Spirulina Effectiveness Study on Child Malnutrition in Zambia

Kazuya Masuda, Yuta Inoue, Ryo Inoue, Akiko Nakamura, Maureen Chitundu, Junko Murakami, Yumiko Ota and Junichiro Matsugami

Abstract Ensuring adequate nutrition among vulnerable children has been a serious challenge in Zambia. Chronic child malnutrition is more predominant at 45 per cent while underweight and wasting are at 15 and 5 per cent respectively. This study tested the effectiveness of spirulina on malnourished children in Zambia. The study took place from June 2012 to February 2013. Sixty children were divided into spirulina treatment and control groups. The outcome of taking spirulina was analysed by collecting anthropometric data. The fixed-effect regression result showed that 10g of spirulina dairy intake leads to improvement by producing 0.29 higher points in the height-for-age z-score (HAZ); confidence interval (CI)[0.0404, 0.535]. On the contrary, the weight-for-age z-score (WAZ) and the mid-upper arm circumference z-score (MUACZ) did not show a significant difference, although treated children showed a larger improvement by 0.09 points and 0.38 points, respectively. This study implied the validity of spirulina in reducing chronic malnutrition.

1 Introduction

Sub-Saharan Africa has one of the most serious rates of chronic malnutrition in the world. In Zambia, the setting for the current study, chronic malnutrition or stunting affects 45 per cent of children under five. This remains the most common nutritional disorder, being slightly above the sub-Saharan Africa average of 42 per cent (CSO 2009) and the eighth highest rate in the world (UNICEF 2013). In addition, micronutrient deficiencies are having an enormous impact on children's health. Around 50–55 per cent of children in Zambia suffer from vitamin A deficiency and iron deficiency (CSO 2009). On the contrary, indicators of acute malnutrition remain comparatively low. Five per cent of Zambian children are wasted while 15 per cent are underweight.

The Zambian nutrition profile shows that 60 per cent of households cannot afford three meals per day (FAO 2009), which leads to inadequate nutrient intake and malnutrition. The same research shows that in the 2000–02 period, the dietary energy supply was only 1,905kcal per capita/day (*ibid.*). This indicates that households' actual calorie intake is lower than the estimated necessary requirement of 2,056kcal per capita/day. Carbohydrates such as cereals and starchy roots are the main source of energy which account for 80 per cent of the total energy intake (*ibid.*). This suggests that the intake of other essential nutrients as well as protein and lipids is generally insufficient.

Health promotions targeting knowledge enhancement about maternal and child nutrition and direct nutrient supplementation are often utilised as nutrition intervention programmes in developing countries. In 2008, *The Lancet* published a series of papers on maternal and child undernutrition in which the need to focus on the crucial period from conception to a child's second birthday was identified. In those articles, various intervention programmes were evaluated based on their cost-effectiveness and Bhutta *et al.* (2008, 2013) reported that breastfeeding promotion and support have the largest effect on child malnutrition, followed by vitamin A supplementation, zinc supplementation and balanced energy protein supplementation.

Spirulina is a blue-green micro-algae indigenous to Africa. It has been suggested that it has the ability to modulate immune function and can be used to treat several diseases (Karkos *et al.* 2011). It is proposed that it can sustainably contribute to alleviating malnutrition because it is rich in various nutrients, is easy to produce, and can be added to many traditional foods (Hug and Weid 2011). Spirulina contains various nutrients such as protein, beta-carotene, iron and vitamin B, which are usually deficient in undernourished populations (Belay *et al.* 1993). Thus, the use of spirulina may be an effective intervention tool to tackle protein deficiency, vitamin A deficiency and iron deficiency, which are common public health problems in Zambia.

In nutrition literature, several in vitro and animal testing studies have provided the evidence of efficacy of spirulina on the treatment not only for lifestyle-related diseases but also infectious diseases. For example, Iwata, Inayama and Kato (1990) showed that spirulina increased lipoprotein lipase activity and alleviated the hyperlipidemia condition in rats. Rodriguez-Hernandez *et al.* (2001) and Ble-Castillo *et al.* (2002) also found that spirulina could be utilised to prevent fatty liver formation. Furthermore, it is reported that spirulina produces an anti-virus effect, such as the inhibition of HIV-1 replication and herpes simplex virus type 2 (Ayehunie *et al.* 1998; Hernandez-Corona *et al.* 2002), and an anti-oxidative effect against lead-induced toxicity (Upasani, Khera and Balaraman 2001; Upasani and Balaraman 2003). A few clinical studies also revealed

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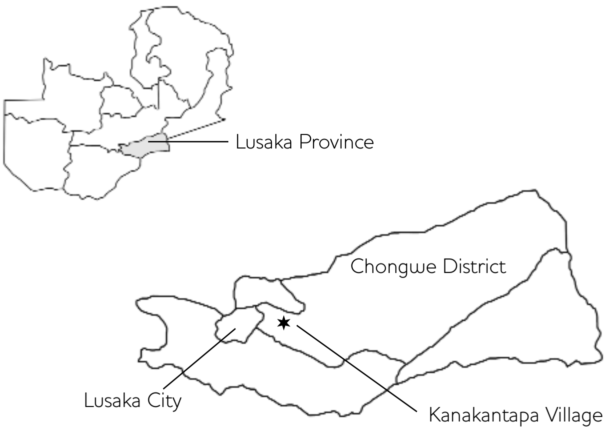
Figure 1 **Study area location**



Source Authors' own adapted from www.diva-gis.org/Data.

Table 1 **Anthropometric indicators at screening point – Kanakantapa**

Observations	**295**
HAZ (Average)	-1.33
WAZ (Average)	-0.27
MUACZ (Average)	-0.19
Stunted (under -2 HAZ)	36.5%
Underweight (under -2 WAZ)	5.1%

Source Authors' own.

spirulina's significant efficacy on lifestyle diseases patients such as reducing weight and blood cholesterol among ischaemic heat disease patients (Ramamoorthy and Premakumari 1996), decreasing serum cholesterol levels among hyperlipidemia patients due to nephrotic syndrome (Samuels *et al.* 2002), and regulating serum glucose and cholesterol levels among type 2 diabetes patients (Parikh, Mani and Iyer 2001). In addition to the effects on these diseases, the beneficial effect on serum iron levels and blood haemoglobin levels was suggested in both animal testing and clinical studies (Kapoor and Mehta 1998; Mani *et al.* 2000).

However, as yet, there are only a few studies which have examined the effectiveness of spirulina on human growth, particularly on weight gain. Azabji-Kenfack *et al.* (2011) studied its effectiveness on the nutritional status of 56 malnourished HIV-infected adult patients aged 18–35 in Cameroon by comparing changes in the nutritional status of patients in two groups; the first group received spirulina and the other groups received soya beans. In this study, they concluded that dairy intake of spirulina for 12 weeks significantly improved weight and BMI among patients who received spirulina. Yamani *et al.* (2009) also tested spirulina's effectiveness among HIV-infected patients and found that its dairy intake for six months improved the weight and arm girth of the patients. However, the results from these studies must be interpreted carefully because time trends which affect the nutritional status of patients, such as seasonality in harvested crops, failed to be taken into account. The most relevant studies to this present research are two experiments conducted by Simpore *et al.* (2005, 2006). Simpore *et al.* (2005) examined spirulina's effects among HIV sufferers aged under five in Burkina Faso. They created four groups by dividing participants into treatment and control and HIV-positive and HIV-negative groups (positive group: 84 children and negative group: 86 children). Traditional mealie meal with spirulina was provided to the treatment group, while the control group received just mealie meal. Weight gain and haemoglobin improvements were reported in the groups supplied with spirulina, particularly the HIV-negative children. Another study that investigated similar groups found that a combination of spirulina and *misola* (millet, coja, peanut) was superior to spirulina or *misola* alone for nutritional rehabilitation of severely and moderately underweight children aged 6–60 months (Simpore *et al.* 2006). However, these studies were not only conducted for a short duration (both were eight weeks), but they also did not precisely estimate the pure impact of spirulina by fully taking into account the time effect, including the impact of nutritional intake from traditional meals. A possible correlation between spirulina treatment status and other unobserved determinants of the outcomes were also not studied. Michaelsen *et al.* (2009) have recently suggested that the evidence of spirulina effectiveness is still sparse and that further research is required.

In relation to this, our study is the first research that rigorously explores the effectiveness of spirulina on the anthropometric nutritional status of malnourished children aged under three in Zambia using a panel data set. Three numeric indicators, height-for-age z-score (HAZ), weight-for-age z-score (WAZ), and mid-upper arm circumference z-score (MUACZ) were used to evaluate the effectiveness of spirulina.

2 Materials and methods

2.1 *Study area*

Kanakantapa Resettlement Scheme in Chongwe District, Lusaka Province was selected for implementing the project (see Figure 1). Kanakantapa is located approximately 60km from Lusaka City.

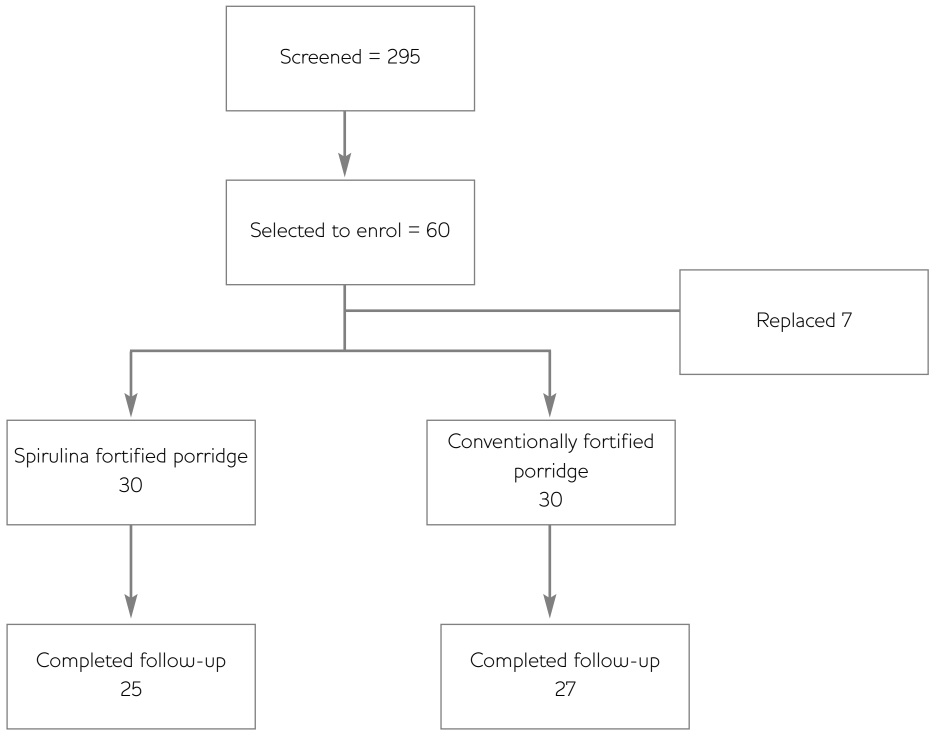
Kanakantapa was selected because neither the government nor non-governmental organisations (NGOs) were distributing food supplements there. In addition, the help of the local NGO, Programme Against Malnutrition (PAM), which has been running programmes in this area, made it easier for the community to gain confidence and to be willing to participate in the study.

Although the proportion of undernourished children in Lusaka Province is the lowest in the country, the most recent data available show that as many as 37.2 per cent of children are stunted and 15 per cent are underweight (CSO 2009). Moreover, when the children were screened in this study area in April 2012, 36.5 per cent of the sample were stunted and 5.1 per cent were underweight (see Table 1). The results of the screening undertaken in the study area correlated with the provincial averages.

2.2 *Study design*

A total of 60 malnourished children under five years old, and aged 18–36 months, were selected from a sample of 295 children who were screened at Kanakantapa Rural

Figure 2 **Flow diagram of participants through the study**



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Health Centre, Chongwe District using the weight-for-age, height-for-age and mid-upper arm circumference (MUAC) indicators.

The 60 chronically least-nourished children were evaluated on an index generated from simple summation of HAZ and WAZ scores. The division into treatment and control groups was undertaken by listing the 60 subjects in ascending order from mild to severely malnourished, which was evaluated by a simple summation of the weight-for-height z-score (WHZ) and MUACZ. Seven children dropped out of the study due to their family's refusal to participate or for other reasons. These children were replaced by other children.

Thereafter, the sample children were alternately divided into treatment and control groups from the top of the list in descending order. The two groups were further adjusted to ensure children were evenly distributed in relation to sex and geographical area. Therefore, our design is not perfectly randomised. However, as discussed in Sections 2.5 and 3.1, in addition to running the individual fixed-effect regression model, there is no significant difference in the socioeconomic characteristics of children across the two groups. Hence, possible bias caused by this adjustment can be seen as minimal.

The selected malnourished children comprised:

a Treatment group, 30 children provided with spirulina; and
b Control group, 30 children without spirulina.

2.3 *Distribution of porridge blends*

Porridge blends, a mix of 5kg of roller meal[1] with 300g of spirulina, 0.8kg sugar and 0.1kg salt, was distributed monthly to the target group. Porridge ingredients were pre-mixed with spirulina so that participants could not just eat roller meal. Spirulina was procured from the USA through our partner, DIC Corporation, the largest spirulina producer in the world. The control group was provided with the same porridge blends but without spirulina. Mothers or caregivers of each child in both the control and target groups were told to feed porridge twice a day, in the morning and afternoon.

The porridge blends were provided monthly from June 2012 to February 2013. Physical measurements of weight, height and MUAC were recorded for both groups every month by trained Child Growth Promoters (CGPs) at each health post. CGPs are community health workers who are trained by the Zambian government to evaluate child growth. Participating children whose mothers or caregivers did not attend growth-monitoring sessions were followed up by CGPs unless they had left the village due to economic factors or family issues.

In case of missing values, the child was omitted from the analysis. However, children who could not continue participating in the project for various reasons in the first two months were replaced. Thereafter, no replacement occurred. Figure 2 shows the process of sample selection.

2.4 *Data collection*

Three indicators were used to assess the nutritional status of children under five years old: height-for-age z-score (HAZ), weight-for-age z-score (WAZ) and mid-upper arm circumference z-score (MUACZ). HAZ is an indicator of chronic malnutrition, while WAZ and MUACZ are indicators of chronic and current malnutrition and acute malnutrition, respectively.

Table 2 **Balanced-check result for selected variables**

Variable	Total n=60	Spirulina treatment group (T; n=30)	Spirulina control group (C; n=30)		
	Mean (SD)	Mean (SD)	Mean (SD)	T-C [SE]	Pr(|T| > |t|)
HAZ	-2.26 (0.86)	-2.26 (0.91)	-2.25 (0.82)	-0.01 [0.22]	0.97
WAZ	-0.67 (0.8)	-0.67 (0.95)	-0.71 (0.63)	0.04 [0.21]	0.83
MUACZ	-0.10 (1.03)	-0.22 (0.96)	0.01 (1.1)	-0.22 [0.27]	0.41
Child's age (months)	27.9 (5.58)	27.4 (5.28)	28.4 (5.91)	-1 [1.45]	0.49
Mother's age (years)	29.9 (7.54)	29.9 (1.4)	29.9 (1.5)	0.04 [2.03]	0.99
Mother's weight (kg)	60 (10.03)	58 (1.4)	62 (2.3)	-3.96 [2.7]	0.15
Mother's height (cm)	158.4 (5.6)	159.2 (0.8)	157.7 (1.2)	1.53 [1.51]	0.31
Mother's educated years	5.95 (3.19)	5.6 (0.6)	6.3 (0.6)	-0.61 [0.86]	0.48
Family size	3.63 (1.97)	3.9 (0.4)	3.4 (0.3)	0.54 [0.53]	0.31

Note SD = standard deviation. SE = standard error. Pr = p-value.
Source Authors' own.

The World Health Organization (WHO) Multicentre Growth Standards (De Onis and WHO 2006) were used as a guideline for nutritional status in the study. WHO and UNICEF define stunting as children whose height-for-age z-score is below minus two standard deviations (HAZ <-2) and underweight as children whose weight-for-age z-score is below minus two standard deviations (WAZ <-2). If these indicators are minus three (-3) standard deviations and below, the child's nutritional status is said to be 'severe'.

The *Anthropo* software, designed by WHO, was utilised to calculate growth indicators using the height, weight and MUAC data. Length-for-age for children under two years old, and height-for-age for children aged two and above were measured according to WHO guidelines.

Anthropometric measurements were conducted by experienced CGPs. In addition, CGPs monitored compliance by regularly visiting participants' households.

2.5 Statistical methods

To measure the average improvement in children's nutritional indicators, the difference between February 2013 (endline) and April 2012 (baseline) was calculated, which is summarised in Table 3. Each index is standardised into z-score values. If there is no difference between the two periods, the implication is that the child grew according to the child growth curve.

Considering that division of sample children into target and control groups in this study was not perfectly randomised, it is unclear whether the average difference was purely caused by spirulina because treatment status can be correlated to other unobserved determinants of nutritional outcomes. To control such factors, fixed-effect regression analysis was conducted, by exploiting the panel nature of our data set. The following is an explanation of the model used to estimate the pure impact of spirulina on child growth followed by the results.

Our identification strategy was to compare changes in the children's nutritional status in the households which received spirulina over the study period to those that did not. To determine the impact of spirulina, we ran individual-level fixed-effect regression models of the child's nutritional status on treatment status for each household. We denoted the health outcome of a child in household i in period t as y_{it} and the household's status in terms of whether it received spirulina as s_{it}. The regression model estimated was:

$$y_{it} = \beta \, \mathrm{s}_{\mathrm{it}} * Time_t + \delta Time_t + \lambda_i + \varepsilon_{it} \qquad (1)$$

where $Time_t$ is a time dummy, which takes 1 for the observations from post-intervention, otherwise 0, λ_i is the full set of individual fixed effects. Coefficient β represents the pure project impact in the equation above under the assumption that *time-variant* unobservable characteristics, which affect the outcome of interest, are not different across samples in treatment and control households.

Overestimation of the project's impact may occur if households in the treatment group harvested significantly

Table 3 **Differences between baseline and endline**[2]

		Baseline	Endline	Change	t-value	Pr(T < t)
HAZ	Treatment	-2.24	-1.79	0.45	1.44	0.078
	Control	-2.15	-1.91	0.24		
WAZ	Treatment	-0.65	-0.55	0.10	0.63	0.263
	Control	-0.71	-0.70	0.01		
MUACZ	Treatment	-0.26	0.13	0.39	0.66	0.254
	Control	-0.31	-0.02	0.28		

Source Authors' own.

more crops than those in the control group during the study period. There is also a possibility that some kinds of intervention were made by other organisations that affected children in only one of the groups. However, there was no such occurrence during the study period according to the reports of the local staff including the CGPs.

2.6 *Ethical issues*

This health intervention project was approved by the University of Zambia Biomedical Research Ethics Committee (UNZAREC) in February 2012, the Ministry of Health, the National Food and Nutrition Commission (NFNC) and the District Health Management Team (DHMT). The study ensured voluntary participation, informed consent and confidentiality of mothers throughout the research period. Careful attention was given to children as much as possible to avoid any risk of harm during the study.

3 Results

3.1 *Balanced check at baseline*

A t-test was conducted to check whether any bias existed in the explained variables and other selected indicators such as HAZ, WAZ, MUACZ and children's age across the two groups. In addition, information on the mother's socioeconomic status (as measured by her level of education), and on family size was also collected and examined. There were no statistically significant differences between the groups with regard to any of the variables (see Table 2). However, it may be important to note that the difference in MUACZ (0.23) was not small compared to the other two indices and thus close attention was paid to MUAC in the subsequent analysis.

3.2 *Descriptive analysis of the baseline and endline data*

The average improvement in the children's nutritional indicators and the difference between February 2013 (endline) and May 2012 (baseline), are summarised in Table 3. Each index is standardised into z-score values. If the difference between the two time points is positive, the implication is that the child grew as expected when evaluated against the standard children's growth chart.

On average, the change of children's growth in the treatment group was higher than the control group for all three indicators. For example, treatment children had an improved HAZ of 0.21 points more than control children.

3.3 *Regression results*

Table 4 shows the results of the regression analysis. It is evident that the time-treatment cross coefficient (β) is the pure project effect. The regression analysis for HAZ indicates that the treatment group improved by 0.29 points more than the control group on average. This was

Table 4 **Impact of spirulina on child growth**

	HAZ	WAZ	MUACZ
Mean at baseline	-2.26	-0.69	-0.1
Spilurina*Time	0.29**	0.09	0.38
	(0.12)	(0.13)	(0.28)
	[0.0404 , 0.535]	[-0.183 , 0.355]	[-0.188 , 0.942]
Time	0.16*	0.01	-0.07
	(0.09)	(0.11)	(0.24)
	[-0.0236 , 0.350]	[-0.203 , 0.226]	[-0.544 , 0.397]
Number of observations	110	111	111
Number of children	59	60	60

Note ** Indicates significance at the 5% level; * indicates significance at the 10% level. Numbers in parentheses are robust standard errors. 95% confidence intervals are shown in brackets. Individual fixed effects are controlled. One child is excluded from analysis due to the extreme value only for HAZ based on the approach proposed by Hadi (1994).
Source Authors' own.

statistically significant at the 5 per cent level. In addition, although insignificant, the regression analysis shows that the coefficient (β) is positive by 0.09 points for WAZ and 0.38 points for MUACZ.

4 Discussion

4.1 *Effect on height*

The results indicated that there was a significant difference in the change in HAZ during the study period between the children in the treatment and control group at the 5 per cent significance level. If this difference was attributable to spirulina intake, it implies that this fortification helped the treatment group children to grow 0.29 points more than the control group on average. The statistical difference in HAZ implies that spirulina consumption can be an effective food intervention particularly in Zambia, where severe stunting is widespread.

4.2 *Insignificant effect on weight and mid-upper arm circumference*

In terms of WAZ and MUACZ, there was no significant difference observed in the change in outcome between the children across the two groups. For WAZ, the marginal size of impact of spirulina is shown in the small point estimate of the Spirulina*Time (β) coefficient (0.09) (see Table 4). This result is possibly attributed to the small energy content of spirulina. Generally, weight reflects the short-term outcome of dietary intake and infection. Although spirulina contains a variety of important nutrients for child development, such as zinc, protein and other minerals, it does not contain much energy in 10g provided to children every day. Therefore, spirulina's rather small contribution in energy may have caused the effect of spirulina on weight to become smaller than the difference observed in height.

In contrast, as for MUACZ, it seems too early to conclude that spirulina has no impact given that Spirulina*Time (β) coefficient (0.38) (see Table 4) is relatively large. Indeed, the larger standard error of this coefficient (0.28) is likely to be attributed to the reason why the statistical test could not detect a significant impact on MUACZ. At baseline point, standard deviations of individual MUACZ were larger compared to the other two indicators (see Table 2). This might have been caused by measurement errors in the MUAC. The MUAC measurement depends relatively on where precisely the measurement is taken and how close-fitting the examiner makes the cord. However, if with a larger sample size, this issue about the power of the statistical test could be overcome. The estimate is that if with the sample of 240 or more children, we expect the effectiveness test to detect a significant impact under the given statistics.

4.3 *Limitations*

Although our study provides valuable evidence on the effectiveness of spirulina, there were several limitations to this study.

a The study was not a double-blind randomised controlled trial with a placebo. Due to spirulina's green colour, mothers or caregivers knew that their children were in the treatment group. This knowledge might have caused changes in the behaviour of mothers in both groups. For example, given the rich nutrients that are contained in spirulina, mothers in the treatment group may pay less attention to the child's nutrient intake from food other than spirulina. Also, it is possible that mothers from households excluded from this study or in the control group within the same health post might receive a small part of spirulina porridge from the treatment household since they acknowledge its effectiveness. However, all these examples will yield an underestimation of spirulina's impact, and thus our estimates are likely to be considered as the lower boundary of its true effect.

b Because it was entirely up to the participating children whether to eat the porridge or not, there was still a problem of 'compliance'. The acceptance level of spirulina may be affected by several factors such as food preference, risk perception, socioeconomic status, and family members' situation. Still, the 24-hour record documenting the children's dietary intake, which was collected by authors to ensure compliance, indicated that generally most caregivers followed our feeding recommendations.

c The drop-outs might have influenced the results. Because the original sample size was small, the population was susceptible to any change. If the reasons for dropping out were correlated with being in the treatment or control group, and were also correlated with unobservable variable(s) which might have affected health status, our results might have been biased (Fitzgerald, Gottschalk and Moffitt 1998).

4.4 *Implications for future research and policy discussion*

Although some previous studies have investigated the effectiveness of spirulina for nutritional rehabilitation and provided significant evidence of its effectiveness, most of them were small scale in size (Azabji-Kenfack *et al.* 2011; Simpore *et al.* 2005; Yamani *et al.* 2009). Unfortunately, the current study was no exception in this respect. Therefore, as we discussed earlier in Section 4.2, larger-scale studies are desirable in order to obtain more precise evidence for the effectiveness of spirulina on child growth, MUACZ in particular.

Since this micronutrient fortification project is one of many policies competing for limited government expenditure, the cost-effectiveness of spirulina intervention must be comprehensively studied to see if it should be a policy priority. By using the approach taken by Bhutta *et al.* (2008) and the market price of spirulina, our current estimate of its health cost-effectiveness is US$73.7 per Disability-Adjusted-Life-Years (DALY) averted. This is higher than that of vitamin A and zinc fortification, US$19 per DALY averted, which is considered as the most cost-effective intervention against child malnutrition in this region (Tan-Torres Edejer *et al.* 2005). However, due to the caveat of our study (i.e. ignoring spirulina's effect on important outcomes other than HAZ), our figure is likely to understate the true benefit of our intervention, and hence its cost-effectiveness. Thus, our estimate should be considered as upper bound in terms of true cost-effectiveness.

Indeed, in future studies the effects on other nutritional deficiencies such as vitamin A deficiency and iron deficiency should also be considered. Previously, a micronutrient fortification intervention study conducted in Zambia resulted in improved iron status among children (CIGNIS Study Team 2010). Another study also reported that maize meal fortification not only improved iron status among children, but also vitamin A status among adolescents (Seal *et al.* 2008). It is possible that spirulina may also have a similar effect considering its highly nutritious content.

We also estimated the effectiveness of our intervention in the context of human capital investment. Alderman, Hoddinott and Kinsey (2006) revealed that the one unit improvement in HAZ of pre-school children significantly increases the number of grades of schooling completed by 0.68 grades. Using this evidence and our estimate of the project's impact, our intervention is likely to promote the educational attainment of a treated child by 0.25 grades. This educational benefit is converted to the increase in labour market earning potential using the private rate of return on education in rural Zambia estimated by Nielsen and Westergård-Nielsen (2006). Under the conservative assumption made by Miguel and Kremer (2004), our rough calculation suggests that the intervention using spirulina increases the net present value of life-time income by over US$140 per treated child at a cost of US$82.4. This implies that the labour market benefit of this nutrition fortification programme may be greater than its cost. Additionally, the cost of the intervention may even be lower once spirulina is domestically produced in Zambia, where its plentiful water and moderate temperature make it an ideal place for cultivation. Therefore, evidence from the feasibility study on domestic production will greatly contribute to the policy discussion.

In the case of introducing a health intervention using spirulina in Zambia, the cultural impact must be carefully observed. In Zambia, where green micro-algae have never been consumed, cultural barriers against this new food are likely to exist. Indeed, initially in our study, a few participants refused to continue due to their hesitation in consuming food that they had never eaten before. However, experience tells us that eventually such a problem can be overcome. As their children's health visibly improved by consuming spirulina, mothers became more dedicated to feeding it to their children. Even after six months of the termination of the spirulina effectiveness test, more than half of 60 sample households, including those in the control group, continued the habit of consuming spirulina, which is available at the study area's health posts for free. Active consumption, even in the absence of the study, implies that if supplemented with the results from the study or information from real cases, especially those involving neighbours or somebody potential consumers know, it will help people to overcome the cultural barriers. Thus, when spirulina intervention is extended nationwide, the role information can play to help potential customers overcome cultural barriers should be correctly understood by policymakers.

5 Conclusion

The main contribution of this study is to provide the evidence that a daily intake of spirulina significantly improves a child's HAZ by 0.29 units when the time effect and individual fixed-effect were controlled. The results from this study indicate that a combination of spirulina and mealie meal is effective in improving the linear growth in height for undernourished children. The uniqueness of this study project comes with its use of indigenous micro-algae in Africa. Utilising an indigenous resource is important for development projects in terms of sustainability and acceptability. In addition, spirulina can be produced with less water and energy than other foods promoted as a nutritional supplement for children, such as soybeans. The plentiful water and moderate temperature in Zambia is ideal for cultivation, although the production of spirulina is also well suited to hot, even desert countries. Thus, this nutrition fortification programme can be a good tool to alleviate nutrition problems in developing countries.

Notes

1 Roller meal is made from maize and has an extraction rate of about 90 per cent.

2 To compare between baseline and endline data, the authors use 52 purely comparable children. Thus, the baseline value is not the same as the balanced check result.

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