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Evaluative Studies on the Impact of an Extruded Soy-Cocoa Based Complementary Diet on Growth of the Undernourished Child

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Abstract

Undernutrition among children under five remains widespread culminating predominantly in linear growth deficits (≤ -2SD Units) with its attendant setbacks. Food-based interventions aimed at completely reversing this phenomenon have not had significant impact. Exploring novel dietary interventions has therefore become necessary.

A standard centrally processed food (soyflour + cocoa + corn starch) was subjected to efficacy trial. Using a pretest-posttest controlled experimental design, the impact of the diet was determined on 30 (randomly selected) undernourished children (aged 6-24 months) at the Nutrition Rehabilitation Clinic, Oni Memorial children's Hospital, Ibadan, Nigeria. Anthropometric, Biochemical and haematological measurements were conducted over a two month duration including follow-up observations according to standard methods.

Results of mean values (cm/month) of linear growth velocity observed for intervention (2.59 ± 2.2) was higher and significantly different from control (0.94 ± 0.08) ($p \leq 0.05$). Elimination of linear growth deficits (≤ - 2SD units) was successful in 75% and 30% of test subjects aged 6-12 months and 12-24 months respectively using WHO (2006) child growth standard as reference. These outcomes were at variance from the control ($p \leq 0.05$) where deficits persisted. Serum Albumin normalized, having risen by 21.8% in the intervention from 35.5 g/L but contrasted sharply with control's 4.4% rise from 33.9g/L. Haemoglobin values attained 6.96 mmol/L (Intervention) and 6.14 mmol/L (control) following a similar trend.

The impact of an extruded soy-cocoa based complementary diet has been evaluated and found to be effective in reducing linear growth deficits in children under age two especially those between 6-12 months. Its use for Nutrition rehabilitation is recommended.

Keywords: undernutrition, child, soy-cocoa, complementary food, linear-growth-deficit

1. Introduction

An estimated 870 million people around the world are perceived as undernourished which includes some 165 million under-fives believed to be stunted or chronically malnourished as well as more than 100 million considered underweight (UNICEF, 2013). Under-nutrition (poor nutrition) has been a long standing experience of many children in low and middle income countries especially in South Asia and Sub-Saharan Africa (Walker et al., 2011). The common indicators include stunting (reduced height-for-age), under-weight (reduced weight-for-age) and wasting (weight-for-height below standard). It wreaks havoc on the body and has been implicated as the major underlying cause of death among pre-school children under five (Pelletier & Frongillo, 2003). For children who survive severe under-nutrition, the scars linger into adulthood, and are reflected in small body size with the attendant functional consequences of diminished work capacity, obstetric risk for women as well as poor scholastic and intellectual performance (WHO, 1995). Evidently no nation can afford a generation of men and women incapable of realizing their full genetic potential. The negative economic impact on National development is too enormous to be ignored: direct losses in productivity from poor physical status; indirect losses from poor cognitive function and losses owing to increased health costs (Baudouy & Sarbib, 2006).

In rehabilitating the under-nourished child a number of dietary regimens have been formulated as part of a multifaceted approach in mitigating this challenge (WHO, 2000; Gakidou et al., 2007). Remarkable success in weight gain have been recorded with several diets such as tempe-fortified maize based foods (Osundahunsi & Aworh, 2004) and liquid milk based food (Diop et al., 2003). The same cannot be said of linear growth deficits (stunting).

Gopalan, et al. (1973) observed that some stunted children (1-2 years) in India whose calorie intake were supplemented for 14 months with a diet prepared from wheat flour, sugar and edible oil gained 2.8 cm over the unsupplemented counterpart. The linear growth of some children (initial age 12-24 months) with the same background in Colombia experienced a rise of 5cm over the control group when fed in twelve months with a blend of dry skimmed milk, high protein vegetable (duryea) fortified with Iron and Vitamins (Mora et al., 1981). A similar study in Jamaica involving stunted children (initial age 18-30 months) using a combination of psycho-social stimulation and a food recipe of dry skimmed milk plus milk formula over one year period resulted in a linear growth difference of 1.0cm in the supplemented group (Walker et al., 1991). “Incaparina” made from processed corn, milk and cotton seed flour, vitamin and minerals when fed children with initial age 18-30 months, improved their height by 0.99 cm (Schroeder et al., 1995). Simondon et al. (1996) reported that there was no significant difference in height gain between intervention group and control group of mild to moderately stunted children (initial age 4 months) in a four country-study (Bolivia, New Caledonia, Congo and Senegal) when the children were fed with a supplement of pre-cooked cereal, soyflour, milk powder, vegetable oils and sugar for three months. However, some stunted children in Malawi showed increase in linear growth by 0.2cm over their controlled counterparts within 2 months of feeding with nutrition intervention foods (Ciliberto et al., 2005) (Table 1). Indeed none attained their linear growth velocity expected of their age. In other words subjects were not able to meet up with the increase in growth length of their well nourished peers who have never been malnourished (ACC/SCN, 2001).

Table 1. Outcome of some intervention trials involving use of complementary foods

Reference	Country	Initial age (months)	Duration of Intervention months	Intervention	Impact on growth	Impact on Micronutrient status
Gopalan et al. (1973)	India	12 – 24	14	Wheat floor sugar, edible oil	+ height + weight	NA
Mora et al. (1981)	Colombia	12 – 24	12	Dry skimmed milk, vegetable protein with vitamin and minerals	+ height + weight	NA
Walker et al. (1991)	Jamaica	18 – 30	12	Dry skimmed milk, milk formula	+ height + weight	NA
Schroedder et al. (1995)	Guatemala	3	33	Corn (processed) milk, cotton flout with vitamins and mineral	+ height + weight	NA
Simondon et al. (1996)	Bolivia New Caledonia Senegal Congo DR	4	3	Soyflour, milk powder cereals (pre-cooked) vegetable oils sugar	NS except in Senegal (+height) only	NA
Engelmann et al. (1998)	Demark	8	2	High meat foods	NS	+ Haemoglobin
Osundahunsi and Aworh (2004)	Nigeria	12 – 36	1.3	“tempe”-maize based food with vitamin minerals	height NS + weight	+ Haemoglobin
Cilberto et al. (2005)	Malawi	12 – 36	2	Peanut butter, milk sugar, vegetable oil V/M	+height weight NS	NA

NA = not assessed; NS = not significant; + = increased; - = decreased.

Source: ACC/SCN, 2001, Gopalan et al., 1973, Osundahunsi and Aworh, 2004, Ciliberto et al., 2005.

With the afore-mentioned intervention outcomes and the phenomenon of stunted growth among children under five rising to unprecedented levels, the time for renewed action is now (the window of opportunity for positive action is small - from pre-pregnancy through the first two years of life) (Baudouy & Sarbib, 2006). There is consensus that the damage to physical growth, brain development and human capital formation (potential capability of producing goods and services) that occurs during this period is extensive and largely irreversible. Therefore intervention must focus on this window of opportunity.

Action taken after this critical period are much less likely to improve the situation (Shrimpton et al., 2001).

There is therefore a compelling need to explore the efficacy of novel complementary foods of adequate macro and micro nutrient density for catch-up growth and development after six months in addition to breast milk. Such dietary formula must not only be largely indigenous (in content) and culturally acceptable but also affordable. Moreover, its method of preparation at the point of consumption should take cognisance of the poor level of sanitation and sanitary practices among most of the target group which is the economically weaker segment of the population (Gakidou et al., 2007).

Fortified soy-cocoa based diet, a gruel, developed through low cost extrusion technology (rural friendly) holds great promise in addressing the afore-mentioned concerns (Arueya, 2013). It is therefore the objective of this work to determine the extent and possible impact of this diet on key growth parameters of the undernourished child.

2. Materials and Methods

2.1 Materials

The extruded soy-cocoa based complementary food as characterized (Table 2) was obtained from the food processing unit of the Department of Food Technology, University of Ibadan, Nigeria.

Table 2. Proximate composition of the complementary food (dry weight basis)

Composition (%) (mean ± SD)	
Moisture	0.1±0.09
Protein	21.7±0.4
Fat	3.7±0.2
Ash	3.0±0.1
Crude fibre	0.5±0.1
** Carbohydrate	71.6±0.8
Potassium	1.4±0.2
Phosphorus	0.39±0.1
Calcium	0.21±0.1
Magnesium	0.15±0.1
Sodium (mg/100g)	8.3±0.4
Manganese	2.5±0.2
Iron (mg/100g)	13±1.0
Copper (mg/100g)	3±0.1
Zinc (mg/100g)	2.1±0.1
Polyphenol(mg/100g)	50.41±0.1
Energy Kcal/100g	406.5±5.6

N.B ** carbohydrate was by difference.

♦ Blend: soyflour + cocoa + corn starch.

Source: Arueya (2013).

2.2 Methodology

2.2.1 Nutritional Rehabilitation of the Children

2.2.1.1 Site of Feeding Trial

Oni Memorial Children's Hospital (Nutrition Rehabilitation Centre) Ibadan, Oyo State Nigeria was used for this study. The centre assists mothers/caregivers whose children/wards are contending with food and nutrition related challenges. Practical Demonstrations and Education are part of the regular activities of the centre handling an average of about 20 cases weekly.

2.2.1.2 Study Design

A pretest-posttest controlled experimental design was applied. Two groups comprising in all thirty stunted infants (out patients) were enrolled between late March and early June 2007. One group (Intervention) [n = 15, age 6-24 months (6-12 months n = 8, 12-24months n = 7), sex: male 7, female 8] received the feeding treatment (X) over a period of two months while the second (control group) [n = 15, age: 6-24 months (6-12months n = 12; 12-24 months n = 3), Sex: male 8, female 7] did not. Assignment of subjects to groups was in a completely randomized fashion. The pre-evaluation and post-evaluation was applied to both groups. After the pre-evaluation tests, there was a practical demonstration of preparation of the meal with a nutrient density of 21.7% protein and 406.5 kcal per 100g amongst others (Table 2). This meal made into a gruel (20% w/v) was done by making a smooth paste and gradually pouring same into boiling water, stirring simultaneously until the entire mass became viscous (Figure 1). Administration of the meal in line with standard methods followed. (PAHO/WHO, 2003; Federal Ministry of Health [FMOH], 2005).

2.2.1.3 Sample Size Determination

The number of subjects required per group to provide 90% power to detect difference in treatment outcome (at the 5% level of significance is shown below).

Power		Proportion 2	
90%	40%	50%	60%
Proportion 1			
10%	34	21	14
15%	53	29	18
20%	88	41	24

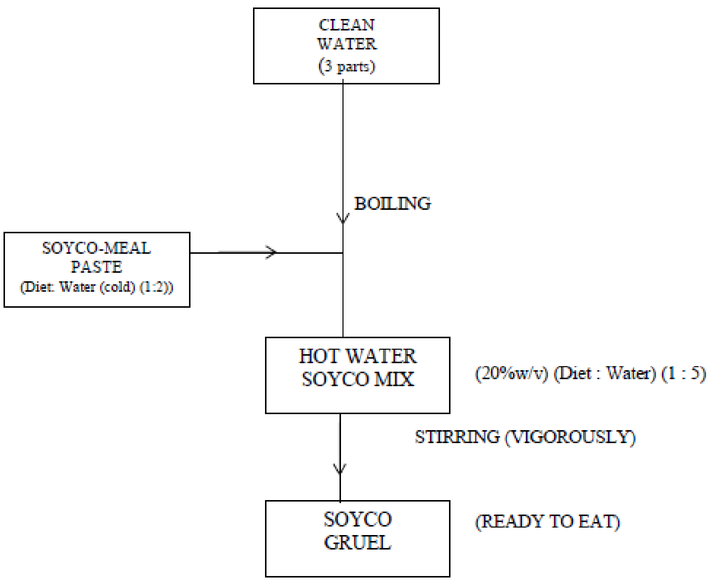

Figure 1. Preparation of soyco-gruel

Based on 60% response (Polit & Sherma, 1990) from a similar study conducted in Colombia (Mora et al., 1981) and a recommendation by Allen and Uauy (1993) per group sufficient to detect a difference in length of 1.0 standard deviation unit with a significance of 0.05 and a power of 80% the following sample size was used for this study: 15 subjects per group (excluding loss to follow-up).

2.2.1.4 Recruitment of Subjects

Using a Technical Assistant (Nutritionist), subjects were enrolled into the study from among children screened free of infection, worm infestation and visible physical and mental handicaps. Those who were within the age group 6 – 24 months and whose standard deviation value for length is ≤ -2 SD Units were asked to wait. The consent of their care-givers were solicited after informing them about the purpose of the study. Growth parameters of subjects during recruitment and random assignment into the two groups were: Intervention group [length (cm) 65.9 ± 6.86, length for age (z-score): -3.25 ± 1.25; weight (kg) 5.75 ± 1.42, weight for age (z-score): -3.57 ± 0.59]; control group [length (cm) 66.1 ± 4.98, length for age (Z-score): -2.93 ± 0.81, weight (kg) 6.31 ± 0.82, weight for age (Z-score): -2.9 ± 0.74] (Table 3).

Table 3. Baseline characteristics of subjects

Characteristics	Control	Intervention
	n = 15	n = 15
Length (cm) @		
Enrolment	66.1± 4.98 (MM)*	65.9 ± 6.86(SM)
1 month intervention	67.08± 4.98 (MM)	69.37 ± 4.9 (MM)
2 months intervention	67.97 ± 4.77 (SM)*	70.97 ± 4.69 (AD)*
Weight (kg) @		
Enrolment	6.31 ± 0.82 (MM)	5.75 ± 1.42(SM)
1 month intervention	6.43 ± 0.74 (MM)	6.37 ± 1.37(MM)
2 months intervention	6.48 ± 0.74 (MM)	6.95 ± 1.28(MM)
Sex		
Male	8	7
Female	7	8
Age (months)	10.7 ± 3.37	11.2 ± 4.39
Length for Age (z – score)	-2.93 ± 0.81	-3.25 ±1.25
Weight for Age (z – score)	-2.9 ± 0.74	-3.57 ± 0.59
Children still Breastfeeding	12	9

NB: * Adequate -2 < z-score < + 2 (AD); Moderately malnourished – 3 < z-score < -2 (MM); Severely malnourished < -3 (SM).

2.2.1.5 Intervention

Every week all subjects and their care-givers were requested to come to the Nutrition Rehabilitation Clinic of the Hospital. The Intervention group were each handed one kilogram of the diet free for the feeding of the subjects five times a day (without prejudice to number of times of breast feeding) (20 g – 1 tablespoonful per meal made into a gruel, i.e. 700g per week). The balance of 300g was expected to be consumed by other members of the household as a strategy to protect the dietary ration of the subject child. For optimum results, those still breastfeeding were advised to allow a sufficient interval (about 20 – 30 minutes) between the complementary feeding and breastfeeding, since milk is known to bind polyphenols preventing the latter from being absorbed into the human body (Serafini et al., 1996).

The control groups were simply given nutrition counselling and various tips on proper hygienic practices when feeding their infants. They were also constantly reassured of getting their share of the test diet immediately after the study.

2.2.1.6 Invasive Sampling

Before and after the 2 month study, blood samples through veni-puncture were collected by a medical personnel and analysed for biochemical/haematological parameters (total serum protein, albumin, packed cell volume, haemoglobin and urea). Randox test kits (Randox Laboratories Ltd., UK) were used for the analysis of these parameters.

2.2.1.7 Data Collection Procedure

Details on relevant Bio-data of the children were ascertained through structured interview. Information on current feeding practices with emphasis on breastfeeding were determined. Comments on the perceived effects of the diet on the subject's health were recorded.

Body measurements such as recumbent length were done by placing the subject on a measuring board (Infantometer). With the mother's assistance, the Head was held firmly against the Board with the eyes looking straight upwards. The knees were pressed straight while moving the sliding board against the heels.

Measurement was done to the nearest 0.1 cm (World Food Program [WFP], 2005). Weights were determined by putting the child on a balance and the readings taken to the nearest 0.1kg. Biochemical/Haemalogical indicators from blood samples were evaluated using Randox test kits at beginning and after the feeding duration.

2.2.2 Follow-Up Details

After 2 months of trial, there was a two week follow-up for any possible negative effect such as allergic reactions.

2.2.3 Instruments

Four separate questionnaires were administered in English and Yoruba by an Assistant to gather pertinent information. These were: Questionnaire A [(pre-evaluation test: Bio-data, current feeding practices)], Questionnaire B [Evaluation test (intervention group only) – weekly observation on diet tolerance, Recumbent length (cm), weight (kg), comments by caregivers], Questionnaire C [Evaluation test (control group only) - weekly observation on diet tolerance, Recumbent length (cm), weight (kg), comments by caregivers] and Questionnaire D [Follow up Evaluation- diet trial termination length/weight, gains of feeding trial sustained or otherwise]. An informed consent form was also used.

2.2.4 Data Analysis

Z-score were calculated for length-for-age (LAZ) and weight-for-age (WAZ) for each subject and group pre, mid and post-feeding duration using standard methods (WFP, 2005). Absolute body length and weight together with their group Z-scores were expressed as mean ± SD. Student t-test was used to determine differences between the intervention group and control group owing to the sample size and random assignment. Length and weight velocities were also computed using WHO Child Growth Standard for 2006 to highlight the catch-up linear growth potential of the complementary food. Students paired t-test was employed to examine the difference between z-scores and WHO (2006) child growth standard reference median, all being treated data. The magnitude of the effect of the diet as reflected in the Z-score between intervention and control group were evaluated by Analysis of Variance (ANOVA). An alpha level of 0.05 was the baseline for all tests. The SPSS version 18.0 (Statistical Package for Social Sciences Incorporated, Chicago) were used for the other data element not mentioned above. Adjustment were made for the confounding impact of breast-milk intake

3. Results and Discussion

3.1 Feeding Practices Evaluation (Pre Intervention 24 Hours Dietary Recall)

Majority of the subjects (70%) participating in the study (Table 3) were found to be partially breastfed at between 5-7 times a day, most (60%) of whom in 6-12 months age bracket. This compares favourably with the findings of UNICEF (2007) that 64% of Nigerian children aged 6-9 months still breastfeed in comparison to the 34% among children aged 20-23 months. Breast milk complemented mainly with ogi (a fermented Nigerian maize gruel) was taken on an average of 5 times in the last 24 hours. The proximate composition of *Ogi* according to Akingbala et al. (1981) consists of protein (6.7%), fat (2.4%), carbohydrate (83.3%) and energy (381.4 Kcal/100g). This poor quality complementary foods caused by poverty and ignorance makes the Nigerian child vulnerable to malnutrition (FMOH. 2005).

3.2 Baseline Characteristics

The baseline characteristics of the control and intervention subjects were as shown in Table 3. The mean ages for control and intervention subjects were 10.7 and 11.2 months respectively having been randomly assigned. The length for age (z-score) for the control (-2.93) compared favourably with those of the intervention group (-3.25); each having about the same sex ratio of male: female (8:7). These baseline characteristics including weights for age z-score in the two groups at the time of enrolment were not statistically different ($p \leq 0.05$) from each other.

3.3 Effect of Diet on Anthropometric Features

Following a two months feeding duration and using length for age z-score as an index of measurement of malnutrition, 75% of subjects (6-12 months old) and about 30% of (12-24 months of age) recovered completely in the intervention group. These were initially either severely (z-score < -3) or moderately (-3 < z-score < -2) malnourished. These results contrasts sharply with those obtained for the control group where none of the subjects within (6-12 months) bracket, but 33% of subjects (12-24 months) recovered. The mid study duration data showed that recovery from linear growth deficit was rapid with more than 65% occurring within the first one month of intervention. The mean length-for-age z score rose from -3.25 to -2.05 after just 1 month of intervention and finally attaining -1.87 at the end of two months. These figures are at variance with those observed for the control having only marginal changes in z-scores. It is obvious by the end of the first month that the z-score for control and intervention groups are significantly different (P ≤ 0.05), a feature sustained till the end of the intervention (Figure 2) The line curve for intervention in Figure 2 tends more towards normalcy rising in the z-score axis (y-axis). This sharply contrasts with the plummeting line graph for control, an indication of a further decrease in z-score (deterioration in nutritional status). Evidently the final attained nutritional status of the intervention subjects is better than the control. Mean scores indicated in Figure 2 at the same time points not followed by the same superscript are significantly different (p ≤ 0.05). About 73% of intervention subjects caught up or exceeded the WHO standard (for length velocity) as against the 6.7% for control (Table 4 and 5). Indeed the mean length velocity for the two were significantly different.

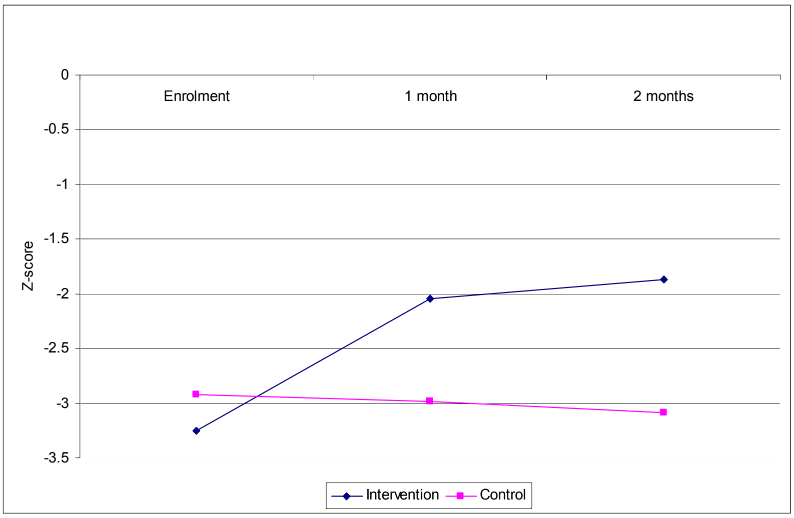

Figure 2. Graph showing change in length-for-age z-score from enrolment to 2 months

Table 4. Analysis of length velocity (intervention subjects)

S/N	Age (Months)	SEX	** REFERENCE (WHO) REFERENCE LENGTH Initial (cm)	Final (cm)	Length Gain (cm)	Feeding Duration (Months)	Length Velocity cm/mth	INTERVENTION SUBJECT SUBJECT LENGTH Initial (cm)	Final (cm)	Length Gain (cm)	Feeding Duration (Months)	Length velocity (cm/mth)	* Catch-Up Factor
1	7	F	67.3	70.1	2.8	2	1.4	59	68	9.0	2	4.5	X 3.2
2	10	F	71.5	74.0	2.5	2	1.25	53.5	71	17.5	2	8.8	X 7.0
3	6	F	65.7	68.7	3.0	2	1.	60	62	2.0	2	1.0	X 0.67
4	8	M	70.6	73.3	2.7	2	1.35	66	75	9.0	2	4.5	X 3.3
5	14	M	78.0	80.2	2.2	2	1.10	71	77	6.0	2	3.0	X 2.7
6	6	F	65.7	68.7	3.0	2	1.5	58	65	7.0	2	3.5	X 2.3
7	17	M	81.2	83.2	2.0	2	1.0	74	76	2.0	2	1.0	X 1.0
8	17	M	81.2	83.2	2.0	2	1.0	74	76	2.0	2	1.0	X 1.0
9	6	F	65.7	68.7	3.0	2	1.5	59	66	7.0	2	3.5	X 2.3
10	6	M	67.6	70.6	3.0	2	1.	60	65	5.0	2	2.5	X 1.7
11	14	M	78.0	80.2	2.2	2	1.1	71	73	2.0	2	1.0	X 0.9
12	14	F	76.4	78.6	2.2	2	1.1	70	74	4.0	2	2.0	X 1.8
13	14	F	76.4	78.6	2.2	2	1.1	70	71	1.0	2	0.5	X 0.5
14	17	F	79.7	81.7	2.0	2	1.0	70	72	2.0	2	1.0	X 1.0
15	12	M	75.7	78.0	2.3	2	1.15	72.5	73.5	2.0	2	1.0	X 0.9

Catch-up Factor = subject length velocity/WHO reference velocity. ** WHO Child growth standard, 2006.

Table 5. Analysis of length velocity (control subjects)

S/N	** REFERENCE (WHO)							CONTROL SUBJECT						
	AGE (MONTHS)	SEX	REFERENCE LENGTH INITIAL (cm)	FINAL (cm)	LENGTH GAIN (cm)	FEEDING DURATION (MONTHS)	LENGTH VELOCITY cm/mth	SUBJECT LENGTH INITIAL (cm)	FINAL (cm)	LENGTH GAIN (cm)	FEEDING DURATION (MONTHS)	LENGTH VELOCITY (cm/mth)	*CATCH-UP FACTOR
16	12	M	75.7	78.0	2.3	2	1.15	68.0	69.5	1.5	2	0.75	X 0.65
17	10	M	73.3	75.7	2.4	2	1.2	63.0	65.3	2.3	2	1.15	X 0.96
18	8	F	68.7	71.5	2.8	2	1.4	63.1	64.6	1.5	2	0.75	X 0.54
19	17	M	81.2	83.2	2.0	2	1.0	76.2	78.0	1.8	2	0.9	X 0.9
20	11	M	74.5	76.9	2.4	2	1.2	68.3	70.1	1.8	2	0.9	X 0.75
21	16	M	80.2	82.3	2.1	2	1.05	73.4	74.4	1.0	2	0.5	X 0.48
22	12	F	74.0	76.4	2.4	2	1.2	68.5	70.2	1.7	2	0.85	X 0.71
23	7	M	69.2	72.0	2.8	2	1.4	62.5	64.7	2.2	2	1.1	X 0.79
24	12	F	74.0	76.4	2.4	2	1.2	63.0	64.5	1.5	2	1.25	X 1.04
25	12	M	75.7	78.0	2.3	2	1.15	69.0	70.4	1.4	2	0.7	X 0.61
26	6	F	65.7	68.7	3.0	2	1.5	60.6	63.4	2.8	2	1.4	X 0.93
27	8	F	68.7	71.5	2.8	2	1.4	61.7	63.3	1.6	2	0.8	X 0.57
28	6	M	67.6	70.6	3.0	2	1.5	58.7	60.7	2.0	2	1.0	X 0.67
29	14	F	76.4	78.6	2.2	2	1.1	70.8	72.7	1.9	2	0.95	X 0.86
30	10	F	71.5	74.0	2.5	2	1.25	65.2	67.4	2.2	2	1.1	X 0.88

* Catch-up Factor = subject length velocity/WHO reference velocity. **WHO Child growth standard, 2006.

The anthropometric indicators of the intervention subjects collectively point to the effectiveness of extruded soy-cocoa and corn starch based complementary food in combating undernutrition. The 75% positive response rate in length-for-age z-score index observed among the 6-12 months old as against 30% for 12-24 months old agrees with the conclusion of Administrative Committee on Coordination – Subcommittee on Nutrition [ACC/SCN], 2001 that optimum results are obtained when interventions are done early in life between 6-12 months. The lack of response in the remainder of intervention subjects may be related to non-dietary factors such as duration of pregnancy, metabolic, physiological and nutritional alterations during intra-uterine development, pre and postpartum infections, pre and postpartum primary or secondary malnutrition ((FAO/WHO/UNU), 2001; Walker et al., 2011).

Linear growth and protein deposition are excellent markers for physiological well being (Reeds & Garlick, 2003). Subjects in the control group some of whom are being partially breastfed had inadequate nutrients such as insufficient protein of 6.7% associated with their diets and therefore had poor linear growth response. Evidently their food intake could not support the growth needs of the body's skeletal system hence the decline (Figure 2). The low nutrient nature of these diets as complementary foods has long been recognized (Achienewu, 1991).

The rapid recovery from the linear growth deficit may have to do with apparent high digestibility/absorption of the nutrient dense food from extrusion cooking. This unit operation reinforced by starch gelatinization at the point of preparation prior to consumption undoubtedly enhanced nutrient bioavailability. By virtue of frequency of consumption (100g diet spread over five times daily) coupled with obvious compliance to feeding guidelines, the final nutritional status attained has a sound basis. Specifically, compliance with the guideline of allowing an interval of about 30mins between breast milk intake and the actual diet is not in question and may have contributed significantly to the rate of recovery. This is imperative in view of Serafini el al. (1996) that reported total loss of anti-oxidative activity of tea (related to polyphenols) following in-vivo studies involving humans who consumed black and green tea with varying levels of milk. The linear growth velocity of 3.65cm gain in length per month among intervention subjects of 6-12 months old is remarkable. Also, the linear growth velocity advantage associated with the intervention subjects (12-24 months age bracket) namely: 1.3cm gain in length per month compared favourably with the 0.98 cm gain in length per month reported in Jamaica (Mora et al., 1981) where a similar study was conducted. The values obtained in this study was higher than the 0.66 cm gain in length per month in India (Gopalan et al., 1973); 0.84 cm gain in length per month in Colombia (Walker et al., 1991); 0.74 cm gain in length per month in Guatemala (Schroedder et al., 1995) and 0.05 cm gain in length per month in Malawi (Ciliberto et al., 2005). The dietary response also had the added advantage of exceeding the

WHO standard reference linear growth velocity for well nourished children, a pre-requisite for a complete catch-up growth. Evidently the diet may have an overall effect on hyperplasia (cell multiplication) of body's skeletal system synonymous with increase in length/height/stature. In analysing the overall outcome of the studies mentioned above, there may have been confounding factors. This might include variation in whether the actual feeding was done at the subject's home or in centralized feeding centres. These though do not nullify the effect of the diet on the growth response in view of the controlled nature of the studies.

The weight analysis for intervention subjects and control indicate that only 13% (6-12, 12-24 months) had their weight deficits (≤ -2 z-score) completely eliminated compared with none for control group. Evidently the cumulative impact of the diet on weight gain following enrolment is comparatively marginal in relation to the food consumed by the control group. The impact of the food on weight gain and weight velocity (weight gain over time) was not as significant ($P \leq 0.05$) as on length gain and length velocity. This may be linked to the low fat content (3.7%) which contrasts with a diet (35.7% fat) used to achieve rapid weight gain in malnourished children (Diop et al., 2003). This low fat property of the diet has the inherent benefit of contributing to reduced gross energy, oxidative stability and better keeping quality. The concomitant weight gain observed though marginal must be those associated with gain in length. If children are gaining weight as well as increasing in length at an appropriate rate, then there is every likelihood that other aspects of physiological well-being would be adequately met by the diet (Reeds & Garlck. 2003). Consequently to be truly effective, diets such as this for catch-up growth have to provide all nutrients in amounts that are proportionally higher than those required by well nourished infants (FAO/WHO/UNU, 2001). The poor quality food intake of the control group in the study period followed the pattern of the pre-intervention 24 hours dietary recall earlier reported and hence could not support catch up growth.

3.4 Effect of Diet on Biochemical Markers

Intervention subjects starting from a mean serum protein level 60 g/L eventually attained 71 g/L. The margin of change is significantly different from that for control 60.8 g/L to 64.5 g/L ($p \leq 0.05$). Albumin levels rose from 35.3 g/L to 43 g/L for intervention group. This is in sharp contrast to that of control rising from 33.9 g/L to 35.4 g/L within the same period. Mean haemoglobin (Hb) values at the beginning of the trial for intervention group was 6.32 mmol/L. This rose to 6.96mmol/L at the end of the study.

The values obtained for the control were 6.02 mmol/L at the start but only attained 6.14 mmol/L at the close of study duration. Urea levels margin of change within the period for both groups compared favourably. When some of these indices (such as albumin) and their absolute values were examined within the permissible limits (Gibson, 2005; Wu, 2006) 67% of intervention subjects became normal as against only 9% of control subjects. Using haemoglobin as an index, 64% of intervention subjects attained normal values after the trial.

This is in contrast to none in the control groups. Urea levels did not however change for both groups. The remarkable improvements in sensitive biochemical and haematological indices underscores the veracity of the fact that other aspects of physiological well-being would be adequately met by the diet if children are gaining weight as well as increasing in length at an appropriate rate. The serum albumin level is one of the most useful biochemical indicators in protein-energy malnutrition because of the relative ease with which it can be measured. It is an excellent indicator of the effect of treatment during the early stages of rehabilitation. The albumin concentration rises very rapidly, long before body weight or muscle mass are restored to normal (De Maeyer, 1976; Osundahunsi & Aworh, 2004). Rise in packed cell volume and haemoglobin concentrations buttress the micro-nutrient adequacy (such as iron) of the diet against anemia commonly associated with Protein Energy Malnutrition (PEM). Kidney functions are seemingly not affected going by the urea levels (18.11 mmol/L) in the intervention group which compared favourably with the control ($p \leq 0.05$).

3.5 Follow Up Study (Observations)

Visual observation and comments (two weeks after the conclusion of the study) from the care givers showed no adverse reaction to the food. Subjects were indeed satisfied with the outcome. It is noteworthy that mothers/care givers in the present study reported other untargeted benefits which include improved appetite, absence of flatulence, physical well being and motor development (sitting without support, standing with assistance etc).

4. Conclusion

The human feeding study involving undernourished children showed that the diet has a tremendous potential for catch up growth using linear growth as a major indicator of recovery. Indeed the diet can be used as a veritable part of food based approaches in fighting under nutrition among children under one year of age – the most crucial growth period in life. A broader picture of the impact of the diet on growth may become evident when alternate experimental designs, larger sample size and longer study duration are employed.

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