observed. The reason for the decline in vitamin A status could be diet-related: in this young age group from a poor environment, introduction of more foods low in vitamin A while decreasing breast-feeding could have been responsible. It could also be related to infection with increased vitamin A requirements[12], and the fortified maize meal may have prevented an increase in infectious episodes, a known effect of vitamin A[13]. However, infection frequency was not measured in this study and a conclusion about the reasons for the decline in vitamin A status in the control children is not possible.

Table 6 Relationships between changes in selected variables (Spearman rank correlations)

	RBP change	Retinol change
Haemoglobin change		+0.399 (*P* = 0.029)
Retinol baseline	−0.441 (*P* = 0.009)	−0.430 (*P* = 0.014)
Change in height	−0.452 (*P* = 0.020)	+0.45 (*P* = 0.823)
Change in weight	−0.171 (*P* = 0.403)	−0.420 (*P* = 0.029)

RBP – retinol-binding protein.

Conclusions

This study showed that daily consumption of a maize meal fortified with vitamin A, thiamine, riboflavin and pyridoxine by undernourished 1–3-year-old African children significantly influenced their weight gain over 12 months and improved their vitamin A status by preventing the decline in serum RBP levels observed in control children over the same time. The study further confirmed the interaction between vitamin A and iron status previously reported by other authors. It is concluded that maize meal is a suitable vehicle for fortification with the aim of improving the growth and micronutrient status of undernourished children.

Acknowledgements

Our co-workers, Sr C Lessing, Dr TA Nell and Ms C Spies, are acknowledged for helping with blood collection and the preparation of serum samples. The study was funded by grants from the National Research Foundation, Potchefstroom University for Christian Higher Education, Hoffman La Roche (Switzerland), Roche Vitamin and Fine Chemicals and a gift of maize from Maizecor.

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