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Ready-to-Use Supplementary Food Increases Fat Mass and BMI in Haitian School-Aged Children[1–3]

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Abstract

Background: In Haiti and other countries, large-scale investments in school feeding programs have been made with marginal evidence of nutrition outcomes.

Objective: We aimed to examine the effectiveness of a fortified ready-to-use supplementary food (RUSF), Mamba, on reduced anemia and improved body composition in school-aged children compared to an unfortified cereal bar, Tablet Yo, and control groups.

Methods: A cluster, randomized trial with children ages 3–13 y (n = 1167) was conducted in the north of Haiti. Six schools were matched and randomized to the control group, Tablet Yo group (42 g, 165 kcal), or Mamba group (50 g, 260 kcal, and >75% of the RDA for critical micronutrients). Children in the supplementation groups received the snack daily for 100 d, and all were followed longitudinally for hemoglobin concentrations, anthropometry, and bioelectrical impedance measures: baseline (December 2012), midline (March 2013), and endline (June 2013). Parent surveys were conducted at baseline and endline to examine secondary outcomes of morbidities and dietary intakes. Longitudinal regression modeling using generalized least squares and logit with random effects tested the main effects.

Results: At baseline,14.0% of children were stunted, 14.5% underweight, 9.1% thin, and 73% anemic. Fat mass percentage (mean ± SD) was 8.1% ± 4.3% for boys and 12.5% ± 4.4% for girls. In longitudinal modeling, Mamba supplementation increased body mass index z score (regression coefficient ± SEE) 0.25 ± 0.06, fat mass 0.45 ± 0.14 kg, and percentage fat mass 1.28% ± 0.27% compared with control at each time point (P < 0.001). Among boys, Mamba increased fat mass (regression coefficient ± SEE) 0.73 ± 0.19 kg and fat-free mass 0.62 ± 0.34 kg compared with control (P < 0.001). Mamba reduced the odds of developing anemia by 28% compared to control (adjusted OR: 0.72; 95% CI: 0.57, 0.91; P < 0.001). No treatment effect was found for hemoglobin concentration.

Conclusion: To our knowledge, this is the first study to give evidence of body composition effects from an RUSF in school-aged children. *J Nutr* 2015;145:813–22.

Keywords: micronutrient-fortified food, fat mass, hemoglobin concentrations, longitudinal regression, dietary intakes

Introduction

Nutrition deficiencies may be less apparent in older children compared with younger children who are experiencing the rapid growth of the first 1000 d of life. Yet vital nutrition processes are likely unfolding in school-aged children, affecting brain development, immunity, and physiology (1). One review of studies examining the nutritional status of school-aged children from developing and transitioning countries found that 20–30% of children had deficiencies in iron, iodine, zinc, and vitamin A (2). Anemia similarly affects high proportions of children >5 y of age (2–4). Globally, large-scale investments in school feeding programs exceed other types of food aid programs, although findings for positive nutrition impacts attributable to these programs have been mixed (5, 6). This may in part be explained by the limited repertoire of nutrition measures applied and the challenges faced in the cluster design of many school-based interventions.

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[3] Supplemental Table 1 is available from the ''Online Supporting Material'' link in the online posting of the article and from the same link in the online table of contents at http://jn.nutrition.org.
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In Haiti, little is known about the nutritional status of school-aged children. Only one study was identified examining anthropometry in Haitian youth ages 11–19 y. This study found that 37% of girls and 45% of boys were stunted (7). Among young Haitian children, studies have shown low dietary diversity and limited animal source food consumption, suggesting widespread micronutrient inadequacies (8, 9). School feeding programs, ostensibly delivered to address nutrition in this age group, are pervasive in Haiti and operate largely outside of the public system. These programs typically offer rice, beans, and oil at mid-day or a morning snack cereal bar; few programs have been rigorously evaluated to understand the nutritional impacts (10).

This longitudinal, cluster, randomized controlled school feeding trial aimed to test the effectiveness of a micronutrient-fortified ready-to-use supplementary food (RUSF)[8], Mamba (50 g, 260 kcal, and >75% of the RDA for critical micronutrients), on nutritional outcomes in school-aged Haitian children compared to an unfortified cereal bar, Tablet Yo (42 g, 165 kcal), and a control group. We hypothesized that children consuming a daily fortified RUSF snack would show reduced prevalence of anemia and improved body composition outcomes by increasing fat-free and fat mass, compared to an unfortified cereal bar, Tablet Yo, or no food supplement. We previously demonstrated that a similar lipid-based nutrient supplement (LNS) was highly acceptable in Haiti and efficacious in increasing linear growth among young children 6–18 mo of age (8, 11). To our knowledge, this is the first trial to test the effects of a specially designed RUSF in school-aged children in Haiti.

Methods

Study schools and participants. The study was conducted in Cap Haitien, the second largest city in Haiti, located in the North Department. Stunting affects 1 in 4 children in the North Department, greater than the national average (12). Formative research was first carried out from March to August 2012 to identify and match schools with similarities in socioeconomic and nutrition factors. A consultant and the principal investigator conducted this research in cooperation with the Ministry of National Education and Professional Training (Ministère de l'Education Nationale et de la Formation Professionnelle). The Ministry of National Education and Professional Training National School Feeding Program (Program National de Cantine Scholaire) provided a comprehensive list of schools in the area.

Twenty eligible schools were identified based on student population, nonparticipation in other school feeding programs, and geographic location (**Figure 1**). Six schools were selected and grouped into matched pairs to achieve comparability based on size, socioeconomic characteristics, and child anthropometry. The pairs were then randomized simultaneously through an allocation number sequence to study group. Group allocation was concealed until the start of the school year, although masking or blinding to group assignment was not possible during the intervention period.

Recruitment and enrollment. All parents of potentially eligible students from the 6 schools were contacted and consented to the participation of their child in the study. The process was initiated through administrator and teacher meetings at the start of the academic year to inform parents about the study. Phone calls were then made and notes were sent home by school officials to parents of potentially eligible students to invite them to information meetings held in October 2012.

Children of interested caregivers were screened for eligibility based on the following criteria: aged 3–13 y; good health (no fever, congenital health condition, or peanut or soy allergy); not severely malnourished [weight-for-height z score (WHZ) < -3]; and registration in study school for 2012–2013. The schools included both preschool-aged and primary school–aged children. We originally planned to enroll children in a more narrow age range, 3–10 y, but expanded to 13 y to reach sufficient sample size. Once eligibility was established, caregivers went through the informed consent process. Written consent forms were read aloud to parents by the enumerators in case of illiteracy, and signatures or crosses signifying consent were obtained. Children were then asked to give verbal assent. A total of 1169 children were eligible and 1167 were enrolled; only 2 parents did not agree to have their children participate in the study, stating the reason that they did not understand or trust the project. One parent-child pair was from the Mamba group and the other from the control group.

Sample size estimations were based on a hypothesized reduction in anemia prevalence in the Mamba group compared to control. An effect size was estimated by combining evidence for anemia reduction from a Sprinkles trial conducted among young children in Haiti (13) together with the findings from school-based studies of fortified supplementation programs in other countries (14, 15). We hypothesized a reduction from 48.3% (16) to 33%. For the 6 schools included in this study, the intracluster correlation coefficient for anemia at baseline was 0.02. Assuming a 10% attrition rate and a design effect induced by school clusters, we estimated requiring 390 per group ($\alpha = 0.05$ and $1\text{-}\beta = 0.80$), for a total of 1170 children.

The study was approved by the National Bioethics Committee of the Ministry of Health (Ministère de la Sante Publique et de la Population) in Haiti and the Institutional Review Board of the Human Research Protection Office of Washington University in St. Louis.

Study design and intervention. The study was a cluster, randomized controlled trial to examine the effectiveness of a fortified peanut butter paste, RUSF, on child hemoglobin concentrations, anemia, anthropometry, and body composition outcomes. A cluster design was applied with schools as the unit of randomization in view of the potential for spill-over effects and social problems that might arise from randomly assigning children to control or different snack groups within schools. Children were followed longitudinally for hemoglobin concentration, anthropometric measures of height and weight, and bioelectrical impedance measures of resistance and reactance at 3 time points: baseline (December 2013), midline (March 2013), and endline (June 2013). Parents were surveyed for household level socioeconomic and demographic information, water and sanitation information, and child diet and morbidities at baseline (January 2013) and endline (June 2013). Administrators in all schools were interviewed at endline (June 2013) to ascertain the deworming and micronutrient supplementation activities in the schools and community.

All children in the Mamba and Tablet Yo schools received the food once per day for a total of 100 d, 90 school days from January to June 2013, and 10 d of spring vacation (March/April 2013) as a take-home ration. Compliance was monitored by enumerators on all school days. Enumerators distributed the Mamba and Tablet Yo cereal bars to students, observed consumption of snacks, and collected empty packages each day. Children in the control schools received Mamba the following academic school year, 2013–2014.

The nutrient specifications of Mamba were developed by the principal investigator after a literature review of the nutritional needs and deficiencies of school-aged children from resource-poor countries (17). Edesia, a US-based nonprofit manufacturer of ready-to-use foods with an expertise in research and development, developed the product based on these desired nutrient specifications. Acceptability testing of the Mamba product was conducted before the intervention study during March 2012 with a subsample of children and parents ($n = 53$) and found acceptable taste, color, and texture. The packaging for Mamba was also tested with use of multiple illustrations, phrases, colors, and overall designs. Crèmes Caprice in Port-au-Prince, Haiti, produced the Tablet Yo cereal bar. This product was selected because it has been used for several years in Haitian school programs with established acceptability among the children and because the production price was similar to Mamba; Tablet Yo is unfortified.

The Mamba and Tablet Yo products were tested by Certified Labs, Inc., in the United States for nutrient composition (**Supplemental Table 1**).

[8] Abbreviations used: BIA, bioelectrical impedance analysis; LNS, lipid-based nutrient supplement; RUSF, ready-to-use supplementary food; WHZ, weight-for-height z score.

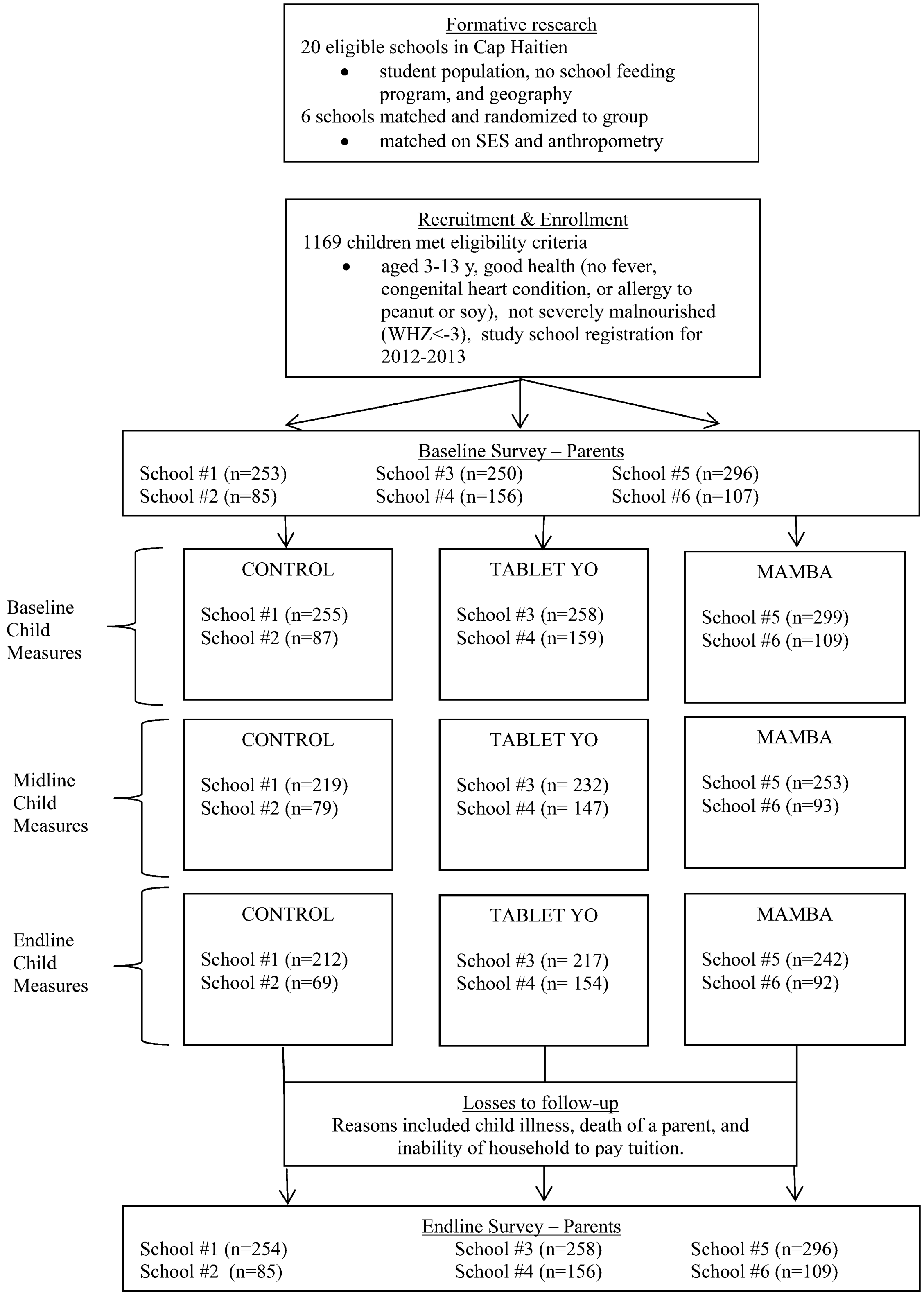

FIGURE 1 Flow diagram of snack intervention trial in Haitian school children. Formative research identified eligible schools based on a set of criteria. Similar schools were then matched and randomized into study arms. After parents were informed of the study, eligible children were recruited and enrolled. Parents were surveyed on socioeconomic and demographic information, child diet, and morbidities at baseline and endline. Children were followed at 3 time points (baseline, midline, and endline) for measures of hemoglobin concentration, height, weight, and bioelectrical impedance measures of resistance and reactance. SES, socioeconomic status; WHZ, weight-for-height *z* score.

Macro- and micronutrient quantities of Mamba were greater than Tablet Yo and consistently met higher proportions of the RDA for children ages 4–8 y.

Anthropometry, hemoglobin concentration, and bioelectrical impedance measures. Child growth, hemoglobin concentration, and body composition outcomes were measured 3 times during the study period in a designated space at each of the 6 schools. For anthropometry, the Seca Model 874 (Digital) 440-lbs × 0.1-lb resolution scale and the ShorrBoard height measuring board were used to collect parent and child weight (to the nearest 0.1 kg) and height measures (to the nearest 1 mm) with use of international protocols (18).

These measures were used to determine BMI [weight (kg)/height (m)^2], anthropometric z scores, and the prevalence of stunting (height-for-age z score < −2), underweight (weight-for-age z score < −2), wasting (WHZ < −2), and thinness (BMI z score < −2) based on WHO Growth Standards (2006) (19) for children 3–5 y of age and WHO Growth References (2007) (20) for children 6–13 y of age. Child lengths and weights were measured twice, and if there was a difference >0.5 mm and >0.5 kg, respectively, a third measurement was taken. Children identified during the study with severe acute malnutrition (WHZ < −3) were removed from the study and referred to the healthcare system. One child from the Mamba group and 2 children from the control group were referred and treated for infection. All 3 children were readmitted to the study after recovery.

Hemoglobin concentrations in all children were determined with use of the Hemocue system, which measures RBC status reported in grams per 100 milliliters (g/dL). Blood was collected in a sterile fashion with a finger stick and a microcuvette in one continuous process and tested in the Hemocue system. The results were compared to WHO anemia cut-offs for anemia in children ages 0–4.9 y, 11.0 g/dL; 5–11.9 y, 11.5 g/dL; and 12–14.9 y, 12.0 g/dL (21).

Bioelectrical impedance analysis (BIA) with the compact Quantum II–BIA analyzer (RJL Systems Inc.) (800 μA; 50 kHz) determined changes in body composition based on a 2-compartment model: *1*) fat mass and *2*) fat-free mass. Protocols developed by the Center for Human Nutrition at Washington University Medical School were used. Children first removed their right shoe and sock and laid down in the supine position on a nonconductive mat surface. Electrode sites were cleaned with alcohol, and the electrodes were placed on the child's right hand and right foot. Reactance (Xc) and resistance (R) values were then read and recorded 3 times. A fourth measure was taken when measures were different by 2 ohms for reactance and 5 ohms for resistance. The mean of these measures was recorded. Measures were taken at the same time of day, mid-morning, at baseline, midline, and endline.

Caregiver surveys and school attendance. Two caregiver surveys were administered, at baseline (December 2012) and at endline (June 2013), to assess household level socioeconomic and demographic factors, caregiver anthropometry, and changes in child morbidities and dietary intakes. These surveys were also undertaken at the schools on scheduled dates with caregivers. Household demographics, income and assets, water, hygiene and sanitation practices and conditions, and caregiver education and livelihood activities were captured.

Child diet was assessed with use of a 24-h food frequency of intake administered during the caregiver survey at baseline and endline. Enumerators asked caregivers to recall the number of times the child had consumed various foods in the previous 24 h. Foods commonly consumed in Haiti in this age group, identified during the formative research phase, were grouped as the following: bread (cassava); bread (white, wheat); cereals, porridge, or other grains (rice, maize, wheat, millet, sorghum, spaghetti, and other pastas); roots and tubers (cassava, potatoes, yams, cooking bananas, other); beans and other legumes (beans, peas, groundnuts, grams, other); eggs; milk (cow, goat); fermented milk or yogurt; cheese and other dairy products; poultry (chicken, duck, guinea fowl, other); meat (beef, goat, pork, lamb, other); fish and shellfish (large and small fish); fruits; vegetables; oils, butter, and other fats; crackers; and cookies. We calculated dietary diversity by first generating dummy variables for whether or not the child had consumed each food item or group listed above ≥1 time, and then summing the variables for total number of different groups consumed in a 24-h period (22). The dietary diversity score could range from 0 to 17. Structured observations were also made at each school to assess food and drink availability and cost during the school days.

Child morbidity outcomes were assessed with use of caregiver recall at baseline and endline. Caregivers were asked whether the child had experienced a diarrhea morbidity in the previous 2-wk period [acute diarrhea (≥3 semisolid or liquid stools in a 24-h period), number of days with acute diarrhea, and bloody diarrhea]. Caregivers also were asked whether the child had experienced other morbidities during the previous month [malaria, fever, respiratory condition (cough plus short, rapid breathing), eye infection, ear infection, skin conditions, and helminth infection].

School attendance for all children participating in the study was tracked daily by enumerators, and reasons for absences were collected weekly from teachers and the index child or from peers and siblings. Additional information regarding school personnel, facilities, and environmental conditions was collected during the intervention period to supplement the formative research. Only 1 school from the Mamba group had access to water from a pump on the grounds. Children from other schools purchased water and other beverages from vendors or brought drinks from home. All schools had pit latrines for sanitation; the mean student-to-latrine ratio was 145 but ranged from 55 to 213.

Statistics. Descriptive statistics were first applied to examine characteristics of the sample and the primary and secondary outcomes. Univariate tests including chi-square tests, t tests, and ANOVA compared socioeconomic and demographic characteristics, anthropometry, body composition measures, hemoglobin concentration, anemia prevalence, morbidity, and attendance outcomes across trial arms. Change in anthropometric z scores and body composition measures from baseline to endline were tested for statistical difference by group with use of ANOVA and t tests. Values for continuous outcomes are presented as means ± SDs, except for coefficient values in regression models presented as means ± SEEs. P values < 0.05 were considered significant.

Two sets of validated equations were applied for deriving body composition measures of fat mass and fat-free mass with use of the reactance and resistance measures taken in the study. We first applied the in-built equations for the Quantum II analyzer derived from a sample of German children (23). The second set of equations, validated with deuterium dilution, were from a sample of school-aged children in Gambia, selected for use in this study given the comparability to Haitian environmental conditions and child nutrition (24):

$$\begin{aligned}\%\text{fat free mass} = \exp[&8.332 + 1.006\ln(\text{height}) \\ &- 0.537\ln(\text{weight}) - 0.360\ln(z) \\ &+ 0.034\text{sex} - 0.008\text{age} + 0.001\text{age}^2]\end{aligned} \quad (1)$$

Fat mass, fat-free mass, and proportionality values were determined from both sets of equations and found to be highly correlated: 0.97 for fat mass and 0.94 for fat-free mass, by Pearson's correlation coefficient. A decision was made to use the Gambia equations given relative comparability to the Haiti context.

Longitudinal modeling for the primary outcomes (hemoglobin concentration, anthropometry, and body composition) were conducted with generalized least squares with random effects (25). We examined the preventative effect of Mamba on reducing the adjusted odds of anemia, stunting, underweight, and wasting at 3 time points with use of panel regression logit models with random effects. Similarly, the logit models were applied to examine adjusted odds of the dichotomous morbidity outcomes. The longitudinal analyses tested differences in the change in continuous and dichotomous outcomes for each child over the 3 time points, compared to the univariate analyses, which examined cross-sectional differences at each time point in average group outcomes. In all regression models, we tested both the group effect (control = 1, Tablet Yo = 2, and Mamba = 3) and the Mamba compared to the control-only effect (control = 1 and Mamba = 2). All inference analyses for the effectiveness of Mamba on outcomes used intention to treat.

To account for school clusters, dummy variables were created to represent one school from each group and included as covariates in the models. Household, caregiver, and child level factors found to differ significantly across clusters were tested as independent variables in the models. The factors were retained in the final models if found to be significant (P < 0.05) and not highly correlated with other terms (r ≤ 0.7). Substrata analyses tested for differential effects based on age [2–5 y (preschool), 6–8 y, 9–11, and 12–13 y] and sex of the child for the primary outcomes only. Regression diagnostics using residual plots were also conducted to assess goodness of fit for covariates. Data analyses were performed with STATA software (version 11.1; StataCorp).

Results

Across the 3 groups, mothers (60.6%) were the primary respondents in the parent survey, followed by fathers (18.0%), others (15.0%), siblings (3.7%), and grandmothers (2.6%). The mean age of children in the study was higher in the control schools compared to Tablet Yo and Mamba schools (**Table 1**). Maternal education level did not differ across groups. On average, maternal BMI was higher than paternal BMI, with no differences by group.

One-half of all parents reported participation in a Sol savings club, a common practice in Haiti where members contribute a set amount of money on a regular basis with the opportunity to periodically draw on the entire pool. The majority of households reported monthly incomes in the lowest category. Mothers were primarily employed in commerce (66.4%), buying and selling goods in Cap Haitien, and approximately one-fifth were unemployed (20.8%). Fathers, by contrast, were employed in construction (24.0%) or other types of employment (33.5%), farming (10.8%), and commerce (10.0%). Pit latrines were the most common toilet type used by households.

Anemia and hemoglobin concentration. Prevalence of anemia was high across all time points and among all children: baseline 73.3%, midline 69.3%, and endline 70.2%. Anemia prevalence did not differ by group in univariate analyses at midline ($P = 0.47$) or endline ($P = 0.32$), nor for mean hemoglobin concentration at midline ($P = 0.83$) or endline ($P = 0.40$). In regression modeling adjusted for child age, sex, and school cluster, the change in hemoglobin concentration did not differ by group ($P = 0.78$). Mamba supplementation compared to control did show a reduced odds of developing anemia for children by 28% compared to control (adjusted OR: 0.72; 95% CI: 0.57, 0.91; $P < 0.001$). The group effect (control = 1, Tablet Yo = 2, and Mamba = 3) demonstrated a reduced odds by 15% (adjusted OR: 0.85; 95% CI: 0.76, 0.95; $P = 0.004$). Parent-reported deworming at endline of the index child in the previous 6 mo varied by group: control, 80.6%; Tablet Yo, 72.4%; and Mamba, 76.5% ($P = 0.02$). School administrators in 3 schools, 2 control schools and 1 Mamba school, confirmed dates of deworming administration. Administrators from 1 control

TABLE 1 Socioeconomic and demographic characteristics of Haitian schoolchildren and caregivers by snack intervention and control groups[1]

	Control (*n* = 324)	Tablet Yo (cereal bar) (*n* = 415)	Mamba (RUSF) (*n* = 377)	All (*n* = 1116)
Child characteristics				
Age,[2] y	9.3 ± 2.3	7.3 ± 2.0	8.0 ± 2.7	8.1 ± 2.5
Sex,[2] %				
Female	58.1	49.4	50.1	52.2
Male	41.9	50.6	49.9	47.8
Caregiver characteristics				
Maternal education, y	4.3 ± 3.4	4.4 ± 3.4	4.7 ± 3.7	4.5 ± 3.5
Maternal BMI, kg/m^2 (*n* = 945)	23.5 ± 5.6	22.9 ± 4.2	23.4 ± 4.2	23.3 ± 4.7
Paternal BMI, kg/m^2 (*n* = 200)	21.0 ± 3.2	21.9 ± 2.4	21.1 ± 3.0	21.4 ± 2.8
Household characteristics				
Total household members, *n*	6.6 ± 2.7	6.4 ± 2.6	6.3 ± 2.6	6.4 ± 2.6
Sol savings club participation, %	50.9	53.3	46.3	50.0
Monthly income,[2] %				
100–500 $H	65.8	71.8	59.4	65.8
501–800 $H	15.5	13.0	15.1	14.4
801–1000 $H	5.6	7.7	10.8	8.1
≥1001 $H	13.0	7.5	14.5	11.5
Electricity,[2] %				
Always	3.4	8.2	12.9	8.4
Sometimes	44.4	51.4	47.6	48.0
Never	52.2	40.4	39.5	43.6
Toilet type,[2] %				
Automatic flush	8.5	4.6	9.0	7.2
Latrine	84.9	73.4	68.3	74.3
No toilet	6.6	22.0	22.7	18.5
Share toilet with other households	31.0	40.9	43.8	39.6
Drinking water source,[2] %				
Faucet inside home	18.2	36.5	17.0	25.9
Public pump	17.5	3.9	11.8	10.0
Sachet or potable water	62.0	54.8	66.2	60.8
Other (truck, well, spring, surface)	2.3	4.8	5.0	4.3

[1] Values are means ± SDs and percentages. RUSF, ready-to-use supplementary food; $H, Haitian dollars.
[2] Groups are significantly different by ANOVA or chi-square, $P < 0.05$.

school also reported some children had received iron supplements from a community-based program.

Anthropometry and body composition. The school children showed negative mean *z* scores throughout the study period across all groups (**Table 2**). Prevalence of undernutrition at baseline before the intervention for all children was 14.0% stunted, 14.5% underweight, and 9.1% thin. Univariate statistical differences in weight-for-age *z* score change from baseline to endline were evident for Mamba compared to Tablet Yo and Tablet Yo compared to control ($P < 0.05$). Mean BMI *z* score change differed significantly across all groups, whereas there were no differences by group in mean height-for-age *z* score change.

Measures of body composition for the school-aged children in Haiti at baseline differed by age group and sex ($P < 0.05$) (**Table 3**). The percentage of fat mass was higher in girls compared with boys and showed reductions in both boys and girls after preschool age (2–5 y).

Fat-free mass increased on average across all groups with univariate statistical differences in the change in fat-free mass evident for Mamba compared to Tablet Yo and Mamba compared to control ($P < 0.05$) (**Table 4**). By contrast, mean fat mass decreased in the control group but increased in the Mamba and Tablet Yo groups from baseline to endline (ANOVA, $P < 0.001$). Children from all 3 groups experienced losses on average in the percentage of fat mass, but the reduction in the Mamba group was smaller than the Tablet Yo and control groups (ANOVA, $P < 0.001$).

In longitudinal generalized least squares modeling for the main trial effects, supplementation with Mamba or Tablet Yo cereal bar significantly increased BMI *z* score, fat mass, and percentage of fat mass in the school-aged children at each time point compared with those in the control group (**Table 5**). In subgroup longitudinal regression analyses, Mamba supplementation in boys increased both fat mass (regression coefficient ± SEE) 0.73 ± 0.19 kg and fat-free mass 0.62 ± 0.34 kg compared with the control group boys ($P < 0.001$). In girls, there was a positive group effect on increased percentage fat mass (regression coefficient ± SEE) of 0.36 ± 0.18 ($P = 0.05$). The odds of wasting for children 3–5 y of age was reduced by 55% in the Mamba group compared to the Tablet Yo and control groups (adjusted OR: 0.44; 95% CI: 0.38, 0.89; $P < 0.001$).

School attendance and other outcomes. Absentee data were collected on the 90 school days of the intervention period. Children in the Mamba and Tablet Yo groups showed a higher rate of absences than the control group children ($P < 0.001$). The primary reasons cited for absences among all the children were fever, diarrhea, vomiting, asthma, conjunctivitis/eye problems, stomach pains, headache, or general illness. Supplementation with Tablet Yo or Mamba significantly reduced the odds of parent-reported malaria and ear infection in the school children, but increased the odds of parent-reported respiratory infection and fever in longitudinal modeling controlling for child age, sex, and school cluster ($P < 0.001$). Dietary diversity scores were reduced from baseline to endline, with statistical differences by group: control (−1.6 ± 2.3), Tablet Yo (−1.1 ± 3.0), and Mamba (−0.8 ± 2.5) (ANOVA, $P = 0.005$). At endline, there were statistically different diversity scores for the Mamba group compared to the control group (difference of 1.1 ± 0.13, $P < 0.001$) and the Tablet Yo group compared to the control group (difference of 1.1 ± 0.15, $P < 0.001$).

Discussion

Among Haitian school-aged children, the fortified Mamba snack delivered daily for 5 mo significantly increased absolute fat

TABLE 2 Anthropometry of Haitian school children by snack intervention and control groups[1]

	Control	Tablet Yo (cereal bar)	Mamba (RUSF)
Weight-for-age *z* score			
Baseline	−0.78 ± 1.19	−0.82 ± 1.11	−1.10 ± 1.18
Midline	−0.87 ± 1.11	−0.74 ± 1.21	−0.87 ± 1.20
Endline	−0.98 ± 0.98	−0.81 ± 1.07	−0.90 ± 1.08
Mean total change[2]	−0.14 ± 0.67[a]	0.01 ± 0.54[b]	−0.01 ± 0.33[b,c]
Height-for-age *z* score			
Baseline	−0.76 ± 1.18	−0.67 ± 1.35	−0.90 ± 1.23
Midline	−0.75 ± 1.20	−0.64 ± 1.28	−0.93 ± 1.24
Endline	−0.86 ± 1.16	−0.74 ± 1.26	−0.99 ± 1.20
Mean total change[3]	−0.09 ± 0.53[a,b,c]	−0.09 ± 0.58[a,b,c]	−0.11 ± 0.54[a,b,c]
BMI *z* score			
Baseline	−0.68 ± 1.17	−0.67 ± 0.93	−0.71 ± 1.04
Midline	−0.88 ± 1.01	−0.62 ± 1.08	−0.51 ± 1.18
Endline	−0.88 ± 0.96	−0.65 ± 0.85	−0.69 ± 1.01
Mean total change[4]	−0.19 ± 1.06[a]	0.07 ± 0.48[b]	0.02 ± 0.49[c]

[1] Values are means ± SDs. Sample sizes for the control group were baseline (n = 300), midline (n = 285), and endline (n = 269). Sample sizes for the Tablet Yo group were baseline (n = 362), midline (n = 366), and endline (n = 338). Sample sizes for the Mamba group were baseline (n = 310), midline (n = 333), and endline (n = 316). Weight-for-age *z* score was only available for children <11 y of age (20): control group (n = 175), Tablet Yo group (n = 330), and Mamba group (n = 221). RUSF, ready-to-use supplementary food.

[2] Unadjusted difference in mean total change in weight-for-age *z* score by ANOVA. Means in a row without a common letter differ, $P < 0.05$.

[3] Unadjusted difference in mean total change in height-for-age *z* score by ANOVA. Means in a row without a common letter differ, $P < 0.05$.

[4] Unadjusted difference in mean total change in BMI *z* score by ANOVA. Means in a row without a common letter differ, $P < 0.05$.

TABLE 3 Baseline body composition measures of Haitian school children by age and sex[1]

Age group	Fat mass, kg			Fat-free mass, kg			Fat mass, %			BMI, kg/m^2		
	Boys	Girls	P[2]	Boys	Girls	P[2]	Boys	Girls	P[2]	Boys	Girls	P[2]
2–5 y	1.82 ± 0.72	2.19 ± 0.80	0.003	15.3 ± 3.39	13.4 ± 2.09	<0.001	10.5 ± 3.2	14.0 ± 3.8	<0.001	15.2 ± 1.3	14.8 ± 1.5	0.12
6–8 y	1.56 ± 0.68	2.59 ± 1.13	<0.001	18.7 ± 3.09	18.1 ± 3.01	0.06	7.7 ± 3.2	12.3 ± 3.4	<0.001	14.4 ± 1.6	14.6 ± 1.8	0.16
9–11 y	2.09 ± 1.96	3.49 ± 2.16	<0.001	24.5 ± 3.81	23.8 ± 4.79	0.15	7.4 ± 4.5	12.2 ± 4.3	<0.001	15.1 ± 1.9	15.6 ± 2.9	0.05
12–13 y	3.05 ± 3.64	4.90 ± 4.54	0.03	31.2 ± 5.96	30.7 ± 5.74	0.68	7.7 ± 6.5	12.2 ± 6.9	0.001	16.7 ± 3.7	17.2 ± 3.5	0.47
All	1.94 ± 1.75	3.14 ± 2.32	<0.001	21.4 ± 5.97	21.0 ± 6.52	0.27	8.1 ± 4.3	12.5 ± 4.4	<0.001	15.0 ± 2.1	15.3 ± 2.6	0.01

[1] Values are means ± SDs. Sample sizes for boys by age were 2–5 y (n = 75), 6–8 y (n = 170), 9–11 y (n = 162), 12–13 y (n = 46), and all (n = 472). Sample sizes for girls by age were 2–5 y (n = 75), 6–8 y (n = 180), 9–11 y (n = 181), 12–13 y (n = 60), and all (n = 505).

[2] Difference in boys and girls by t test.

mass, percentage fat mass, and BMI compared to an unfortified cereal bar and a control group. No effect was found for hemoglobin concentration, although Mamba compared to control did reduce the odds of developing anemia in longitudinal analyses of change in status. These findings, in our view, have importance for 3 reasons. First, the study provides information about the nutritional status of Haitian school children, which has not been examined for many years in the country. Second, Mamba produced a potentially important impact on body composition indicated by changes in BIA measures, an under-studied effect in this age group for resource-poor settings (2, 5, 26).

TABLE 4 Body composition measures of Haitian school children by intervention and control groups[1]

	Control	Tablet Yo (cereal bar)	Mamba (RUSF)
Fat mass, kg			
Baseline	2.91 ± 2.95	2.33 ± 1.24	2.51 ± 2.05
Midline	2.76 ± 2.26	2.39 ± 1.98	3.10 ± 3.67
Endline	2.62 ± 2.22	2.31 ± 1.38	2.56 ± 2.14
Mean total change[2]	−0.48 ± 2.65[a]	0.01 ± 0.70[b]	0.14 ± 0.70[c]
Fat-free mass, kg			
Baseline	23.7 ± 6.45	19.0 ± 4.47	21.3 ± 6.89
Midline	24.7 ± 6.68	19.8 ± 4.80	21.4 ± 7.40
Endline	25.3 ± 7.05	20.4 ± 4.64	22.0 ± 7.12
Mean total change[3]	1.53 ± 2.11[a]	1.44 ± 1.09[a]	1.28 ± 1.01[b]
Fat mass, %			
Baseline	10.1 ± 5.7	10.8 ± 4.3	10.3 ± 4.6
Midline	9.6 ± 4.7	10.4 ± 4.8	11.6 ± 5.8
Endline	9.1 ± 4.5	9.9 ± 4.3	10.2 ± 4.5
Mean total change[4]	−1.48 ± 5.16[a]	−0.76 ± 3.31[b]	−0.11 ± 2.60[c]
BMI, kg/m^2			
Baseline	15.8 ± 3.6	14.8 ± 1.5	15.1 ± 2.1
Midline	15.4 ± 2.1	15.1 ± 2.7	15.7 ± 3.3
Endline	15.5 ± 2.0	15.0 ± 1.3	15.3 ± 1.9
Mean total change[5]	−0.4 ± 3.5[a]	0.3 ± 0.9[b]	0.3 ± 1.1[b]

[1] Values are means ± SDs. Sample sizes for the control group were baseline (n = 288), midline (n = 281), and endline (n = 251). Sample sizes for the Tablet Yo group were baseline (n = 347), midline (n = 357), and endline (n = 332). Sample sizes for the Mamba group were baseline (n = 301), midline (n = 330), and endline (n = 314). RUSF, ready-to-use supplementary food.

[2] Unadjusted difference in mean total change in fat mass by ANOVA. Means in a row without a common letter differ, $P < 0.05$.

[3] Unadjusted difference in mean total change in fat-free mass by ANOVA. Means in a row without a common letter differ, $P < 0.05$.

[4] Unadjusted difference in mean total change in percentage fat mass by ANOVA. Means in a row without a common letter differ, $P < 0.05$.

[5] Unadjusted difference in mean total change in BMI by ANOVA. Means in a row without a common letter differ, $P < 0.05$.

Finally, to our knowledge, it is the first known study to test an RUSF in children >5 y of age.

Body composition and anthropometry. High levels of thinness and low fat mass percentage were evident in these Haitian school children. Nationally, wasting prevalence among children <5 y of age in the country is 5.1% (12). Although wasting prevalence cannot be calculated in the older children, the prevalence of thinness was nearly double at 9.1%. The body composition data also indicated a low percentage of fat mass relative to fat-free mass in the school-aged children at baseline: girls 12.5% and boys 8.1% (Table 3). The fat mass percentages were lower than those found for Gambian children, with the following range among children 5–13 y of age: boys 11.4–14.4% and girls 16.9–17.9% (25). The Haitian children also showed lower fat mass percentages than school-aged populations in wealthier settings. A US-based study using NHANES data among children 5–18 y of age found girls in the 50th percentile to range from 15% to 24% fat mass and boys ranged from 14% to 18% (27), whereas a study in German children 3–18 y of age gave evidence for comparable curves, with girls showing 18–20% and boys 15–20% fat mass (28). Although our intent with this study design was to examine change in body composition measures to protect against measurement error, the relatively low markers of fat mass warrant attention.

Previous studies have demonstrated impacts of school feeding on BMI and other markers of anthropometry. In Bangladesh, BMI was increased by 4.3% in children consuming a fortified wheat biscuit compared to controls (29). A school feeding study in Jamaica similarly found that a breakfast consisting of a cheese sandwich and milk over 8 mo increased BMI, weight, and height (30). Children supplemented with meat in Kenya showed improved midupper arm circumference relative to other groups (31), whereas those stunted at baseline who received milk showed improved height (32). In Colombia, there was also a positive height effect found in association with a school snack (4). We did not hypothesize that Mamba would affect linear growth, as was found for the LNS trial conducted in Cap Haitien (11), because of the older age range of the children in this study and the shorter period of supplementation. However, similar to the school studies described previously, our findings did show increases in BMI and other markers of body composition.

The nutrition transition literature has concentrated attention on the negative aspects of body fat (33). However, in populations with lower than normal levels, it is also important to highlight the critical and diverse physiologic roles played by adipose tissue. White adipose tissue, for example, contributes to immunity, reproduction, and glucose and lipid metabolism, among others roles; brown adipose tissue primarily regulates

TABLE 5 Longitudinal regression models of intervention effects in Haitian school children

	BMI *z* score[1]		Fat mass,[2] kg		Fat mass,[2] %	
	Group effect (n = 2329)	Mamba effect (n = 1479)	Group effect (n = 2460)	Mamba effect (n = 1565)	Group effect (n = 2269)	Mamba effect (n = 1441)
Group effect (Mamba = 3; Tablet Yo = 2; control = 1)						
Coefficient ± SEE	0.12 ± 0.03	—	0.21 ± 0.06	—	0.64 ± 0.13	—
P	<0.001	—	0.001	—	<0.001	—
Mamba effect (Mamba = 2; control = 1)[3]						
Coefficient ± SEE	—	0.25 ± 0.06	—	0.45 ± 0.14	—	1.28 ± 0.27
P	—	<0.001	—	0.002	—	<0.001
R^2 overall	0.07	0.08	0.15	0.14	0.24	0.23
Wald chi^2	177.17	130.00	403.82	229.66	732.41	431.31
$P <$ chi^2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

[1] Generalized least squares regression with random effects adjusted for age of the child, maternal BMI, monthly income, and school cluster.
[2] Generalized least squares regression with random effects adjusted for age of the child, sex of the child, maternal BMI, monthly income, and school cluster.
[3] A separate model was generated to examine the Mamba effect compared to control only, excluding the Tablet Yo group.

body temperature (34). During childhood, body fat is also necessary for brain development (35). Thinness in the school-aged child may be associated with increased infectious disease morbidities, anemia, impaired cognitive and motor development, and poor reproductive outcomes for adolescent pregnancies (35, 36). The effect found for this RUSF on body fat mass was likely positive for the Haitian children, but should be re-evaluated for populations undergoing nutrition transition.

Anemia. Neither supplementation with Mamba nor the Tablet Yo cereal bar produced significant increases in hemoglobin concentration. Anemia prevalence in the univariate group comparisons at endline was not reduced, although the more powerful longitudinal models detected a small effect on reducing the odds of becoming anemic for children in the Mamba group compared to control group. One likely explanation for this may be that anemia in school-aged children arises from multiple etiologies that extend beyond nutrition including helminthes and other gastrointestinal infections, malaria or dengue infection, and hemoglobinopathies (37). Previous studies demonstrating effects of LNSs or other RUSF products on anemia have been in younger children, when potentially, the nutritional causes of anemia were proportionally higher than infection-related causes (38, 39).

In Haiti, the national Ministère de la Sante Publique et de la Population protocol for deworming is Albendazole (400 mg) administered twice during the academic calendar, one dose at the beginning of the school year and a second dose 6 mo later, which aligns with WHO guidelines (40). We found that only 2 of the study schools followed the protocol, largely because of a lack of pharmaceutical supplies. Parent-reported deworming for the children also varied across supplementation groups. Finally, the unanticipated iron supplementation program in the community of one of the control schools may have attenuated the Mamba anemia reduction effect. Moving forward, we recommend that this study be replicated with an integrated nutrition-deworming approach (41, 42). Also critically important in our view would be studies to better understand the spectrum of anemia etiologies in these school-aged children.

Diet and morbidities. Supplementation was shown to be protective for dietary diversity. The effect is likely attributable to the added daily snack in the child's diet; however, the difference in the dietary diversity score exceeded one between both snack groups compared to the control group, suggesting other foods were added. The finding also supports the conclusion that the snack did not replace other foods in the child's diet, a concern sometimes articulated around food supplementation programs (43). We previously showed that an LNS, similar to Mamba, increased dietary diversity among young children (8, 11). Mothers reported mixing the LNS with other foods as one potential mechanism. Appetites may have also improved in association with the positive nutrition effects of the LNS or the RUSF in this study.

Child morbidities in ear infection and malaria were shown to be significantly reduced in the Mamba schools. We acknowledge the potential for reporting bias in the parent-recall morbidity data because this was not a blinded study. However, the data gives some indication for validity in the findings. Parent-reported malaria correlated with cases of severe anemia among the children, a known comorbidity. Furthermore, ear infection has been previously shown to be associated with vitamin A and other deficiencies, suggesting some plausibility in this finding (44). It should also be noted that respiratory infection and fever were increased in the supplementation groups. Pathogenic micro-organisms can compete for and thrive in the presence of added micronutrients (45). Infection should be investigated more broadly with nutrition among school-aged children in Haiti.

Study limitations. We applied a cluster design because of the difficulties of randomly assigning children within schools to different comparison groups. Although formative research was conducted to enhance the process of matching clusters, differences in socioeconomic, demographic, and health factors remained. In our view, this limitation should not undermine the conclusions drawn from these findings. We also applied a statistically powerful longitudinal design to examine change in outcome measures. This controls for residual confounding in any unmeasured differences across schools. Furthermore, factors found to differ across schools were all included in the initial longitudinal models and retained if shown to significantly predict outcomes (child age, sex of the child, and monthly income). The range in child age from 3 to 13 y may also be considered a limitation. Our original design was to include children 3–10 y of age to avoid the period of adolescence when growth is driven by multiple factors, but this was later broadened to increase sample size. We considered the risk of unmeasured growth factors in this age window to be lower than the benefit of the power gained. Furthermore, we adjusted for age in all regression models and investigated effects across stratified age groups.

Another limitation was the shortened intervention period. The study was originally designed to supplement children over the entire academic period of approximately 8 mo, but because of administrative delays the intervention period was truncated to 5 mo. Ten additional days were included with a take-home ration over the spring holiday, although compliance could not be monitored during that period. Despite this limitation, Mamba was found to significantly increase fat mass and BMI. Trends in improved anthropometry suggest a longer period of intervention possibly combined with systematic deworming would result in additional positive impacts from school feeding with the Mamba RUSF.

Conclusions. Undernutrition was prevalent in these Haitian school children, with rates of underweight and thinness exceeding those found in younger children (12). To our knowledge, this was the first study to test the effects of an RUSF in older children and show changes in body composition with potentially positive implications on child health and development (33, 46). Mamba was highly accepted among the children, feasible from a programmatic perspective, and produced locally with the potential for positive economic implications. However, in consideration of the nutrition transition, there may be a need to limit the use of an RUSF as a school snack to populations where undernutrition and thinness are prevalent.

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