Spirulina Project – Efficacy Study on Child Malnutrition

Final Report

Kanakantapa, Chongwe District

June 2013

Prepared by:

Programme Against Malnutrition
and Alliance Forum Foundation

ACKNOWLEDGEMENTS

The Spirulina pilot research was conducted in Kanakantapa, Chongwe district by the Programme Against Malnutrition and Alliance Forum Foundation. The spirulina study was co-funded by Alliance Forum Foundation and Programme Against Malnutrition and was authorized by the University of Zambia Biomedical Research Ethics Committee (UNZAREC).

Sincere thanks go to Dr. Charles Msiska and Agness Aongola, Ministry of Health; Dorothy Sikazwe, Ministry Community Development, Mother and Child Health; Charles Simulunda and Nancy Sakala, Ministry of Agriculture and Livestock and, Albertina Kapeshi, National Food and Nutrition Commission for their technical support and guidance during the study period.

Many thanks go to Dr. Takashi Hanada and Dr. Toru Rikimaru (JICA), Dr. Masato Yasui and Dr. Toru Takebayashi (Keio University), Dr. Satoshi Morita (Yokohama City University), and Dr. Shonchoy Abu (IDE-JETRO) for their comments and general support during the design and implementation of the research.

The Ministry of Health, Ministry of Agriculture and Livestock, Ministry of Community Development, Mother and Child Health, National Food & Nutrition Commission (NFNC), Chongwe District Health Management Team and District Agriculture Office and University of Zambia Biomedical Research Ethics Committee (UNZAREC) are acknowledged for the support and supervision provided during the study.

More notably many thanks go to the parents who willingly allowed their children to participant in the study; Kanakantapa Cassava Women Processors for having mixed and distributed the porridge blends and the Child Growth Promoters who ensured that the required children's data was regularly recorded.

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Acronyms

AFF	Alliance Forum Foundation
CGP	Child Growth Promoter
DALYs	Disability-Adjusted Life Years
DHMT	District Health Management Team
ZDHS	Zambia Demographic and Health Survey
DID	Difference in Differences
FAO	Food and Agriculture Organization
IISAM	Intergovernmental Institution for the use of Micro-algae Spirulina Against Malnutrition
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
LIC	Low Income Countries
MDGs	Millennium Developing Goals
MUAC	Mid-Upper Arm Circumference
MUACZ	Mid-Upper Arm Circumference Z score
NFNC	National Food and Nutrition Commission
PAM	Programme Against Malnutrition
SADC	Southern African Development Community
UNICEF	United Nations Children's Fund
UNZAREC	University of Zambia Biomedical Research Ethics Committee
USAID	United States Agency for International Development
WHO	World Health Organization

Executive Summary

This study tested the efficacy of spirulina on malnourished children in Zambia. Zambia is situated in sub Saharan Africa where the rate of malnutrition especially stunting is very high among under five children. Spirulina is a blue green micro algae that comprise abundant nutrients such as protein, minerals and vitamins.

The study was conducted from April 2012 to February 2013. The sample size comprised sixty (60) children who were divided into two groups: spirulina treatment group and the control group. The outcome of taking spirulina regularly was compared by collecting anthropometric data every month from June 2012 to February 2013.

The results show improvement for all indicators to be higher in the treatment group compared to the control group. Furthermore, the regression result shows that spirulina intake leads to 0.231 points more improvement in Height for Age Z-score (HAZ) (CI: -0.055 – 0.516). As for Weight for Age Z-score (WAZ) and Mid-Upper Arm Circumference Z-score (MUACZ), spirulina intake had higher effect by 0.086 point and 0.377 point respectively, though not statistically significant.

This may be attributed to the relatively high average values of WAZ and MUACZ before the treatment (WAZ: -0.7, MUACZ: -0.11). Both groups had relatively mild malnutrition in reference to the two indicators in contrast to the seriously low value of HAZ - Score, which was below -2 points. WAZ is a measure of both long and short term nutritional adequacy while MUACZ reflects a recent and severe process that leads to substantial weight loss.

WAZ and MUACZ show insignificant effect because they are sensitive to short term changes and may fluctuate from month to month. This may explain why spirulina intake did not cause any statistically significant difference to WAZ and MUACZ. On the other hand, a relatively high effect was observed in HAZ – score, a chronic malnutrition indicator. The results imply that spirulina consumption is effective in Zambia where severe “stunting” is high in the country.

1 Introduction

Infant and child malnutrition is one of the most serious health problems in developing countries and Zambia is no exception. Malnutrition impairs a child's physical and mental development and can result in lower IQ and compromised immunity. Plletuer *et al* (1995) reported that 56% of children's deaths in developing countries are caused by malnutrition. According to the World Health Organization, underweight in low income countries is a major health risk in infants and young children.

Improving the nutritional status of infants and young children is cardinal to the attainment of Millennium Development Goals (MDGs) which were set for countries to reduce poverty, foster people's development and to improve their living conditions. MDG No. 1 to halve, between 1990 and 2015, the proportion of people who suffer from hunger and MDG No. 4 to reduce by two thirds, between 1990 and 2005, under-five mortality rate are particularly important.

Although the nutritional status of under-five children is improving worldwide, African children still suffer from high rates of malnutrition. Figure 1 below shows that the rate of underweight children in Africa between 1990 and 2010 has not changed much, while that of Asia and Latin America and Caribbean has significantly reduced.

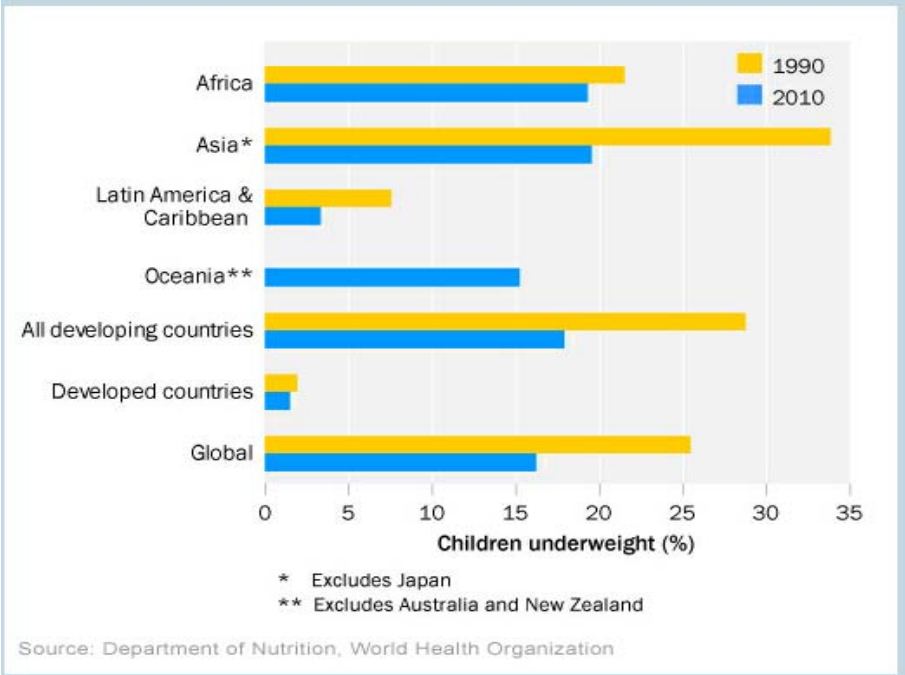
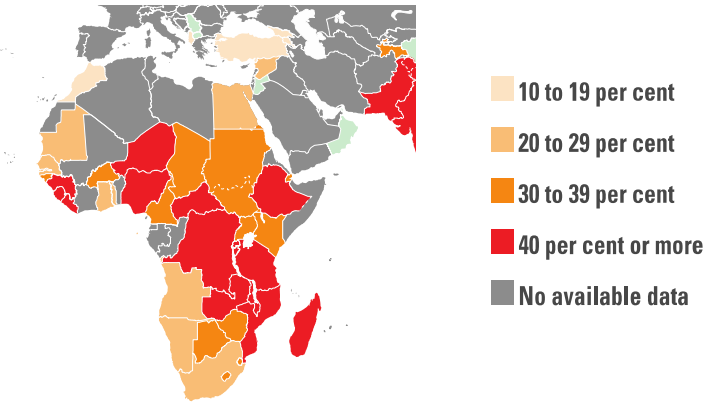


Figure 1: Under Five Rate of Malnutrition by Region (1990-2010)

1.1 Malnutrition in Zambia

Sub-Saharan Africa has one of the most serious rates of chronic malnutrition in the world. In Zambia, chronic malnutrition or stunting affects 45% of under five children and remains the most common nutritional disorder, above the Sub-Saharan Africa average of 42% (ZDHS, 2007) and is the eighth highest rate in the world (Figure 2). Besides stunting, 5 % of the children are wasted while 15 % are under weight.

In addition, micronutrient deficiencies have enormous consequences to individuals and society through reduced productivity. 54% and 53 % of the children in Zambia suffer from vitamin A deficiency and iron deficiency respectively (CSO, 2009). Under five Mortality Rate (U5MR) is at 119 per 1000 live births (ZDHS, 2007).



(Source: UNICEF, 2011)

Figure 2: Distribution of stunted under 5 Children in Africa

1.2 Food and Nutrition in Zambia

Maize and cassava are the main staple foods albeit maize is consumed by over 90% of the population. *Nshima* prepared from maize or cassava is eaten with different types of relish such as vegetables, meat, fish, eggs and legumes. However, the Zambian nutrition profile shows that 60% of households do not afford 3 meals per day (FAO, 2009) which leads to inadequate nutrient intake and malnutrition.

The dietary energy supply was 1 905kcal per capita/day in 2000-2002. Households did not meet the estimated energy requirement of 2056kcal per capita/day. Carbohydrates such as cereals and starchy roots are the main source of energy which account for 80%

of the total energy intake. The level of intake suggests a general insufficient intake of other essential nutrients as well such as protein and lipids.

2 Project Overview

The spirulina pilot study was conducted in Kanakantapa, Chongwe district. The study covered households engaged in small scale farming and have similar dietary patterns and lifestyle. The mothers and children who participated in the study continued with their normal day to day activities during the pilot study undertaken from May 2012 to February 2013.

2.1 Project Objective

The aim of the spirulina pilot project was to explore the effectiveness of spirulina on malnourished under five children. 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.

2.2 Efficacy of Spirulina

Spirulina is a blue green micro algae indigenous to Africa. Spirulina can sustainably contribute to alleviating malnutrition in Zambia because it is rich in various nutrients, is easy to produce, and can be added to many traditional foods.

Spirulina contains various nutrients such as protein, beta-carotene, iron, and vitamin B which are usually deficient in undernourished populations. Kwashiorkor (caused by protein deficiency), vitamin A deficiency, and anaemia (caused by iron deficiency) are common public health nutrition problems in Zambia and increased intake of spirulina can help control these deficiencies.

The United Nations and other international bodies recognize the importance of spirulina in combating malnutrition. The United Nations Economic and Social Council established the Intergovernmental Institution for the use of Micro-algae Spirulina Against Malnutrition (IISAM). The organization works to promote the use of spirulina in tackling malnutrition.

The ease with which spirulina can be cultivated is attractive. Spirulina needs less water and energy compared with other protein rich foods such as soybeans and meat and is cost effective as it takes only takes two weeks to grow. The abundant rivers and sunlight in Zambia provide a suitable environment for growing spirulina.

From a nutrition point of view, spirulina’s blue and green colours are useful. The colours help to raise awareness on the rich nutrient content of spirulina.

2.3 Significance of Spirulina Project

Health promotions targeting knowledge enhancement on maternal and child nutrition and direct nutrient supplementation are often utilized as nutrition intervention programmes in developing countries. The Lancet in 2008, published a series of papers on maternal and child under nutrition in which the need to focus on the crucial period from conception to a child's second birthday was identified.

Various intervention programmes were evaluated based on their cost-effectiveness and it was concluded that breastfeeding promotion and support, vitamin A supplementation, and zinc supplementation have the largest effect on child under nutrition. As described above, spirulina can contribute to increased supply of vitamin A and balanced protein.

There are few studies which document the effectiveness of spirulina. Simpore *et al.* (2006) reported that spirulina was effective in undernourished children in Burkina Faso. However, the study did not avoid the other factors which could have affected the results. K. F. Michaelson *et al.* in 2009 pointed out that the evidence of spirulina efficacy was sparse and further investigations were required. In this respect, the spirulina pilot study is the first in Zambia that examined the effectiveness of spirulina on malnourished children and contributes to accumulation of sound evidence of spirulina's efficacy.

3 Survey Design

3.1 Materials and Methods

A total of 60 malnourished under five children between the ages of 18 - 36 months were selected from a sample of 295 children who were screened at Kanakantapa Rural Health Centre, Chongwe district using the weight for age, height for age and MUAC indicators.

The 60 chronically least-nourished children were evaluated on an index generated from simple summation of HAZ and WAZ. The division into treatment and control groups was undertaken by putting the 60 samples in ascending order from mild to the severely malnourished and evaluated by simple summation of WHZ and MUACZ, which indicate acute-malnutrition.

Thereafter, the sample children were alternatively divided into treatment and control groups from the top of the list. The two groups were further adjusted to ensure children were balanced in relation to sex, geographical area and the rate of malnutrition to avoid generating any bias in the initial level of malnutrition. This sampling method was not pure-random sampling. The t-test results in Table 4 for both treatment and control groups prove that there was no difference at 10% significance level.[1] The selected malnourished children comprised:

a) Treatment Group, 30 children provided with spirulina and
b) Control Group, 30 children without spirulina.

3.2 Distribution of Porridge Blends

Five (5) kg of roller meal[2] mixed with 300g of spirulina, 0.8 kg sugar and 0.1 kg salt was distributed monthly to the target group to ensure compliance. The control group was provided with the same blend but without spirulina. Each child in both the control and target groups was fed porridge twice a day in the morning and afternoon.

The porridge blends were provided for nine (9) months i.e. June 2012 – February 2013. Physical measurements of weight, height and MUAC for both groups were recorded every month by trained Child Growth Promoters (CGPs) at each Health Post. Participating children whose mothers or caregivers did not attend growth monitoring sessions were followed up by CGPs unless they had gone out of the village for a while

[1] A few children dropped out from the project during the study due to father's opposition or moving out of the village. In the first month of the project, the children were replaced. The number of replaced children was 7 (6 treatment group, 1 control group). The balanced-check result which proves HAZ and WAZ are almost balanced is given below. Treatment group had moderate to severe initial value of HAZ and MUACZ compared to the control group which could have been due to the selection and replacement of children who dropped.

[2] Roller meal is made from maize and has an extraction rate of about 90%.

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 after the first two months were replaced. Thereafter, no replacement was made and Table 1 shows the number of samples in each month.

Table 1: Sample size（counts on post-replacement children）

	2012								2013	
Health Post	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**
F	30	16	28	26	28	20	26	27	28	26
H	12	12	12	11	10	10	11	10	10	10
K	18	17	18	15	16	17	11	17	15	16
Total	**60**	**45**	**58**	**52**	**54**	**47**	**48**	**54**	**53**	**52**

3.3 Project Area

Kanakantapa Resettlement Scheme in Chongwe district, Lusaka province was selected for implementing the pilot project. Kanakantapa is located approximately 60 km from Lusaka city and the project covered Health Posts F, H and K as shown in Figure 3 below.

Kanakantapa was selected because neither government nor NGOs were distributing food supplements such as Plumpy'nut[3], thus there was no influence from other projects. In addition, the involvement of the Programme Against Malnutrition (PAM) in conducting the study made it easier for the community to gain confidence and to be willing to participate in the study.

The proportion of undernourished children in Lusaka province is the lowest in the country, however 37.2% of children are stunted and 9.7% are wasted (ZDHS, 2007). When the children were screened in this study area in May 2012, 36.5% of population was stunted and 5.1% were wasted. The results of the screening undertaken in the study area correlated with the provincial averages.

[3] A peanut-based paste distributed in small sachets

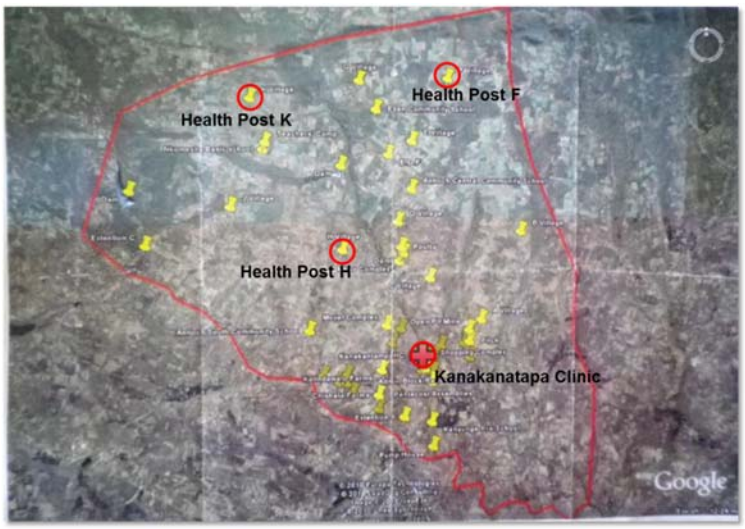


Figure 3: Map of Kanakantapa Resettlement Scheme

Table 2: Average values for the three indicators - Kanakantapa

	Obs	Average		
		HAZ	WAZ	MUACZ
Health Post H	80	-1.316	-0.289	0.083
Health Post F	116	-1.366	-0.355	-0.474
Health Post K	99	-1.306	-0.151	-0.065
Total	295	-1.332	-0.269	-0.186

In addition, Kanakantapa has limited access to medical facilities. Chatt and Robert (2010) revealed that about 1/3 of the population did not go to a clinic even if they needed medical assistance because of the difficulty in accessing a clinic compounded by inadequate medical supplies. Poor health facilities are acknowledged as a common feature in the country (MoH, 2005).

3.4 Project Organization

The project was approved by University of Zambia Biomedical Research Ethics Committee (UNZAREC), Ministry of Health, the National Food and Nutrition Commission (NFNC) and, District Health Management Team (DHMT). Meetings to discuss the purpose of the study were held with community leaders and local politicians.

A steering committee comprising the Ministries of Health, Agriculture and Livestock, Community Development, Mother and Child Health; National Food and Nutrition Commission, Programme Against Malnutrition and Alliance Forum Foundation was

constituted to monitor and supervise the project.

Quarterly progress reports were submitted to the Ethics Committee and government after 3 months and 6 months of project implementation.

Mixing, packaging and distribution of porridge blends was undertaken by the Kanakantapa Cassava Women Processors. The women processors were engaged because they own the Cassava-Processing Centre which has good facilities; because of their processing skills and to encourage ownership of the project in the study area. The blends were distributed to each Health Post once a month, see Figure 4 below.

Anthropometric measurements were conducted by experienced CGPs who were further trained by the National Food and Nutrition Commission. CGPs in addition monitored compliance by regularly visiting participants' households. In addition, CGPs administered the 24 Hour Recall once a month for each child. Disease incidence over a period of one month and comments from mothers or caregivers were also recorded.

The data was collected and submitted to PAM and AFF. AFF Tokyo office conducted statistical analysis and consulted with PAM after which reports were developed and submitted to relevant authorities.

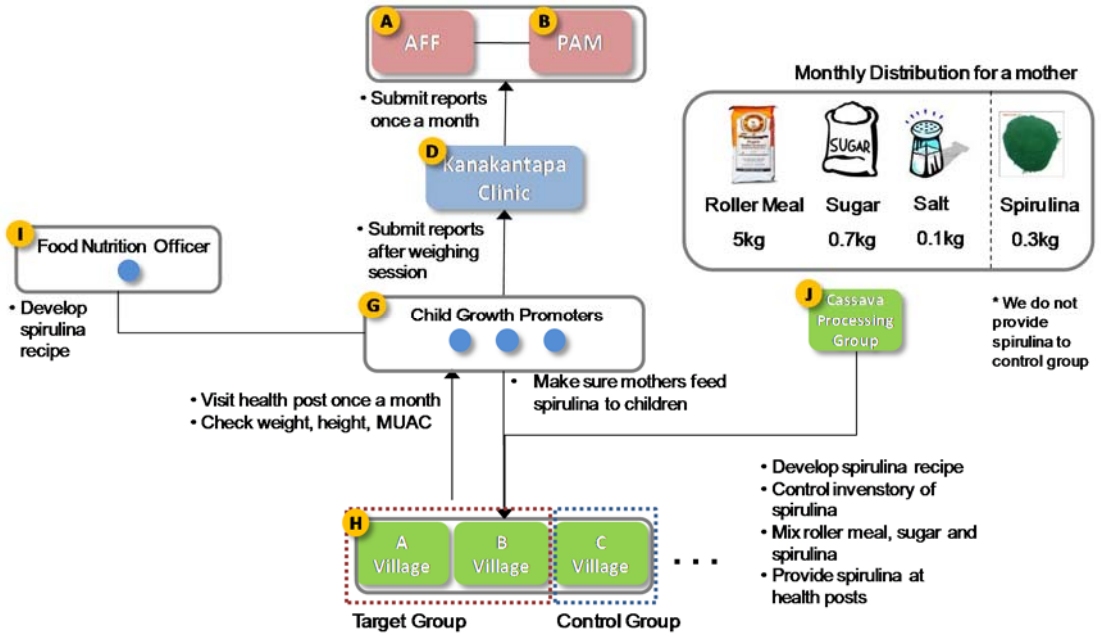


Figure 4: Operational Structure

3.5 Ethical Issues

The research project was approved by UNZAREC in February 2012. 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. Stakeholders' participation was also acknowledged and supported throughout the study period.

3.6 Malnutrition Indicators (HAZ / WAZ / MUACZ)

Three indicators were used to assess the nutritional status of under five children: 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.

WHO Multicentre Growth Standards (WHO, 2006) were used as reference for the nutritional status in the study. WHO and UNICEF define stunting as children whose height – for – age Z-score is below minus two standard deviation (HAZ <-2) and underweight as children whose weight – for – age Z-score is below minus two standard deviation (WAZ <-2). If these indicators are minus three (-3) standard deviation and below, the child's nutritional status is said to be "severe".

Table 3: Explanation of Three Indicators

Abbreviation	
HAZ	Height for Age Z-score
MUACZ	Mid Upper Arm Circumstance Z-score
WAZ	Weight for Age Z-score

Figure 5 below shows the height and weight growth curves for 295 children in Kanakantapa as plotted during the baseline study in May 2012. The standard growth curve (HAZ / WAZ =0) is the third line from the top (blue line), and the bottom line shows -2SD (red line). Many children screened fell below the blue line. Few children were underweight (WA Z-score <-2) but many children were stunted (HA Z –score <-2).

Figure 7 and 8 below showed that the main staple food in the study area is maize (carbohydrate), and households had inadequate foods rich in protein and micronutrients. This may be one possible explanation for the high rate of stunting in Kanakantapa.

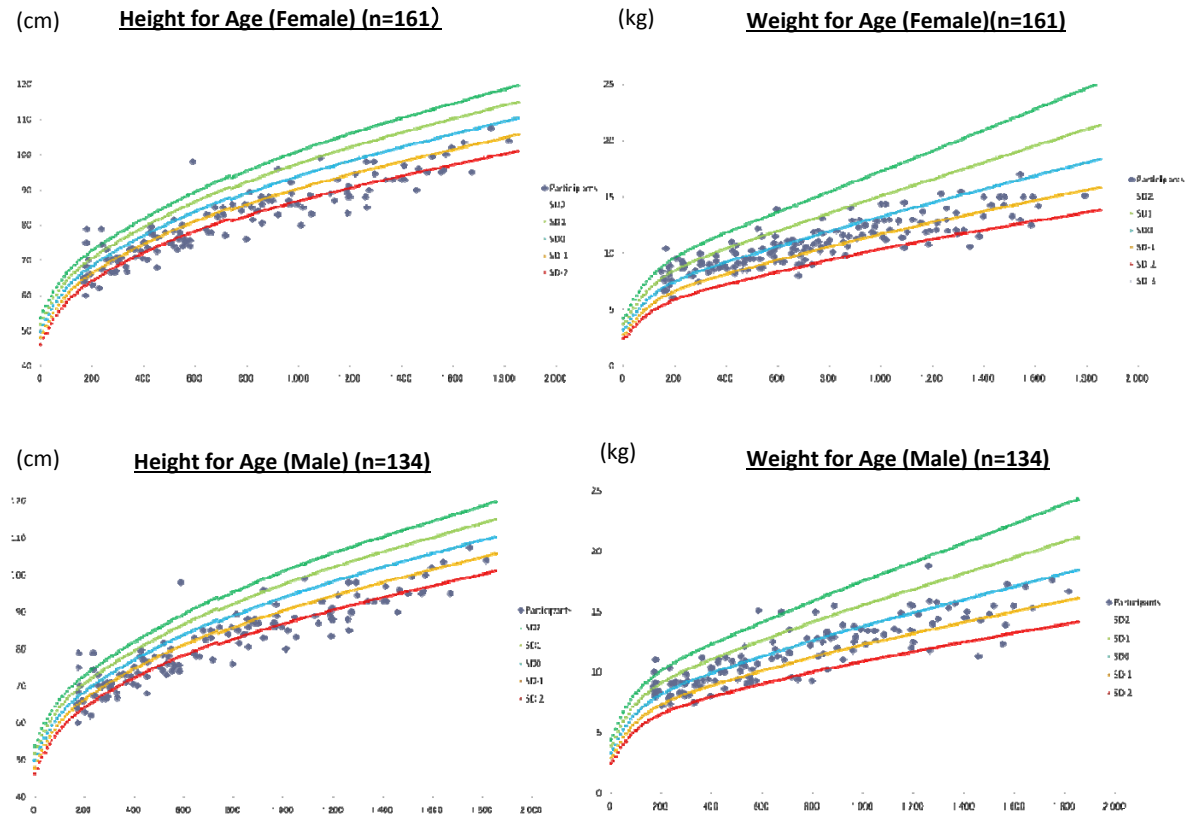


Figure 5: Growth Curves in Kanakantapa

The *Anthropo*[4] software, designed by WHO, was utilized to calculate growth indicators using the height, weight, and MUAC data. Length for age for children under 2 years old, and height for age for children aged 2 and above were measured according to WHO guidelines.

4 http://www.who.int/childgrowth/software/en/

4 Analysis

4.1 Descriptive Statistics

Data analysis involved comparison of averages between target and control groups on collected indices; HAZ, WAZ and MUACZ. Chapter 4 is firstly a check of the balance of three indices using the baseline data collected in May; Chapter 4.2.2. Chapter 4.2.3, the difference between February 2013 and April 2012 is analyzed to determine how much of the level of improvement in the nutritional status of children was due to spirulina.

4.1.1 Balance Check at Baseline

To assess the effectiveness of spirulina, the most desirable condition is to ideally have children at the same level of development between treatment and control groups. Above all, the initial nutritional status must be the same. The larger the difference in the initial data, the more serious is the bias in the results.

A t-test to check whether any bias existed in the explained valuables (HAZ, WAZ, MUACZ) between the two groups was conducted. The result did not show any statistically significant difference, see Table 4 below. However, it is important to note that the difference in MUACZ (0.23) is not small compared to the other two indices, thus the need for paying closer attention to MUAC in the subsequent analysis.

Table 4: HAZ, WAZ and MUACZ Balanced-Check result in Base line data

	(1) HAZ		(2) WAZ		(3) MUACZ	
	Treatment	Control	Treatment	Control	Treatment	Control
Mean	−2.252	−2.26	−0.71	−0.67	0.01	−0.22
Variance	0.667	0.831	0.39	0.9	1.2	0.91
Observation	30	30	30	30	30	29
Degree of freedom	57		50		56	
t-value	0.033		−0.21		0.84	
P-value (one-side)	0.487		0.42		0.2	
One-side test	1.672		1.68		1.67	
P-value (two-side)	0.974		0.83		0.41	
Two-side test	2.002		2.01		2	

4.1.2 Descriptive Analysis on May and February Data

To measure the average improvement of children's nutritional indicators, the difference between February 2013 and May 2012 was calculated, which is summarized in Table 5. Each index is standardized into z-score value. If the difference of the two periods is positive, the implication is that the child grew as expected when evaluated against the standard children's growth chart.

On average, the growth of children in the treatment group was higher than the control group for all the three indicators. Of the three indicators, WAZ had the least average improvement compared to the considerable improvement in HAZ (0.47: treatment, 0.34: control).

Table 6 illustrates the number of undernourished children who became healthier. Table 6 shows the headcount ratio of 60 undernourished sample children, defined by two standard lines: that is z<-2 and z<-1.5. In total, 58% of children were "stunted" (HAZ<-2) in April. The proportion of stunted children decreased to 34.6% in February 2013. In the same way, 8% of children were "underweight" (WAZ<-2) in April, but decreased to 3.8% in February.

Table 5: Differences between February 2013 and April 2012

		WAZ	HAZ	MUAC
Baseline	Treatment	-0.71	-2.252	0.01
	Control	-0.67	-2.26	-0.22
Change	Treatment	0.12	0.47	0.35
May and Feb	Control	0.02	0.34	-0.03

Table 6: Headcount Ratio of Malnourished Children

		HAZ		WAZ		MUACZ	
		April	Feb	April	Feb	April	Feb
Treatment	<-1.5	73.3%	51.9%	20.0%	14.8%	3.3%	3.7%
	<-2	56.7%	37.0%	13.3%	7.4%	3.3%	0.0%
Control	<-1.5	76.7%	68.0%	16.7%	20.0%	10.0%	4.0%
	<-2	60.0%	32.0%	3.3%	0.0%	6.7%	0.0%
ALL	<-1.5	75.0%	59.6%	18.3%	17.3%	6.7%	3.8%
	<-2	58.3%	34.6%	8.3%	3.8%	5.0%	0.0%

4.1.3 Proportion of Infected Children

Mothers or caregivers were asked whether the children had malaria, a cough, fever and diarrhoea in the months preceding the social economic survey that was conducted in December 2013 according to the categories listed in Zambia Demographic and Health Survey (ZDHS, 2007). The duration of recall is set at 6 months for malaria and 2 weeks for other illnesses.

The number of sick children in each group was recorded and thereafter, a χ^2test was conducted to determine whether there was a significant difference. The results presented in Table 7 showed that the spirulina treatment group had fewer sick children due to malaria than the control group. However, there was no significant difference for the other illnesses.

Table 7: Number of Sick Children by Disease

Disease	Y=infected/N＝not infected	Group		total	Chi-square	Pvalue
		Treatment	Control			
Malaria	Y	4	11	15	4.462	0.0347
	N	24	17	41		
Fever	Y	8	10	18	0.447	0.5036
	N	20	17	37		
Coughing	Y	8	10	18	0.327	0.5671
	N	20	18	38		
Diarrhoea	Y	8	6	14	0.381	0.5371
	N	20	22	42		

4.2 Regression Analysis

According to descriptive statistics, the average point of improvement for each nutritional index is larger in the treatment group than the control group. However, it is unclear whether the average difference was purely caused by spirulina because a child's development status can be correlated to many other factors. To account for such factors, regression analysis was conducted. Given below is an explanation of the model used to estimate the pure impact of spirulina on child growth followed by the results.

4.2.1 Quantitative Strategy

To determine the impact of spirulina, the Difference in Difference (DID) model was

used. The following formula shows how the variable was calculated.

$$y_{it} = \alpha Time_t + \beta T\text{reatment}_t \times \text{Time}_{it} + \lambda_i + \varepsilon_{it}$$

y_{it}: Output variables (HAZ, WAZ, MUACZ)

$Treatment_t$: Takes 1 if child is in treatment group, 0 otherwise

Time_{it}: Time specific effect

λ_i: group specific effect

The DID analysis is a popular method widely used in project evaluation analysis. The basic concept of the model is to compare average point "before" and "after" the programme between the treatment group and the control group. The objective of this model is to estimate the pure project effect excluding both time-specific effect and group specific-effect. Coefficient β represents the pure project impact in the equation above. This concept is summarized in Figure 6 below.

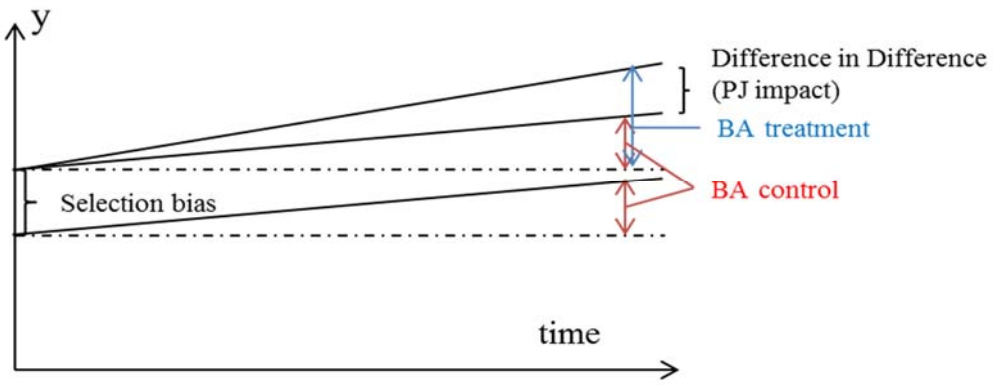


Figure 6：Basic Concept of DID Model

Time specific-effect captures seasonally specific factors common to both treatment and control groups. For example, variation in feeding caused by seasonality between April and February, see Figures 7-9 below or the effect of blended mealie meal given to the control group has a time-specific effect. Mealie meal distribution is one of the time-specific effects, because occurrence of the intervention differs depending on the periods. No distribution was conducted in April 2012, the baseline month. Distribution of mealie meal was undertaken from June 2012 to February 2013.

Group specific effect captures and controls individual trends correlated with child nutrition such as age and diseases. In this sampling method, unobservable variables may be unevenly distributed among the two groups. Therefore, a method to control their

influences was applied. These group-specific factors are able to capture the effect of time-invariant factors. The DID model is robust against both time-specific and group specific factors.

4.2.2 Regression Results

Table 8 shows the results of the regression. It is evident that the time-treatment cross coefficient (β) is the pure project effect. Regression analysis on HAZ indicates that the treatment group improved by 0.231 points more than the control group on average. This is statistically significant at 10% level. In addition although insignificant, the regression analysis shows that the coefficient β is positive by 0.086 point on WAZ and 0.377 points on MUACZ.

Table 8 : Impact of Spirulina on Child Growth

	HAZ	WAZ	MUACZ	**Note**
Mean value at baseline	-2.26	-0.69	-0.10	** p<0.01, ** p<0.05, * p<0.1
Time (α)	0.22	0.0117	-0.0732	Coefficient
	(0.17)	(0.26)	(0.21)	P-value
	(0.33)	(0.97)	(0.76)	SE
	[-0.518 , 0.959]	[-1.126 , 1.149]	[-0.971 , 0.825]	95% CI
Treatment Time (β)	**0.231***	0.0861	0.377	Coefficient
	(0.07)	(0.16)	(0.28)	P-value
	(0.07)	(0.64)	(0.31)	SE
	[-0.0547 , 0.516]	[-0.598 , 0.770]	[-0.824 , 1.578]	95% CI
Sample size	108	111	111	
Number of children	58	60	60	
Housman p-value	0.7721	0.9993	0.4064	

5.0 Dietary Patterns

Food diversity was investigated in Kanakantapa using the 24 hour recall method. Project participants were asked what the children ate in the 24 hours preceding the date of data collection. The findings are shown in Figures 7 – 9 below.

In Kanakantapa, Chongwe district, *nshima* made from maize and sweet potatoes are often consumed as staples. Figure 7 shows the proportion of households that consumed those two staples during the study period. Nshima was consumed by more than 90% of the households throughout the project period. On the other hand, sweet potato was consumed by more than 50% of the households from June to July, while only few of households consumed sweet potatoes after October.

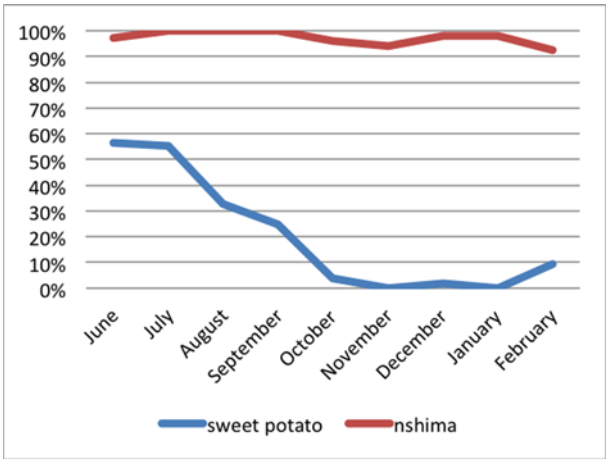


Figure 7: The proportion of households eating sweet potato/nshima during the project period

In Kanakantapa, maize nshima is the staple food. However, maize protein is deficient in tryptophan, one of the essential amino acids. The low quality protein in maize can lead to serious health problems if dietary diversity is limited. One such health problem is kwashiorkor, due to protein deficiency in children who consume enough calories, but are still malnourished because they do not get enough protein.

Another health problem sometimes related to maize consumption is pellagra, a vitamin deficiency that occurs when one does not get enough niacin or tryptophan. In 2002, an outbreak of pellagra was reported in the southern part of the country (Reliefweb, 2002) signifying the importance of consuming foods that contain enough tryptophan to prevent malnutrition.

Other foods such as meat, fish, and vegetables are also consumed as side dishes. Figure 8 below shows the percentage of studied households confirming the consumption of each food category: meat/egg/dairy products; fish, vegetables, and pulses. Vegetables, which are a source of vitamins and minerals are consumed by almost 80% of households. Of the other foods (meat/egg/dairy products, fish, and pulses), fish is consumed by 30-50% of households.

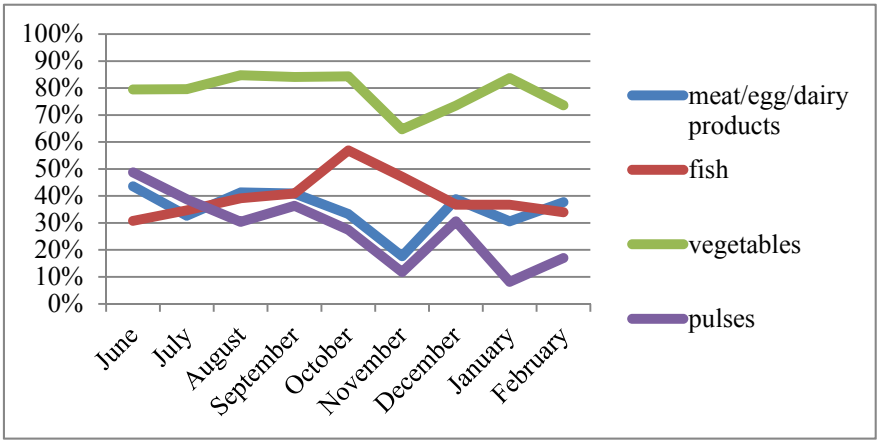


Figure 8: Proportion of Households Consuming Food by Category

In comparison, meat/egg/dairy products and pulses are consumed by fewer households, 10-40% and 5-40% respectively. There were variations through the project period. The results indicate that protein intake of the population is affected by seasonality or other factors and thus varies from month to month.

To understand how such factors may affect household diets, an evaluation of the percentage of households that did not eat protein-rich foods (meat/egg/dairy products, fish, and pulses) was conducted. The proportion in each month is shown in Figure 9 below. The percentage varied from month to month although generally the proportion of households increased from October 2012 to February 2013.

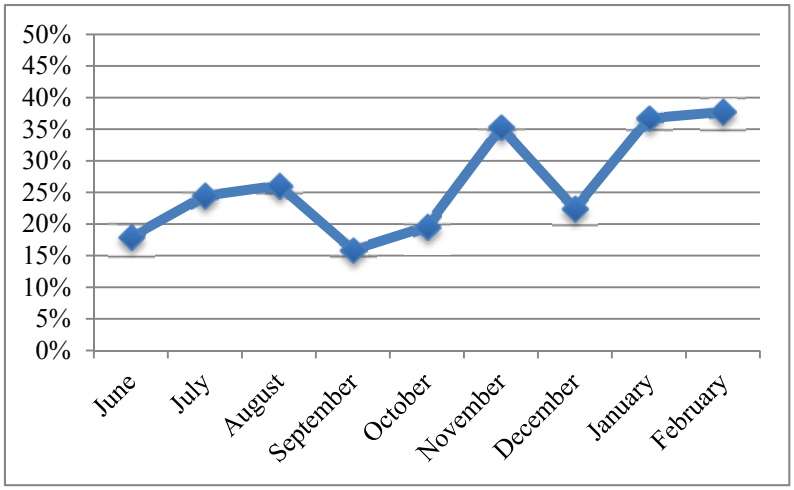


Figure 9: Households that did not Consume Protein Rich Foods per Month

Although human growth is affected by both hereditary and environmental factors, children in this age group are more strongly affected by environmental rather than hereditary factors. The study findings revealed chronic inadequate consumption of protein as shown in Figure 8, inadequate of staples and side dishes in the dry season especially between October and January (Figure 7 and 8).

The results show that one of the obstacles for improving child development in this study area is not being able to access and feed children with sufficient amounts of nutritious foods. Spirulina can thus be expected to contribute remarkably to improve growth of under five children.

6 Discussion

6.1 Weight for Age Z-score and Mid Upper Arm Circumference Z-score

There are three possible reasons for obtaining insignificant Treatment_Time (β) coefficient when WAZ and MUACZ variables are analyzed.

A) Children had mild malnutrition as seen in the initial average value of -0.7 point for WAZ and -0.11 for MUACZ in contrast to HAZ which was more than -2 points (HAZ: -2.25 point). The two indicators are sensitive to recent changes in dietary intake and infection. Thus, the children's growth was more likely to have fluctuated during the study period giving statistically insignificant difference.

a) Although spirulina is a nutritious food that contains a variety of important nutrients for child development such as zinc, protein and minerals, it does not contain much energy in 10g. An adequate diet particularly in energy is necessary for child growth and building of muscle and fat tissues.

b) Weight and MUAC largely fluctuated from one month to month because they are affected by seasonal or individual factors such as seasonal food availability, disease incidence and daily activity. Spirulina's effect can be concealed by such factors.

Further, the study was only conducted for 9 months, a timeframe which is not enough to assess the long term impact of spirulina. A much longer study with a bigger sample size could reveal significant results on the effect spirulina for the two indicators, WAZ and MUACZ.

6.2 Limitations of the Study

The following were the limitations of this study.

a) The study did not include a "double blind test" with a placebo. Mothers or caregivers knew the children or households that were in the treatment group and the control group. This might have led to creating biases in their reactions[5].
b) Because it was entirely up to the study children to eat porridge or not, there was still a problem of "compliance". The assumption was that the study children in the control group ate the blended porridge as recommended. However, sharing

[5] The direction of bias is not uniquely defined. For example, the result was upwardly biased if only control children sold porridge because control children eat less amount of porridge. However, the mother could earn cash income. Nutritional indices might have been improved by Income effect (such as other food intervention). It might have induced downward bias. Moreover, the mother might have increased other food intervention due to porridge consumption decreasing. It causes the amount of other food intake is fewer in control group meaning the result was biased downwardly.

the porridge with other family members affected compliance. If this was the case, the amount of porridge consumed was no longer the same between treatment and control groups.

The same can be said of the treatment group. If the treatment group children disliked spirulina and refused to eat, the quantity of porridge consumed between the treatment and control groups was not the same.

However, the study revealed high acceptance of spirulina among the treatment group and perhaps the spillover effect was minimal based on the results obtained for the three indicators.

c) The few drop-outs might have influenced the results. Because the original sample size was small, the population was susceptible to any changes. When the reasons for dropping out are correlated with being in treatment or control group and, are correlated with unobservable variable which affects health status, the result could be biased.

For example, if a treatment child dropped out due to the father's opposition stemming from the father's dislike of spirulina due to superstitious ethnic or religious reasons such as "satanism", the number of drop outs could concentrate in specific ethnicity or religion in the Target group.

6.3 Comparing Results with Previous Studies

There are few studies that have tested the efficacy of spirulina on malnourished children. Simpore *et al* (2005) created four groups by dividing treatment and control and HIV positive and negative groups. Traditional mealie meal with spirulina was provided to the treatment group, while the control group received just mealie meal.

Weight gain and hemoglobin improvement were reported in groups supplied with spirulina particularly for HIV negative children. Other studies 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).

The studies demonstrated that spirulina supplementation proved to be good treatment for rehabilitating malnourished children evaluated on WAZ and WHZ. However, there does not seem to be any study that shows evidence of spirulina efficacy for chronic child malnutrition (stunting). This is the first semi-clinical study testing spirulina efficacy not only in Zambia, but also in southern Africa. The evidence from this study

implies that a combination of spirulina and mealie meal is effective in improving the nutritional status of undernourished children.

6.4 Other Effects

In this study, quantitative analysis of three indicators: HAZ, WAZ, and MUACZ was conducted. Apart from child growth, other studies showed that spirulina can have good effect on health. As discussed above, disease incidence data collected and analyzed during the study period showed that there were fewer malaria cases in the treatment group compared to the control group.

Both natural and acquired immunity are activated by malaria infection which contributes to decreased susceptibility to clinical malaria (Osier, *et al*., 2008). For example, malaria infection activates T-cells leading to macrophage activation, phagocytosis of parasite red blood cells, and elaboration of cytokines and small inflammatory molecules (Good, 2001). Some studies have confirmed that spirulina helps to activate the immune system in vitro (Karkos, Leong, Karkos, Sivanji, & Assimakopoulos, 2011). Such immune system activation may enhance immunity to malaria and reduces susceptibility to infection.

Furthermore, other effects on health were reported by mothers or caregivers and stakeholders which are important to qualitatively evaluate as given in Appendix 1.

7 Conclusion

The study was conducted to assess the nutrition impact of spirulina on 60 undernourished children in Zambia. To assess the impact of daily spirulina intake on the growth of malnourished children, the 60 children were divided into treatment and control groups. The treatment group was fed with 10g of spirulina per day which was mixed with roller meal.

Three numeric indicators to measure the effect of spirulina i.e. Height for Age Z-score (HAZ), Weight for Age Z-score (WAZ), and Mid Upper Arm Circumference Z-score (MUACZ) were employed. According to the results, the treatment group improved more than the control group by 0.086 points for WAZ and 0.377 points for MUACZ. However, the differences in the results for both indices were not statistically significant.

On the other hand, there was a significant difference in HAZ at 10% significance level. Through spirulina intake, the treatment group children improved on average by 0.231 points more than the control group. The statistical difference in HAZ implies that spirulina consumption is an effective food intervention particularly in Zambia, where severe “stunting” is wide-spread.

Appendix 1

The appendix highlights reactions from field officers and mothers of participating children of their experience during the study period. Besides the quantitative results discussed above, these qualitative results are useful findings of the study.

1. Voice from field officers in Kanakantapa

a) "I am satisfied to see that not only did the child grew well but that the effect on child health was better than expected throughout this project when children aged 18 to 36 months old were fed with spirulina porridge two times a day for 9 months (including the 3 months extension period.)"

b) "I am so happy to hear mothers' comments, such as "My baby became more active and gained weight" and "Her skin is now in good condition." Many people have confidence on the effects of spirulina."

c) "I am also interested in the positive changes of their dietary habits, "My child overcame his poor food consumption habits. He can finally eat vegetables!" and "Feeding my baby regularly with porridge became a habit for me."

d) "This spirulina project provided local people not only with positive results but also the positive changes in their dietary habits and the wonderful chance to think about their basic food needs on a daily basis were encouraging."

2. Voice from mothers participated in this project

1) I will not change my dietary style after starting the project. (C/T)

2) Since my child started eating spirulina, the weight increased; so did the energy level. (C/T)

3) My child's skin condition is much better now; I really hope the project continues. (C/T)

4) At the beginning of this project, my child could not eat spirulina porridge but he is used to it now. (T)

5) After the project, my child asked "Aren't you cooking the porridge, mom? "(T)

6) I was afraid that people think I am in "satanism" when the project started. (T/C)

7) Cooking porridge on time; became part of our daily practice. So when I delayed, my child said, "Mom, please cook the porridge! "(T/C)

8) The children's appetite has improved (T/C)

9) Before the project, my children did not eat vegetables. But they like vegetables now. (T)

10) My child can eat anything, no dislikes. (C/T)

11) I am spending much time to prepare porridge than before. (T/C)

12) There are improvements on the children's health. (T/C)

(Source: Minutes of the final meeting in Kanakantapa)

Reference

[1] BhuttaZA et al. [2008] "Maternal and Child Undernutrition 3. What works? Interventions for maternal and child undernutiriton and survival." *Lancet, vol.371 (9610) p417-440*

[2] Chatt,C. and Robert, L. [2010] "Access to, and the delivery of, free healthcare in Kanakantapa, and rural Zambia" , *African Journal of Health Science* , vol.14(3-4), p15-25

[3] Food and Agriculture Organization [2010] "Nutrition country profile the republic of Zambia"

[4] Kim,F.M. et al. [2009] "Choice of foods and ingredients for moderately malnourished children 6 months to 5 years of age" , *Food and Nutrition Bullitain,S343-404*

[5] KarkosDP, et al. [2011] [2011]P, utrition Bullitain,S343-404nts for moderately malnourished c*Evidence-Based Complementary and Alternative Medicine*.

[5] Ministry of Health Zambia [2005] "Fourth National Health Strategic Plan 2006 – 2010", p22-24

[6] PelletierDL., Frongillo. E. A., Schroeder D.G., and Habicht J.P. [1995]] "The effect of malnutrition on child mortality in developing countries." *Bulletin World Health Organization*, vol.73(4) p443-448

[7] OsierFH, et al. [2008] "2008] , et al. ealth OrganizationG., and Habicht J.P. [1995]] "The effect of malnutrition on child mortality in developing countries." *Infect Immun vol.76(5), 2240-2248.*

[8] Simpore,J et al [2005] "Nutrition Rahabilitation of the HIV-Infected and Negative Undernourished Children Utlizion Spiruline, *Pakistan Journal of Biological Science* 8 (4):p589-595

[9] SimporeJ, et al. [2006] "Nutrition rehabilitation of undernourished children utilizing Spirulina and Misola." *NutrJ. Vol5(3)*

[10] UNICEF [2013] "Improving child nutrition. The achievable imperative for global progress"

[11] Woodridge, J. M. [2012] "Economic analysis of cross section and panel data 2nd edition", Cambridge, *the MIT press, p146-150*

[12] World Health Organization Department of Nutrition [2011]

[13] Zambia Central Statistical Office [2007], Zambia Demographic and Health Survey 2007

[14] "Pellagra breaks out in famine-hit Zambia" [2002], (http://reliefweb.int/report/zambia/pellagra-breaks-out-famine-hit-zambia)