Impact of a Balanced Protein-Energy Supplement in Pregnancy and Early Lactation on Reproductive Outcomes and Growth in Southern Nepal

Final Report

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Background

Undernourished women in many low and middle-income countries (LMICs) enter pregnancy with low nutritional reserves, and low maternal BMI and short stature are associated with increased risks of a variety of adverse reproductive outcomes (Kozuki et al., 2015; Rahman et al., 2015). Systematic reviews of balanced protein-energy (BEP) supplementation during pregnancy demonstrate only moderate levels of evidence than such dietary supplementation can decrease the risk of stillbirth and small-for-gestational-age (SGA) births (Ota et al., 2015; Stevens et al., 2015). The recently released WHO antenatal care guidelines recommend providing pregnant women in undernourished populations with balanced protein energy dietary supplementation and specifically do not recommend high-protein (WHO, 2016). More recent evidence on multiple micronutrient supplementation in pregnancy however, suggests that this should be reconsidered (Haider & Bhutta, 2017).

The current evidence base for BP-E supplementation draws from a number of studies where BP-E supplements varied widely in composition and form (Imad & Bhutta, 2002), and programmatic experience with food supplementation of pregnant women is limited to providing undernourished women with fortified blended foods. Two recent studies using fortified blended foods found that although approximately 800 kcal/d was provided, the net energy intake increased by a much smaller amount (200-300 kcal) likely due to replacement of other meals, sharing of the food supplement in the family, and/or other physiological, behavioral or practical reasons that limit food intake during pregnancy (Janmohamed et al., 2016; Saville et al., unpublished trial in Nepal).

In order to promote use of nutritious food supplements for pregnant women in undernourished populations, formative research to better understand the acceptability, utilization and delivery of selected product types is required. Further evidence of the impact of such supplementation regimens on adverse birth outcomes and early infant growth and development is also needed especially in populations with chronic, poor nutritional status.

Evidence regarding dietary practices and preferences among pregnant women in Nepal is generally limited, however, some studies have shown that intra-household food allocation and specific food beliefs/behaviors do not favor adequate energy or micronutrient intake among adolescent girls and adult women (Gittelsohn, 1991; Gittelsohn et al., 1997). Christian et al more recently showed that staple food intake can be reduced during pregnancy; which could be attributed to an aversion to food, lack of appetite, feeling unwell, or concern regarding having a “large” baby and difficulties with labor and delivery (Christian et al., 2006). Low nutrition knowledge may also play a role in suboptimal intake among women (Jones et al., 2005). Uptake of reproductive health services and antenatal care has increased dramatically over the past 15 years in Nepal (Ministry of Health, 2017). Approximately 80% of rural women report attending at least one antenatal care visit, but this varies by socioeconomic status (SES) with lower SES women significantly less likely to present for antenatal care (Ministry of Health, 2017; Furuta & Salway, 2006). Use of antenatal care is also influenced by other household members, especially the mother-in-law (Simkhada et al., 2010). A randomized study has shown that participation in women’s groups can improve antenatal care uptake in Nepal (Manandhar et al., 2004). This finding, together with the government’s incentive scheme for improving rates of

facility deliveries, have likely played a large role in the improving use of antenatal care services in Nepal.

Project Objective: These dynamic changes in access and use of services offer the opportunity to nest additional nutritional support services within the antenatal care system, including BP-E supplementation. However, the variation in formats, ingredients and nutrient composition of previously used supplements has made progress in this area difficult. Recognizing this lack of consistency, the Bill and Melinda Gates Foundation brought together experts to make recommendations on the optimal nutritional composition of a BP-E for use in pregnancy and lactation in populations where such supplementation might be appropriate. However, information is limited regarding preferences for format, flavors, and mechanisms for delivery of such nutritional supplements and the impact such supplementation will have on the key birth outcomes that affect child health and development.

The aim of the study is to evaluate the efficacy of daily fortified BEP supplementation during pregnancy and lactation on SGA and mean length-for-age z-score (LAZ) in the first six months of life. Prior to the main trial formative research was done to 1) to identify the two most preferable BEP supplements among a larger group of eleven supplements specifically produced for use in pregnancy and lactation in the South Asian context for this study and 2) aimed to assess the compliance with and acceptability of the two short-listed supplements from the first phase through a mixed-method 8-week home feeding trial of daily supplementation among pregnant women. The BEP supplement found to be most acceptable and utilized from this formative research was used in the larger efficacy trial in the same study population.

Methods

This project was done in three phases. Phase one identified preferable supplement types among a group of potential products for use in pregnancy in the South Asian context. Phase two used the results of phase one to narrow these options and conduct a medium-term feeding trial to assess acceptability and consumption of women during pregnancy for daily consumption of the two short listed supplement types. Phase three was a large, community-based randomized trial using at least one of these supplement options for use in pregnancy and through the first 6 months post-partum on birth outcomes and early infant growth. Each of these phases are described in more detail below.

Phase 1 methods:

Study Design and Overview

This study employed a mixed-methods formative research design to assess the acceptability of multiple fortified balanced energy–protein (BEP) supplements among pregnant women in rural Nepal. The research constituted the first phase of a two-phase formative process designed to inform the selection of BEP supplements for a subsequent home-tasting pilot trial and a larger randomized controlled trial (ClinicalTrials.gov Identifier: NCT03668977).

The primary objective of this phase was to identify the most acceptable BEP supplements among eleven candidate products, using a combination of quantitative sensory evaluation and qualitative exploration of preferences, perceptions, and anticipated use during pregnancy.

Study Setting

The study was conducted in Sarlahi district, located in the southern Terai region of Nepal. This rural setting is characterized by a high prevalence of maternal undernutrition, low birth weight, and small-for-gestational-age births, making it representative of populations for whom BEP supplementation is programmatically relevant.
Participants were recruited from two former Village Development Committees (Pidari and Pipariya) within Haripur and Kabilasi municipalities. These areas were selected to reflect the district's ethnic, caste, and religious diversity, with particular attention to including both Hindu and Muslim women. Field implementation was carried out by the Nepal Nutrition Intervention Project–Sarlahi (NNIPS), a long-standing research collaboration between Johns Hopkins Bloomberg School of Public Health and Nepali partner organizations.

BEP Supplements Evaluated

Eleven fortified BEP supplements were specifically developed for pregnant and lactating women according to Bill & Melinda Gates Foundation nutritional guidelines. Nine products were produced in collaboration with Nutriset (France) and two with MARS Incorporated (India).
The supplements varied in form and flavor, comprising six sweet and five savory products, including lipid-based nutrient supplements (LNS), biscuits, bars, drinks, and pillow-shaped snacks. All products were nutritionally aligned with recommended macro- and micronutrient specifications or could be modified to meet those standards if selected.

Participant Recruitment and Eligibility

Eligible participants were married, pregnant women aged 15–40 years residing in the study area. Women with known allergies to soy, dairy, eggs, gluten, or nuts were excluded. For participants under 18 years of age, informed consent was obtained from a husband or legal guardian in accordance with national ethical guidelines.
From a community-based recruitment list of 82 eligible women, a purposive sample of 40 women was selected to ensure variation in age and gestational stage. All participants provided written informed consent prior to enrollment.

Data Collection Procedures

Each participant took part in two consecutive days of data collection.

Quantitative Sensory Evaluation

On Day 1, participants completed individual tasting sessions at home for six sweet BEP supplements. On Day 2, participants attended the field office to taste the remaining five savory supplements. Products were presented in randomized order to minimize order effects.
Participants were given test portions equivalent to 25% of a daily ration and up to 30 minutes to consume each product. After tasting each supplement, participants rated its organoleptic properties—color, smell, taste, texture, and overall liking—using a 7-point hedonic scale. Additional Likert-scale questions assessed perceived ease of preparation, suitability as a snack, perceived portion size, willingness to consume the supplement daily for up to 12 months, and

likelihood of sharing with others. Participants also ranked products by preference within sweet and savory categories and provided an overall ranking of their top three preferred supplements across all eleven products.

Qualitative Data Collection

Following the tasting sessions, five focus group discussions (FGDs) were conducted, each comprising 7–9 participants. Groups were stratified by age and caste/religion to promote open discussion and minimize social hierarchy effects.
FGDs explored perceptions of taste and smell, cultural familiarity, anticipated use during pregnancy, sharing norms, cost concerns, and preferences for variety versus long-term consumption of a single product. Participants also completed a group ranking exercise to reach consensus on their top three supplements. All discussions were conducted in Maithili, audio-recorded, and later transcribed and translated into English.

Training and Quality Control

Field staff underwent intensive training on study procedures, questionnaire administration, sensory testing protocols, and qualitative facilitation techniques. Tools were pre-tested locally, and revisions were made to improve comprehension. Quantitative data were collected electronically using REDCap on password-protected mobile devices.

Data Analysis

Quantitative data were analyzed using Stata (version 15.0). Participant characteristics were summarized using descriptive statistics. Hedonic scale responses and Likert-scale measures were summarized using medians and interquartile ranges. Ranking data were converted into weighted scores to generate overall product preference rankings.
Qualitative data were analyzed using thematic analysis. Two researchers independently coded transcripts using a shared codebook, with discrepancies resolved through discussion. Coding was conducted using Dedoose software and manual methods. Quantitative and qualitative findings were triangulated to identify convergent and divergent patterns in acceptability and anticipated use.

Phase 2 Methods

Study population and setting

This study was conducted from May to August 2019 in two municipalities in Sarlahi district: Ishwarpur and Chandranagar. Forty pregnant women from each municipality, totaling 80 women, were purposively sampled and enrolled in this study. The inclusion criteria for women recruited to the study were: married; age (15-40 years); gestational age (13-28 weeks); and residing in the study area for at least two months. The efficacy trial will supplement pregnant women starting from their second trimester at 14 weeks as we don't want early miscarriages to be blamed on the supplement. We therefore restricted enrolment in this pilot trial to similarly enrol women from 13 weeks but who would not deliver before the end of the 8-week pilot follow-up. Women with known allergies to one or more of the product ingredients (soy, dairy products, eggs, gluten and nuts) were excluded from participation. In addition to the pregnant women, a small number of other stakeholders such as family members of the pregnant women and health

workers were also included in this study to gain their opinion and perspectives on the BEP supplements.

Study design and procedures

This study was an 8-week, community-based acceptability and compliance trial conducted among pregnant women in two municipalities of Sarlahi district, Nepal. Participants were assigned to one of two BEP supplement groups based on municipality to minimize contamination through social interaction and to facilitate distribution logistics. Women in Ishwarpur municipality received a vanilla biscuit supplement, while women in Chandranagar municipality received a lipid-based peanut paste.

A recruitment list of eligible pregnant women was compiled by female community-based field staff. From this list, a purposive sample of 40 women per municipality (total n=80) was selected to ensure variation by age, gestational age, and geographic location. Trained NNIPS staff obtained informed consent, administered baseline sociodemographic and pregnancy history questionnaires, and provided standardized instructions on daily supplement consumption, non-sharing, and packet retention.

Participants received a weekly supply of supplements, with one additional packet provided each week to prevent missed doses due to loss, damage, or scheduling challenges. Unused packets from the previous week were collected at each visit. Eight trained local female field workers conducted weekly home visits to deliver supplements and assess compliance using structured questionnaires that captured daily consumption, portion size, timing, sharing, meal replacement, and reasons for non-consumption. Phone interviews were conducted when in-person visits were not possible, and advance supplies were provided for anticipated absences.

At the end of the 8-week period, participants completed a quantitative acceptability assessment using 7-point Likert scales to rate sensory attributes, ease of consumption, perceived product classification (food, medicine, or both), and satiety. Willingness to consume the supplement daily for up to 12 months was assessed using a 5-point Likert scale. Participants also evaluated additional flavor variants within their assigned supplement type.

Qualitative data were collected through in-depth interviews with a purposive sub-sample of women after four weeks of supplementation and focus group discussions conducted at trial completion with women not included in interviews. These explored dietary practices, supplement experiences, acceptability, compliance, and future use. Additional interviews were conducted with family members and health professionals to capture broader stakeholder perspectives on supplementation during pregnancy.

All data collection was conducted in Maithili. Quantitative data were collected using REDCap on encrypted mobile devices. Qualitative interviews and discussions were audio recorded, transcribed, and translated into English for analysis.

Statistical analysis

Analyses focused on descriptive summaries of compliance and acceptability outcomes. Compliance indicators were calculated as percentages of recommended doses consumed, and distributions were examined across pregnancy and lactation. Acceptability responses were summarized using proportions and central tendency measures as appropriate.
Where relevant, subgroup analyses were conducted to explore differences in compliance and acceptability by maternal, household, or time-related factors. Quantitative findings were

interpreted alongside qualitative responses to provide a comprehensive understanding of women's experiences with BEP supplementation.

Phase 3 Methods

Study design and setting

The main trial was a 2x2 factorial, household randomized, unblinded, efficacy trial to assess the effect of a daily fortified BEP supplement during pregnancy and lactation on birth outcomes and infant growth outcomes. Details of the trial protocol published previously are summarized here for this analysis, which focuses on the effect of pregnancy specific intervention.17 The study was conducted from 2021 to 2024 in Sarlahi District, Madhesh Province, in the Terai region (low-lying plains) of Nepal by the Nepal Nutrition Intervention Project Sarlahi (NNIPS) research team. The study area included 34 wards across six municipalities.

Intervention

Women in the supplement group were provided a daily fortified BEP supplement from approximately 14 weeks' gestation as determined by the last menstrual period (LMP) method until the pregnancy outcome. Women in both the no supplement and supplement groups received a 1) recommendation to enroll in ANC at a local health clinic and deliver at a certified birthing facility, 2) nutrition, hygiene, and breastfeeding and infant care counselling, 3) clean birthing kit, and 4) iron-folic acid (IFA) tablets and albendazole when not provided as part of ANC at their health facility. The daily fortified BEP supplement is an individually packaged lipid-based peanut paste designed to meet the expert consensus specifications for nutritional requirements during pregnancy and lactation.11 The product, a variation of 'Plumpy'Mum' produced by Nutriset, France, is a 72-gram sachet with calories (~400kcal), protein (~14g) and fifteen multiple micronutrients plus 500 mg of calcium. Ingredients and nutritional composition of the supplement are described in the study protocol.17-19 (Supplementary table 1). Masking the intervention for participants or data collectors was not possible due to the nature of the intervention and control.

Census and enumeration

A census was implemented to enumerate households to identify and recruit eligible participants in the MINT study area in July 2019 with an update in December 2022 to January 2023. Eligible married women 15-30 years of age who were identified as living in the study area by the census and consented for a pregnancy surveillance were enrolled. They were visited at home every 5 weeks by local, female data collectors to ask if they had a period, determine their LMP, and provide urine-based pregnancy tests to confirm pregnancies for amenstrual women in the past 30 days. Women who became pregnant and had no self-reported allergy to nuts, milk, or soy were eligible for enrollment in the trial during enrollment periods that occurred in two waves spanning November 2021 to July 2022 and January 2023 to August 2023. The census and enrollment periods were divided into two periods due to disruptions related to the COVID-19 pandemic and funding considerations.

Sample size

We estimated that a sample size of 1,548 women/infant pairs visited for anthropometry within 72 hours would allow us to detect a 17.5% relative reduction in SGA with 80% power and type I error (two-sided) of 5%. MINT was designed to enroll between 1,800-2,000 pregnant women to

yield the target analytical sample size assuming a 14% reduction due to fetal loss and loss to follow-up in pregnancy.

Randomization

At the enrollment visit, households were randomly allocated to pregnancy supplement or no supplement groups. Randomization was stratified withing two categories of low and adequate maternal height (≥150 cm, <150 cm), a known risk factor for fetal growth restriction and preterm birth, to ensure balance across trial groups. The median of three height measurements from the first woman enrolled in each household was used to assign that household to supplement or no supplement within either height group. Subsequent pregnant women enrolled from that household were assigned to the same group. Using a household-level randomization scheme allowed for families with more than one eligible participant to contribute multiple pregnancies for enrollment and avoid the risk of intervention crossover. Given that few households would contribute more than one pregnancy, this randomization approach allows for statistical strength of an individually randomized trial while reducing the risk of intervention cross-over due to sharing of the supplement. Randomization was conducted using pre-generated sequences (R software) with randomly permuted blocks of sizes 4, 6, 8, and 12 to balance assignments sequentially across groups during enrollment.

Procedures

Study visits were conducted at participant households by experienced field interviewers (FIs) and local data collectors due to the wide dispersion of households in this rural community. An enrollment visit was scheduled for each participant the week after pregnancy detection. At the enrollment visit, data were collected by FIs on participant and household demographic characteristics, socioeconomic status, pregnancy and reproductive history, 24-hour food group intake (Minimum Dietary Diversity for Women (MDD-W) questionnaire), household food insecurity (Household Food Insecurity Access Scale, FANTA), and anthropometric measurements (height, weight, mid-upper arm circumference (MUAC), blood pressure, and pulse). A separate visit was conducted by a cadre of auxiliary nurse midwives (ANMs) for ultrasound assessment for gestational dating. Gestational age was assessed using first or second trimester ultrasound examination prior to 24 weeks.20,21 ANMs used a portable machine (SonoSite NanoMaxx) and followed the INTERGROWTH-21st methodology for early and late fetal gestational age assessment, including collecting measurements of crown-rump length and/or biparietal diameter, head circumference, and femur length. Ultrasound measurements were taken in triplicate, and the median was used for analysis. We averaged the gestational ages at the ultrasound visit for twins to generate a single value for this participant. A 10-15% sample of ultrasound images were reviewed for quality by a local radiologist. Participants were visited weekly during pregnancy beginning at 14 weeks' gestation by the local data collectors to collect data on pregnancy morbidities, measure supplement consumption, and provide additional supplements.

Weekly supplement consumption was measured by asking women to report the number of supplements consumed in the last seven days, which was confirmed by collecting the empty sachets. A late pregnancy visit was conducted by FIs at approximately 32-34 weeks' gestation to collect data on maternal anthropometry (similar measures as enrolment), maternal morbidities, tobacco/alcohol use, ANC utilization, delivery planning, 24-hour food group intake, household food security, and depression (using a version of the Edinburgh Postnatal Depression Scale validated in Nepali). Pregnant women and local data collectors were instructed to notify our staff immediately about the occurrence of the pregnancy outcome. FIs aimed to visit participants within 72 hours of delivery to collect infant anthropometry for the

primary and secondary outcomes, including infant weight (g), length (cm), head circumference (HC) (cm) and information about the birth and delivery process, early breastfeeding and feeding behaviors, and newborn care practices. Newborn weight was measured with pediatric digital scales (Tanita BD-585) and length with Shorr-type boards; non-digital measures were taken in triplicate, and the median was used for analysis. In a subsample, 120 women in both groups (n=240) were systematically selected for duplicate, non-consecutive 24-hour diet recalls using the multiple pass method in their third trimester of pregnancy. A comprehensive food list and photo atlas developed and validated in adjacent terai districts, was used for portion size recall, and standard recipes were sourced from another local dietary assessment study while the remaining were developed by project staff.

Outcomes

The primary birth outcome for this analysis was incidence of SGA among live born infants for whom birthweight was measured within 72 hours of delivery. SGA was defined as birth weight <10th centile for gestational age and sex according to the INTERGROWTH-21st reference (Villar 2014). Secondary outcomes included binary variables for LBW (<2,500 grams), SGA (<3rd percentile), short-for-gestational age (<10th and <3rd percentile of expected length for gestational age and sex using the INTERGROWTH-21st reference), and preterm birth (<37 weeks' gestation at delivery). We assessed continuous variables for weight-for-age centile and z-score, birth weight (g), head circumference (cm), and gestational age at delivery (weeks). We also considered differences between groups for large-for-gestational age (LGA, >90th percentile). Primary and secondary outcomes utilizing gestational age at delivery date were constructed using first or second trimester ultrasound data or, if unavailable, LMP self-reported by the mother at baseline.20,21 We set a priori cutoffs to assess data quality for various measurements. These included birth weight for values <500 grams or ≥6,000 grams and gestational age at delivery for live births for values <22+0 weeks or >44+6 weeks. We reviewed gestational age and birthweight combinations to identify birth weights greater than five times the standard deviation from the mean weight for each gestational age week by sex. We also reviewed fetal measurement values to identify measurements greater than five times the standard deviation above or below the mean.

The primary infant growth outcome was mean infant LAZ at 6 months of age, calculated using the WHO Child Growth Study criteria (WHO, 2006). Secondary outcomes included mean WLZ and WAZ at 6 months of age. For a subset of infants, data was available for these outcomes at 12 months of age. Additional outcomes included mean infant weight (g), length (cm), head circumference (cm), MUAC (cm) and prevalence of stunting, wasting, and underweight at 6- and 12-months of age. Anthropometric outcomes (continuous variables) were also evaluated monthly to compare patterns of growth between groups over time.

Statistical analysis

Birth outcome analysis

We conducted an intention-to-treat analysis to assess the effect of pregnancy supplementation with fortified BEP on primary and secondary birth outcomes. The analytical population for the primary analysis included all live births, including twins, with a weight collected within 72 hours of delivery (n=1,209). Analyses considering preterm birth or continuous gestational age at delivery used all observations with gestational age data (n=1,581).

We compared the baseline participant and household characteristics across groups for balance. We presented the incidence of birth outcomes by group as mean (SD) or frequency (%) as appropriate. We estimated the relative risk (RR) and associated 95% confidence interval (CI) of SGA using log-binomial regression models using the no supplement group as the reference. Similar models were used for other dichotomous outcomes. For each continuous outcome, we used linear regression models to estimate the mean differences and 95% CIs using the no supplement group as the reference. All models included maternal short stature (≥150 cm, <150 cm) as a binary covariate to adjust for the randomization stratification on this factor. For secondary outcomes where log-binomial regression models failed to converge, Poisson regression with robust standard errors was used to estimate relative risks.

Interaction was assessed for the primary outcome between the intervention and pre-specified potential effect measure modifiers ($p<0.10$), including maternal short stature (≥150 cm, <150 cm), maternal BMI (underweight <18.5 kg/m2, not underweight ≥18.5 kg/m2), maternal age (<20, ≥20 years), parity (multiparous, nulliparous), and education (no schooling, some schooling). Stratified analyses were presented for maternal short stature and underweight as these are important potential modifiers of the supplement intervention. Adjusted analyses for primary and secondary outcomes were conducted by including covariates for factors commonly associated with adverse birth outcomes, including continuous variables for maternal age (years), maternal height (cm), BMI, parity (number of previous live births and stillbirths), education (years of schooling), infant sex, and multiple birth. Given the balance in participant and household factors across groups, no other covariates were included in these models. As a secondary analysis, clustering at the household level was accounted for using generalized estimating equations with an exchangeable correlation structure, which did not substantially affect the primary results.

We explored modification of the intervention effect by the proportion of intended supplement doses consumed by supplement group participants. Intended supplement consumption was calculated as the number of supplements consumed as a proportion of the number of days from 14 weeks' gestation to the pregnancy outcome date. We categorized consumption as 0-<80%, 80-<100%, and 100%. We estimated the relative risk or mean difference for each outcome, as appropriate, by supplement consumption by including dummy variables for each consumption category in the supplement group and using the no supplement group as the reference.

We calculated participant-level nutrient intakes using South Asian food composition tables and averaged the two 24-h diet recalls to estimate daily energy and macronutrient intakes. We assessed the mean differences in energy and macronutrient intakes (excluding BEP consumption) between groups using two-sample t-tests to explore substitution of the home-based diet due to provision of a food supplement.

In a secondary analysis, we recalibrated weights collected before 10 days after birth to time=0 and imputed missing weights using an empirical Bayes model of early neonatal weight change developed by our team using data from a previous longitudinal study.24 Using the imputed birth weights, we estimated the proportion of SGA and LBW, mean birth weight, relative risks, and mean differences for these and other outcomes using similar regression models to the primary and secondary analyses. For infants without birth length and head circumference collected <72 hours after delivery, we used multiple imputation with chained equations to impute missing data using 50 imputations and predictors including maternal age, baseline height, BMI, and MUAC, parity, infant sex, month of enrollment, and gestational age at birth.

We used quantile regression models to estimate the treatment effect across the distribution of the continuous outcomes, including birth weight (grams), birth weight for gestational age and sex (centile), birth length (cm), birth length for gestational age and sex (centile). We graphed the intervention effect by percentile of the outcome and 95% CIs (Stata packages rqr and rqrplot).

Infant growth outcome analysis

The aim of this analysis was to assess the effect of pregnancy and lactation supplementation on mean infant LAZ at 6 months of age and secondary infant growth outcomes at 6- and 12-months of age. Our analysis followed a modified intention-to-treat approach by including all infants with anthropometry data at any timepoint from birth to 6- or 12-months of age (n=1555). We compared baseline participant and household characteristics between the four intervention groups to assess balance at enrollment. We summarized measures of infant growth by intervention group at 6 months of age and other timepoints as mean (standard deviation (SD)) or frequency (percent) as appropriate.

To determine our approach to analysis of the 2x2 factorial trial, we assessed whether the pregnancy and lactation supplementation interventions interacted on the primary infant growth outcome. This was evaluated using a multivariable linear regression model with an interaction term for treatment; statistical significance was prespecified as $p<0.10$. As a significant interaction was not observed, marginal treatment effects were reported separately for pregnancy supplementation vs. not and lactation supplementation vs. not. Given the factorial design, marginal models estimating the main effects of the supplementation interventions were adjusted for allocation to the other intervention to isolate their independent effects on the outcome.

Our objectives were to estimate the direct effect of the pregnancy intervention on infant outcomes and the effect of the lactation intervention on infant outcomes. Accordingly, marginal models for both intervention periods were conditional on infant size at birth, achieved by including the outcome-specific measure at birth as a covariate (e.g., LAZ at birth (<72 hours) when modeling LAZ at 6-months). For the primary outcome of LAZ and other continuous outcomes, we estimated mean difference and 95% confidence intervals (CIs) between each group vs. control using multivariable linear regression models. For binary outcomes, including stunting, wasting and underweight, we estimated relative risks and 95% CIs using generalized linear models (GLMs) with a Poisson distribution and robust standard errors,

All models were adjusted for measures of infant growth at birth (as explained above), infant sex, and infant age (days) at the 6-month anthropometry visit. A sensitivity analysis accounting for clustering at the household level using generalized estimating equations with an exchangeable correlation structure did not substantially affect the primary results.

As a secondary analysis, we estimated the monthly change in continuous growth outcomes and 95% CIs at 6 months using mixed-effects linear regression models, including quadratic terms of child age, supplement group as a fixed effect and infant as a random intercept and time of visit as a random slope to account for repeated measures. An interaction term between time and supplement group represented the effect of the supplementation on growth over time. The mean difference and 95% CIs in the monthly rate of change between groups were estimated using contrasts of average marginal effects from the mixed-effects linear regression models.

Analyses were conducted using Stata 18.0 (Stata Corp, TX, USA).

Ethical Considerations

The study received ethical approval from the Institutional Review Board (IRB) at Johns Hopkins Bloomberg School of Public Health, Baltimore, USA (IRB00009714), the Committee on Human Research IRB at The George Washington University, Washington, DC, USA (081739), and the Ethical Review Board of the Nepal Health Research Council, Kathmandu, Nepal (174/2018). The trial is registered at clinicaltrials.gov (NCT03668977). A data and safety monitoring board was established to review the study design and procedures prior to the start of the trial and monitor progress, safety, and findings during data collection. Written informed consent was obtained for participation in the trial from all women prior to enrollment.

Serious adverse events

Serious adverse events, as defined under Good Clinical Practice (GCP) guidelines, included death, a life-threatening reaction to the supplement or other study procedure, hospitalization for a reason other than routine delivery, significant or persistent disability or impairment, or a congenital anomaly/birth defect. All data collection staff are trained to recognize a range of serious and other adverse events (AEs). SAEs were investigated and reported to the DSMB and IRBs according to the study research and ethical protocols. Our most senior data collectors conducted verbal autopsies in the case of a maternal or infant death.

Ancillary care

The study provided iron folic acid tablets and albendazole to women who report that they have not received these from the health facility during their ANC visits. Women with low hemoglobin (Hb <11g/dL) were referred to a health facility. Women with suspected fetal abnormality detected during the ultrasound gestational age dating visit are referred for clinical examination.

Confidentiality

Study investigators and staff treat all data as confidential, and participants are informed that their information will be protected. All data collection forms are kept in secure locations with access limited to relevant study staff. All electronic databases are stored on encrypted, password-protected servers, and data transfer uses secure encrypted transfer protocols. Access to identifying information is restricted to the principal investigator and few key co-investigators and staff. Only anonymized datasets are shared beyond the study team.

Results

Phase 1:

The mean (SD) age of study participants was 22.7 (3.7) years and the ages ranged from 16 to 30 years. The religion of the majority of the participants was Hindu (72.5%) and their ethnicity was Madeshi (i.e. southern plains) (97.5%). The pregnancy characteristics of the study participants are presented in Table 2.

Table 4. Socio-demographic and pregnancy characteristics of study participants

Socio-demographic characteristics	N=40
Age in years, mean (SD)	22.7 (3.7)
Marital Status, n (%) Married and with husband	 40 (100)
Education background, n (%) None Primary (1-5) Secondary (6-10) Higher secondary Mean number of years (SD)	 24 (60.0) 4 (10.0) 10 (25.0) 2 (5.0) 3.1 (4.3)
Religion, n (%) Hindu Muslim	 29 (72.5) 11 (27.5)
Ethnicity, n (%) Madeshi (southern plains) Pahadi (hill)	 39 (97.5) 1 (2.5)
Pregnancy characteristics	
First pregnancy, n (%)	11 (27.5)
Number of living children, mean (SD)	2.1 (1.2)
Gestational age in months, mean (SD)	5.4 (1.9)
Number of antenatal consultations, mean (SD)	(1.8)

Hedonic properties

Table 5. shows the results of the hedonic scale responses rating the sensory properties (color, taste, smell, texture and overall) of the eleven BEP supplements. The sweet LNS, sweet vanilla drink, savory LNS and savory seasoned pillows were rated highly, with a median response of '7=Like very much' on all sensory properties. The taste, smell and/or texture of the sweet mango bar, sweet cocoa drink, savory masala bar and savory curry biscuit received lower ratings; the lower quartile (Q1) of the interquartile range show several scores between 1 (dislike very much) and 3 (dislike slightly) (Table 5). The distribution of the responses on the 7-point hedonic scale showed that sweet LNS and savory seasoned pillows were liked very much by

the vast majority of the participants (75% and 70% respectively). In contrast, 30% and 35% of the participants reported disliking the sweet cocoa drink and savory curry biscuits very much, respectively (Table 5).

The qualitative findings from the FGDs supported the quantitative responses to the sensory assessment. Participants commented favorably on the sweet LNS having a sweet/salty flavor mix, and contrasted it to the savory LNS which, though well liked, was not as popular as the sweet version due to what some perceived as excessive salt. Participants likened the sweet LNS to a number of favorite local foods, including 'Halwa' a sweet pudding, 'Satu', a cereal-based snack, and a variety of commercial products. Women consistently liked the savory seasoned pillows for color and for the taste, which many described as 'a little salty and a little sweet' but also 'a little spicy'. One response from a woman in FGD group A was illustrative: "Yes, its sour and spicy type, that's why they would eat more during pregnancy". The seasoned pillows was positively associated with a number of other familiar tasting foods, particularly Indian crisps and snacks. The vanilla drink also had positive reviews during the FGDs, where most of the participants liked its color, smell and taste. One person in FGD group B commented that the smell resembled that of ice cream, while the taste was positively likened to peanut 'satu' and baby food or malted milk powders. In FGD group C the vanilla drink was also likened to a powdered protein drink for pregnancy and lactation available in the local market. The vanilla biscuit was liked by most of the women in the FGDs, although some participants in FGD group C did not like its taste and smell and suggested it tasted like medicine.
The FGDs also highlighted the reasons for not liking certain properties of the BEP supplements. For instance, some participants in FGD group B disliked the savory masala bar for its taste and smell; the texture was also described negatively as something that felt 'rough' and 'sticks to your teeth'. The savory curry biscuit was also disliked for its color, taste and texture where participants in group B made specific and negative reference to individual flavors in the product, such as cumin, pepper, fenugreek, turmeric and 'jwano' (thyme seed), and commented that it was too salty and tasted like medicine as it was bitter to taste. A few women liked the cocoa drink but most did not, because of its color and bitter taste, which was compared to medicine. Some of the most negative comments came from participants in FGD group B: "It tastes bitter and it's black"; "Just looking at the color might make people feel like vomiting. It looks like sewage water". Participants disliked the unseasoned pillows because of its bland taste, although they found it similar to popcorn in terms of taste and smell.

Table 5. Hedonic scales results for all eleven BEP supplements

	Sweet LNS	Sweet Mango Bar	Vanilla filled sticks	Vanilla Biscuit	Cocoa drink	Vanilla drink	Savory LNS	Savory Masala Bar	Savory Curry Biscuit	Seasoned Pillows	Unseasoned Pillows
Hedonic scale scores, median (IQR) scores based on 7-point Likert scale (1=Dislike very much to 7= Like very much)											
Color	7 (6, 7)	6 (5, 7)	7 (6, 7)	7 (6, 7)	6 (5, 7)	7 (6, 7)	7 (6, 7)	7 (5.5, 7)	6 (2, 7)	7 (6.5, 7)	6 (5.5, 7)
Taste	7 (6, 7)	5.5 (1.5, 7)	7 (6, 7)	7 (6, 7)	5 (1, 7)	7 (5, 7)	7 (6, 7)	6 (3, 7)	5 (1, 7)	7 (6, 7)	6 (3, 7)
Smell	7 (6, 7)	6 (2, 7)	6 (5.5, 7)	7 (6, 7)	6 (4, 7)	7 (6, 7)	7 (6, 7)	6 (3, 7)	5.5 (1,7)	7 (6, 7)	6 (5, 7)
Texture	7 (6, 7)	6 (1.5, 7)	7 (6, 7)	6 (5.5, 7)	5 (1, 7)	7 (5.5, 7)	7 (6, 7)	6 (4, 7)	5 (1, 7)	7 (6, 7)	6 (5, 7)
Overall appreciation	7 (6.5, 7)	5 (2, 7)	6 (5, 7)	7 (6, 7)	5 (1, 7)	7 (5.5, 7)	7 (6, 7)	6 (5, 7)	6 (1, 7)	7 (6, 7)	6 (5, 7)
Perceived child likeability	7 (6.5, 7)	6 (4, 7)	7 (7, 7)	7 (7, 7)	6 (3, 7)	7 (6, 7)	7 (6, 7)	6 (5, 7)	5 (3, 7)	7 (7, 7)	7 (5, 7)
Perceived adult likeability	7 (6, 7)	6 (4, 7)	6 (6, 7)	7 (5, 7)	4.5 (3.5, 6)	7 (5, 7)	7 (6, 7)	6.5 (5, 7)	5 (2.5, 7)	7 (6, 7)	6 (5, 7)
Distribution of overall likeability responses on 7-point Likert scale											
Liked very much	75.0%	35.0%	45.0%	52.5%	32.5%	62.5%	57.5%	47.5%	30.0%	70.0%	35.0%
Liked moderately	7.5%	12.5%	25.0%	25.0%	12.5%	12.5%	22.5%	12.5%	22.5%	15.0%	22.5%
Liked slightly	7.5%	22.5%	20.0%	12.5%	17.5%	10.0%	12.5%	17.5%	10.0%	10.0%	22.5%
Neither like/dislike	5.0%	0%	0%	0%	0%	0%	2.5%	0%	0%	0%	2.5%

Dislike slightly	0%	2.5%	2.5%	2.5%	2.5%	2.5%	0%	0%	2.5%	0%	2.5%
Dislike moderately	0%	7.5%	0%	2.5%	5.0%	2.5%	0%	2.5%	0%	0%	2.5%
Dislike very much	5.0%	20.0%	7.5%	5.0%	30.0%	10.0%	5.0%	20.0%	35%	5.0%	12.5%

The results of the individual ranking of 'Top 3' by each participant are presented in Table 6. The most preferred product was the sweet LNS (51 points), followed by the seasoned pillows (43 points), vanilla drink (37 points), savory LNS (34 points) and vanilla biscuit (28 points).

Table 6. 'Top 3' overall product ranking, sum of ranks results

BEP Supplements	Sum of ranks	Rank
Sweet LNS™	51	1
Seasoned Pillows	43	2
Vanilla Drink	37	3
Savoury LNS™	34	4
Vanilla Biscuit	28	5
Filled Sticks	14	6
Mango Bar	12	7
Masala Bar	8	8
Cocoa Drink	6	9
Curry Biscuit	6	9
Unseasoned Pillows	1	11

The group rankings of the 'Top 3' supplements, conducted at the end of each FGD discussion, are presented in Table 7. Only four supplements were ever named in the 'Top 3' in the FGDs: sweet LNS, vanilla biscuit, vanilla drink and seasoned pillows. In this ranking, the sweet LNS ranked first, with 14 points, followed by the vanilla drink with 8, and the vanilla biscuit and seasoned pillows, each of which had 4 points.

Table 7. Focus group rankings of 'Top 3' BEP supplements

	1st choice overall	2nd choice overall	3rd choice overall
FGD A	Sweet LNS	Vanilla Drink	Sweet Vanilla Biscuit
FGD B	Vanilla Drink	Sweet LNS	Sweet Vanilla Biscuit
FGD C	Sweet LNS	Savory Seasoned Pillows	Sweet Vanilla Drink
FGD D	Sweet LNS	Vanilla Drink	Seasoned Pillows
FGD E	Sweet LNS	Sweet Vanilla Biscuit	Seasoned Pillows
Cumulative	Sweet LNS (14 points)	Sweet Vanilla Drink (8 points)	Vanilla Biscuit and seasoned pillows (4 points)

Phase 2: ***Home-feeding trial to assess acceptability and at-home consumption***

Supplement preference and hedonic evaluation

Table 8 shows the results of the hedonic scale responses rating the sensory characteristics (color, taste, smell, texture) and overall appreciation of the two supplements. The results present consistently high appreciation for lipid-based peanut paste and the vanilla biscuits on all metrics, with an overall appreciation median (IQR) score of 6 (6-7) for both products.
In the qualitative interviews, although women in both groups responded positively to the taste overall, a few commented that the product was 'very sweet' or 'too sweet' and suggested it would be better if it had a little salt. Women in both groups proposed adding additional ingredients, such as salt or spice, or reducing the sugar content to improve taste. Identity (ID) 22 in the lipid-based peanut paste group reported, 'cashew, raisins, ground nuts, grams, ghee if all these would be there then it would be even better'. Many of the lipid-based peanut paste group compared the taste to familiar ingredients such as nuts (cashews and almonds), chickpeas and raisins. A few women in the biscuit group noted a very strong aversion to the smell of the biscuits, describing it as a 'stink' and a smell like medicine: "Its taste is good, but it stinks. It smells like medicine… and it smells like pesticides which are used in green leafy vegetables."- ID 71, biscuit group.

Women in both supplement groups reported that the supplements were easy to eat overall and in between meals (Table 8). The vast majority in both groups reported feeling moderately to very full after eating a full portion of the supplements. Similarly, a majority of women in both groups reported they would definitely or probably eat the supplements daily for up to 12 months if this product were recommended to them as beneficial for them and their baby and was provided for free. Only three women (7.5%) reported they would probably or definitely not eat the vanilla biscuit daily, and one woman (2.6%) would definitely not eat the lipid-based peanut paste daily. These data were confirmed in one of the lipid-based peanut paste FGDs where one woman said she might not eat it every day; another said that she would not be able to eat it at all because she did not like it.

A higher proportion of women in the biscuit group (35%) perceived the supplement to be medicine only compared to 18.4% in the lipid-based peanut paste group, but the majority in both groups perceived the supplements as food (Table 8). Two pregnant women in FGD 2A biscuit group mentioned not liking the biscuit after eating it for a while as it smelled like medicine. Participant 2, in FGD 2A stated “Some medicines have some chemical smell, like that, I felt like that in the beginning. One feels like that having had the product in the beginning up to now.”

Compliance

Table 9 shows the overall compliance rates for both products for the three compliance measurements. For the packet count method, which was restricted to those who were met in person every week (n = 60/80), the mean overall compliance in both groups was high at 95.5% for lipid-based peanut paste and 93.9% for the vanilla biscuit. The median and IQR of the compliance measurement for both groups were similar. The mean self-reported consumption of a full portion and any portion of the required servings in both groups were similar at 88% and 93%, respectively. The median compliance for the biscuit groups was slightly higher using the self-reported measurement (Table 9).

Table 8. Acceptability, perception and willing to use supplements after an 8-week home trial period, by supplement group

Table 9. Overall compliance over an 8-week period, by supplement group

	Lipid-based peanut paste N=38 1,2	Biscuit N=402
Appreciation of Product (1=Dislike very much to 7=Like very much), median (Q1-Q3)		
Color	7 (6-7)	6 (6-7)
Taste	7(6-7)	6 (6-7)
Texture	6 (6-7)	6 (6-7)
Smell	6 (6-7)	6 (5-7)
Overall appreciation	6 (6-7)	6 (6-7)
Perceived child likeability	6 (6-7)	6 (6-7)
Perceived adult likeability	6 (5-7)	6 (4.5-7)
Perception of product use (1=Very difficult to 7=Very easy), median (Q1-Q3)		
Product is convenient to eat	6 (6-7)	6 (6-7)
Product is convenient to eat between meals	6 (6-7)	6 (6-7)
Product is medicine or food or both, n (%)		
Medicine	7 (18.4)	14 (35)
Food	28 (73.7)	20 (50)
Both a medicine and food	3 (7.9)	6 (15)
Feel full after full portion, n (%)		
Very full	16 (42.1)	17 (42.5)
Moderately full	18 (47.4)	18 (45)
Slightly full	4 (10.5)	5 (12.5)
Would use daily if provided, n (%)		
Definitely would eat every day	25 (65.8)	25 (62.5)
Probably would eat every day	9 (23.7)	9 (22.5)
Not sure if I would eat every day	3 (7.9)	3 (7.5)
Probably would not eat every day	0 (0)	2 (5)
Definitely would not eat every day	1 (2.6)	1 (2.5)

	Lipid-based peanut paste	Vanilla Biscuit
Overall compliance over 8 weeks using various definitions:	median (Q1-Q3), mean	median (Q1-Q3), mean
Packet count method	N=26	N=34
Overall compliance (%) over 8 weeks among those met in person	100 (94.8-100) 95.5	100 (96.4-100) 93.9
Self-reported method (non-packet count method)	N=30	N=37
Overall compliance of full portion only over 8 weeks among those met in person or over the phone	91.1 (85.7-98.2) 87.6	96.4 (87.5-98.2) 88.4
Overall compliance of any portion only over 8 weeks among those met in person or over the phone	98.2 (87.5-100) 92.9	100 (94.6-100) 93.0

Phase 3:

Primary aim 1: Birth outcome results

Among 15,876 married women 15-30 years of age enumerated in the study area, 11,963 were eligible for pregnancy surveillance, and 2,090 became pregnant during the enrollment period (Figure 1). A total of 1,944 pregnant women were consented and enrolled in the study across 1,834 households from November 2021 to August 2023. Of these households, 916 were randomized to no supplement and 918 to supplement groups, resulting in 959 and 985 pregnant women assigned to each arm, respectively. Reasons for not enrolling were fetal loss (n=133, 6.4%), loss to follow-up (n=10, 0.5%), and refusal (n=3, 0.1%). The number of participants enrolled per household was 1 (n=1,730, 89.0%), 2 (n=196, 10.1%), or 3 (n=18, 0.9%).

All pregnancy outcomes were recorded among enrolled participants, including 1,581 (80.7%) live births, 353 (18.0%) miscarriages or abortions, and 26 (1.3%) stillbirths. There were 16 pairs of twins, including 15 pairs of live births and 1 pair with a live birth and stillbirth. A total of 1,209 (76.5%) infants had gestational age at birth, birth weight collected <72 hours, and sex data required for the primary analysis; one SGA observation was excluded due to an implausible weight-for-gestational age value .

Baseline participant and household characteristics were balanced across supplement groups for a range of demographic, socioeconomic, and nutritional factors (Table 10). At enrollment, mean participant age was 24.5 (3.5 SD) years, and 10.8% (n=210) were nulliparous. Most participants were of Madheshi ethnicity (n=1,910, 98.3%), and 77.9% (n=1,515) were Hindu. Nearly half of participants had no formal education (n=876, 45.1%) or were illiterate (n=863, 44.4%). Forty percent (n=781, 40.2%) of participants were short stature (<150 cm) and almost one-third (n=576, 29.6%) were underweight (<18.5 kg/m2). The median gestational age at enrollment was 8.8 weeks (IQR: 7.3, 10.5; range: 3.1, 31.9) and the median gestational age at start of supplementation was 13.1 weeks (IQR: 12.4, 14.1; range: 6.7 32.2).

Among pregnant women with at least one live birth, the median proportion of intended supplement doses consumed was 96.7% (IQR: 80.7%, 100%) and 194 (24.4%) reported consuming between 0-<80%, 279 (35.1%) reported 80-<100%, and 322 (40.5%) reported 100%. At the late pregnancy visit (approximately 30-34 weeks' gestation), there was no difference between groups in self-reported IFA consumption, receipt of calcium, or receipt of albendazole from a health facility as part of ANC. Pregnant women in the no supplement group reported a slightly higher consumption of other nutritional supplements containing protein or other vitamins during pregnancy (no supplement: n=377, 49.6% vs. supplement: n=342, 44.7% (RR: 0.90, 95% CI: 0.81, 1.00)).

There was no evidence of dietary substitution due to supplementation based on 24-h dietary data collected in a subsample (n=183). Mean differences in energy (60 kcal, 95% CI: -139, 258), protein (1.1 g, 95% CI: -5.3, 7.4), carbohydrates (17.1g, 95% CI: -17.1, 51.3), and fat (-1.7 g, 95% CI: -8.6, 5.2) intakes were not significantly different between the two groups.

The incidence of SGA (<10%) was high and did not differ between the no supplement (n=247, 41.9%) and supplement groups (n=252, 40.8%) (Table 11). The RR of SGA was 0.99 (95% CI:

0.86, 1.13). After stratification, RR of SGA were similar for women who were not short stature (RR: 0.91, 95% CI: 0.76, 1.10) and short stature (RR: 1.06, 95% CI: 0.88, 1.27) groups (Table 3). Stratification by maternal underweight produced similar results. Additionally, maternal age, parity, education, and infant sex did not modify the relationship between supplementation and primary outcome. Also, RR of SGA were similar for women with lower and higher proportion of intended supplement doses consumed (0<80%, RR: 1.04, 95% CI: 0.84, 1.29; 80-<100%, RR: 0.93, 95% CI: 0.77, 1.13; 100%, RR: 1.00, 95% CI: 0.84, 1.19). Adjustment for covariates or adjusting for clustering by household did not change the findings. Supplementation may have had a significant positive effect at the higher end of the weight-for-gestational age centile distribution (Figure 2). Results for the primary outcome were similar in imputation analyses.

Among secondary outcomes, the RRs for LBW, SGA (<3%), ShGA (<10%), ShGA (<3%), and preterm birth were not statistically significant. The mean difference in birth weight was 37.4 grams (95% CI: -6.9, 81.8) and birth length was 0.20 cm (95% CI: -0.03, 0.43) between groups. Weight-for-age centile and z-score were higher in the supplement group by 2.82 (95% CI: 0.53, 5.12) and 0.09 (95% CI: -0.00, 0.19), respectively, as was head circumference by 0.23 cm (95% CI: 0.09, 0.38). The effect on head circumference was consistent after stratification by maternal short stature and underweight status. Several secondary outcomes were improved with BEP supplementation among women not short stature (weight-for-age centile, WAZ, ShGA (10%)) or not underweight (ShGA (<3%), weight-for-age centile, WAZ). BEP consumption at the medium adherence level (80-<100%), rather than the highest (100%), was favorable for outcomes of ShGA (<3%), weight-for-age centile, WAZ, and head circumference (not shown). The intervention effect on weight-for-age centile was higher for younger maternal age (<20 years: 6.10, 95% CI: -1.00, 13.2; >20 years: 2.58, 95% CI: 0.16, 5.00; interaction term p=0.032). Short stature, underweight, age, parity, and infant sex did not modify the relationship between the supplement and LBW or continuous outcomes of birth weight, birth length, or WAZ. Results from the imputation analyses were similar or slightly attenuated to those using the primary analytical population for secondary outcomes .

LGA births did not differ by trial groups (no supplement: n=3, 0.5%, supplement: n=3, 0.5%; RR: 0.94, 95% CI: 0.19, 4.64). The C-section rate was similar in both groups (supplement: n=110, 13.9%, no supplement: n=111 14.0%; RR: 1.00, 95% CI: 0.79, 1.28).

Primary aim 2: Infant growth results

Women with a liveborn neonate who were randomized for postpartum BEP supplementation stratified by the pregnancy control and BEP arm, gave rise to four 2x2 groups with BEP vs. no BEP in either pregnancy or during lactation, both periods or neither. Baseline characteristics collected at the time of pregnancy enrollment across the four study arms did not differ (Table 12). Only 8.3% of the total sample was <20 years of age and 11.2% were nulliparous. Undernutrition was high in early pregnancy with 40% of women having short stature (<150 cm) and 29.5% had low body mass index (BMI, weight/height2). A high proportion (45.3%) of women had not received any formal education. A fourth of the population were Hindu, with Muslims being the second largest religion practiced in this setting. Household ownership of electricity and a mobile phone was almost universal and 40-45% owned a motorcycle and television.

We found no interaction between BEP supplementation during pregnancy and lactation (Supplemental Table 2), and present marginal effects of BEP supplementation in each period (vs. no supplementation) for all outcomes. BEP supplementation during pregnancy or lactation had no impact on the primary outcome of LAZ in infants at 6 months of age; the mean difference was 0.01 (95% CI: -0.10, 0.12) and -0.02 (95% CI: -0.13, 0.09), respectively (Table 2). Birth weight adjusted difference was negative for the pregnancy intervention but not significant; neither was the lactation BEP significant in the adjusted analysis. Predicted LAZ from 0 to 6 months of age by supplement group showed that a small qualitative difference in LAZ at birth related to pregnancy BEP supplementation was not apparent and reversed at 6 months of age, when the birth difference was adjusted for, with the LAZ at 6 months in the BEP arm being slightly lower than the control (Figure 2). Secondary outcomes of mean length, weight, head and MUAC, nor did the mean WAZ and WLZ differ by either intervention. All anthropometric measures improved from birth until 6 and 12 months of age. LAZ improved in a small but incremental way whereas WLZ worsened, indicating increased wasting over the course of the six months. The monthly rate of change from birth to 6 months of age in length was close to 3 cm whereas infant weight increased by about 0.67 kg during this time; neither supplementation during pregnancy nor lactation impacted the monthly rate of length or weight gain. The monthly rate of change in head circumference and MUAC and in LAZ, WAZ, and WLZ (Table 12), none of which were different by study arm. Predicted WAZ and WLZ from 0 to 6 months of age, while not different by supplement arm in the analysis unadjusted for birth, showed qualitatively lower predicted values at 6 months in the BEP arms.

The prevalence of stunting, wasting and underweight among infants at 6 months of age ranged from 8-9%, 13-14%, and 17-18%, respectively, and the prevalence risk ratio was close to 1.0 when comparing BEP vs. no BEP in pregnancy and lactation and the 95% CI included 1.0, indicating no difference due to supplementation (Table 13).

Post-supplementation BEP effect on infant anthropometric status at 12 months of age and rate of change was examined by supplementation arm (Table 3. Supplemental Table 3). None of the anthropometric measurements differed by intervention arm, although prevalence rates of wasting and stunting were high and similar ranging between 18-20% by this age.

Conclusion

In a rural South Asian population with high rates of undernutrition, daily fortified BEP supplementation provided to women starting in the second trimester may be insufficient to meaningfully reduce incidence of SGA births, though small benefits were observed for other adverse birth outcomes. The present study does not support our hypothesis that additional supplementation of energy, protein, and micronutrients during lactation has an impact on the growth of infants during their first 6 months of life. Further research is needed to understand the finding that infants of younger women and more well-nourished women may benefit more from supplementation, including through examination of intervention effect on gestational weight gain and exploration of biological mechanisms, such as changes to the infant gut microbiome. To meaningfully reduce the burden of adverse birth outcomes and infant linear growth linked to maternal undernutrition, future trials may need to explore alternative strategies, such as targeted supplementation, preconception interventions, addressing adolescent nutrition, or integrated intervention packages.

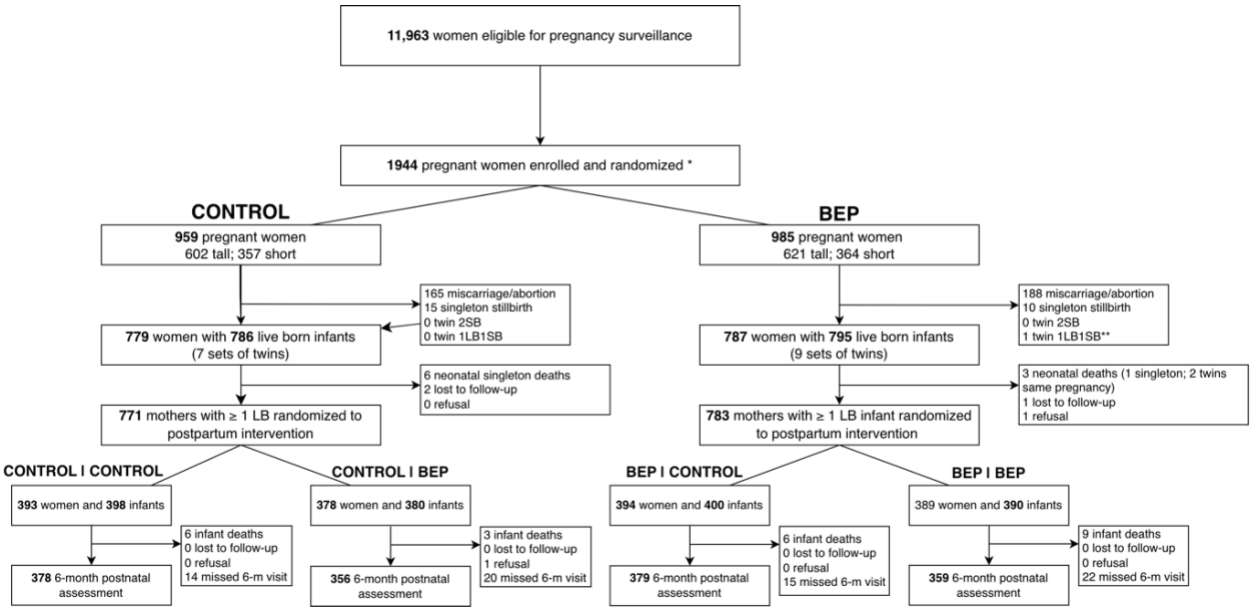

Figure 1: Study participants by pregnancy and postpartum supplement group

Table 10. Baseline participant and household characteristics (n=1,944)

	No supplementation	**Supplementation**
Participant or household characteristic[1]	**n=959**	**n=985**
Maternal age (years)		
15-19	72 (7.5%)	76 (7.7%)
20-24	480 (50.1%)	508 (51.6%)
25-29	325 (33.9%)	319 (32.4%)
≥30	82 (8.6%)	82 (8.3%)
Parity		
0	111 (11.6%)	99 (10.1%)

1	332 (34.6%)	337 (34.2%)
2	302 (31.5%)	313 (31.8%)
3+	214 (22.3%)	236 (24.0%)
Gestational age at enrollment (weeks)		
<8	348 (36.3%)	348 (35.3%)
8-11	490 (51.1%)	509 (51.7%)
12-15	82 (8.6%)	97 (9.8%)
16-19	32 (3.3%)	20 (2.0%)
≥20	7 (0.7%)	11 (1.1%)
Maternal short stature (cm)		
≥150	578 (60.3%)	585 (59.4%)
<150	381 (39.7%)	400 (40.6%)
BMI (kg/m²)		
Underweight (<18.5)	287 (29.9%)	289 (29.3%)
Normal weight (18.5-<25)	592 (61.7%)	597 (60.6%)
Overweight (25-<30)	70 (7.3%)	89 (9.0%)
Obese (≥30)	10 (1.0%)	10 (1.0%)
Ethnicity		
Pahadi	15 (1.6%)	19 (1.9%)
Madhesi	944 (98.4%)	966 (98.1%)
Education (years)		
0	424 (44.2%)	452 (45.9%)
≤11	457 (47.7%)	466 (47.3%)

>12	78 (8.1%)	67 (6.8%)
Literacy		
No	417 (43.5%)	446 (45.3%)
Yes	542 (56.5%)	539 (54.7%)
Religion		
Hindu	745 (77.7%)	770 (78.2%)
Buddhist	4 (0.4%)	4 (0.4%)
Muslim	210 (21.9%)	211 (21.4%)
Electricity		
No	37 (3.9%)	47 (4.8%)
Yes	922 (96.1%)	937 (95.2%)
Motorcycle		
No	505 (52.7%)	536 (54.4%)
Yes	454 (47.3%)	449 (45.6%)
Mobile phone		
No	29 (3.0%)	23 (2.3%)
Yes	930 (97.0%)	961 (97.7%)
Television		
No	541 (56.5%)	576 (58.5%)
Yes	417 (43.5%)	408 (41.5%)

[1] Variables missing values include electricity (n=1, 0.05%), mobile phone (n=1, 0.05%), and television (n=2, 0.10%)

Table 11: Incidence and risk of adverse birth outcomes by supplement group

Primary outcome[1,2]	**No pregnancy supplement (n=590)**	**Pregnancy supplement (n=619)**	**Unadjusted measure of association (95% CI)[3]**	**Adjusted measure of association (95% CI)[4]**
SGA (<10%)	247 (41.9%)	252 (40.8%)	0.99 (0.86, 1.13)	1.00 (0.88, 1.14)
Secondary outcomes				
PTB (<37 wks)[3]	45 (5.7%)	50 (6.3%)	1.09 (0.74, 1.62)	1.03 (0.71, 1.51)
LBW (<2,500g)	129 (21.9%)	119 (19.2%)	0.87 (0.70, 1.09)	0.93 (0.75, 1.16)
SGA (<3%)	116 (19.7%)	107 (17.3%)	0.88 (0.70, 1.12)	0.93 (0.74, 1.17)
ShGA (<10%)	195 (33.1%)	181 (29.3%)	0.90 (0.77, 1.06)	0.92 (0.78, 1.08)
ShGA (<3%)	93 (15.8%)	82 (13.3%)	0.84 (0.64, 1.11)	0.89 (0.68, 1.16)
Weight-for-age centile	19.7 (19.7)	22.7 (21.6)	**2.82 (0.53, 5.12)****	**2.28 (0.08, 4.49)****
Weight-for-age z-score	-1.12 (0.86)	-1.02 (0.90)	0.09 (-0.00, 0.19)*	0.07 (-0.02, 0.16)
Gestational age (wks)[3]	39.3 (1.5)	39.3 (1.7)	0.01 (-0.15, 0.17)	0.02 (-0.13, 0.17)
Birth weight (grams)	2789.9 (388.9)	2829.3 (411.9)	37.4 (-6.9, 81.8)*	23.3 (-18.5, 65.3)
Birth length (cm)	47.7 (2.0)	47.9 (2.1)	0.20 (-0.03, 0.43)*	0.12 (-0.09, 0.34)
Head circumference (cm)	33.4 (1.3)	33.6 (1.3)	**0.23 (0.09, 0.38)****	**0.19 (0.05, 0.34)****

[1] Mean (SD) or Frequency (%) as appropriate.

[2] Models for these primary and secondary outcomes include infants with anthropometry collected within 72 hours of delivery (n=1,207-1,209), except those for gestational age data, which include all infants (n=1,581).

[3] We estimated unadjusted relative risks for binary outcomes using log-binomial regression models and mean differences for continuous outcomes using linear regression models for intervention vs. control. We used Poisson regression models to estimate the adjusted measures of association for

binary outcomes due to convergence issues. All models included maternal short stature (<150 cm) as a binary covariate to adjust for the randomization stratification on this variable.

[4] Adjusted for maternal age (years), maternal height (cm), BMI, parity (number of previous live births and stillbirths), education (years of schooling), infant sex, and multiple birth.

*p<0.1, **p<0.05

Table 11: Effect of BEP supplementation by supplement group on post-natal growth at 6 mo and across birth to 6 months of age

Characteristics	No BEP in pregnancy	BEP in pregnancy			No BEP in lactation	BEP in lactation	
Effect at 6 mo postpartum							
	Mean (SD) (a)	Mean (SD) (b)	Mean difference[1] (95%CI) (b)-(a)		Mean (SD) (a)	Mean (SD) (b)	Mean difference[1] (95%CI) (b)-(a)
Primary Outcome							
LAZ (n=1471)	-0.59 (1.09)	-0.58 (1.06)	0.01 (-0.10, 0.12)		-0.57 (1.08)	-0.59 (1.06)	-0.02 (-0.13, 0.09)
Adjust birth LAZ (n=1471)			-0.04 (-0.14, 0.06)				-0.01 (-0.11, 0.08)
Secondary Outcomes							
Length (cm) (n=1471)	64.62 (2.62)	64.70 (2.50)	0.08 (-0.18, 0.34)		64.71 (2.55)	64.61 (2.57)	-0.10 (-0.36, 0.17)
Adjust birth length (cm) (n=1471)			-0.04 (-0.25, 0.18)				-0.02 (-0.24, 0.20)
Weight (kg) (n=1472)	6.61 (0.86)	6.61 (0.82)	0.01 (-0.08, 0.09)		6.63 (0.82)	6.59 (0.86)	-0.03 (-0.12, 0.05)
Adjust birth weight (kg) (n=1472)			-0.04 (-0.11, 0.30)				-0.03 (-0.10, 0.42)
HC (cm) (n=1472)	41.5 (1.3)	41.6 (1.2)	0.13 (-0.01, 0.26)		41.6 (1.3)	41.5 (1.3)	-0.04 (-0.17, 0.09)
Adjust birth HC (cm) (n=1472)			-0.00 (-0.10, 0.11)				-0.01 (-0.12, 0.10)
MUAC (cm) (n=1469)	13.6 (1.1)	13.6 (1.1)	-0.03 (-0.14, 0.09)		13.6 (1.1)	13.6 (1.1)	-0.02(-0.13, 0.09)
Adjust Birth MUAC (cm) (n=1469)			-0.05 (-0.16, 0.06)				-0.02 (-0.13, 0.09)
WAZ (n=1472)	-1.07 (1.01)	-1.08 (0.96)	-0.01 (-0.11, 0.09)		-1.06 (0.98)	-1.09 (1.00)	-0.03 (-0.13, 0.07)

Adjust birth WAZ (n=1472)			-0.07 (-0.16, 0.02)				-0.04 (-0.13, 0.05)
WLZ (n=1471)	-0.80 (1.10)	-0.83 (1.08)	-0.04 (-0.15, 0.07)		-0.80 (1.10)	-0.83 (1.08)	-0.03 (-0.14, 0.09)
Adjust birth WLZ (n=1471)			-0.05 (-0.16, 0.06)				-0.04 (-0.15, 0.07)
Monthly rate from birth to 6 mo postnatal							
	Mean (95%CI)[2] (a)	Mean (95%CI)[2] (b)	Difference in rate of change (95% CI) (b-a)[3]		Mean (95%CI)[2] (a)	Mean (95%CI)[2] (b)	Difference in rate of change (95%CI)[3] (b-a)
Length (cm) (n=10224)	2.99 (2.96, 3.02)	2.98 (2.95, 3.01)	-0.01 (-0.05, 0.03)		2.99 (2.96, 3.01)	2.99 (2.96, 3.01)	0.00 (-0.04, 0.04)
Weight (kg) (n=10225)	0.68 (0.67, 0.69)	0.67 (0.66, 0.68)	-0.01 (-0.02, 0.01)		0.68 (0.67, 0.69)	0.67 (0.66, 0.68)	-0.00 (-0.02, 0.01)
HC (cm) (n=10225)	1.40 (1.39, 1.42)	1.38 (1.37, 1.40)	-0.02 (-0.04, 0.00)		1.39 (1.38, 1.41)	1.39 (1.38, 1.41)	0.00 (-0.02, 0.02)
MUAC (cm) (n=10198)	0.68 (0.66, 0.69)	0.66 (0.64, 0.67)	-0.02 (-0.04, -0.00)		0.67 (0.66, 0.68)	0.66 (0.65, 0.68)	-0.01 (-0.03, 0.01)
LAZ (n=10224)	0.05 (0.04, 0.07)	0.04 (0.03, 0.05)	-0.01 (-0.03, 0.00)		0.05 (0.04, 0.06)	0.05 (0.04, 0.06)	-0.00 (-0.02, 0.02)
WAZ (n=10225)	-0.02 (-0.03, -0.00)	-0.03 (-0.05, -0.02)	-0.02 (-0.03, -0.00)		-0.02 (-0.03, -0.01)	-0.03 (-0.04, -0.02)	-0.01 (-0.02, 0.01)
WLZ (n=10224)	-0.08 (-0.10, -0.06)	-0.09 (-0.11, -0.07)	-0.01 (-0.04, 0.01)		-0.08 (-0.09, -0.06)	-0.09 (-0.11, -0.08)	-0.02 (-0.04, 0.01)
Relative risk of undernutrition at 6 mo postpartum							
	n(%)	n(%)	PR (95%CI)[4]		n(%)	n(%)	PR (95%CI)[4]
Stunting (n=1471)	66 (9.0)	62 (8.4)	0.93 (0.70, 1.30)		65 (8.6)	63 (8.8)	1.01 (0.74, 1.43)

Adjust birth stunting (n=1471)			0.95 (0.69, 1.31)				1.07 (0.77, 1.48)
Wasting (n=1471)	100 (13.6)	102 (13.8)	1.01 (0.78, 1.31)		100 (13.2)	102 (14.3)	1.08 (0.84, 1.40)
Adjust birth wasting (n=1471)			1.01 (0.78, 1.30)				1.10 (0.86, 1.43)
Underweight (n=1472)	130 (17.7)	126 (17.1)	0.96 (0.77, 1.20)		131 (17.3)	125 (17.5)	1.01 (0.81,1.26)
Adjust birth underweight (n=1472)			0.97 (0.78, 1.20)				1.08 (0.88, 1.34)

LAZ, length-for-age z-score; WAZ, weight-for-age z-score; WLZ, weight-for-length z-score, MUAC, mid-upper arm circumferences; HC, Head circumference; PR, Prevalence ratio

1 Linear regression analysis was used to derive the intervention effect

2 Multi-level mixed-effects model estimated the monthly change in growth outcomes (95%CI). Program exposure was included as a fixed effect, while individual participant was treated as a random intercept and time of visit as a random slope to account for repeated measures. Interaction terms between time to assessment (month) and supplementation allocation presented the intervention effect.

3 Differences (95% CI) in monthly change of growth outcomes between control and supplementation group were derived using contrasts of average marginal effects.

4 Generalized linear regression models with a Poisson distribution and robust standard errors were used to derive relative risk (95%CI).

Table 13. Effect of BEP supplementation by supplement group at 12 months of age

Characteristics	No BEP in pregnancy	BEP in pregnancy	Marginal effect		No BEP in lactation	BEP in lactation	Marginal effect
Effect at 12 mo postpartum							
	Mean (SD) (a)	Mean (SD) (b)	Mean difference (95%CI) (b)-(a)		Mean (SD) (a)	Mean (SD) (b)	Mean difference (95%CI) (b)-(a)
Length (cm) (n=1100)	71.37 (2.91)	71.44 (2.70)	0.07 (-0.26, 0.41)		71.47 (2.84)	71.33 (2.78)	-0.14 (-0.47, 0.19)
Adjust birth length (cm) (n=1100)			-0.10 (-0.39, 0.19)				-0.07 (-0.36, 0.21)
Weight (kg) (n=1101)	7.83 (1.00)	7.90 (1.02)	0.07 (-0.05, 0.19)		7.88 (0.99)	7.85(1.03)	-0.02 (-0.14, 0.97)

Adjust birth weight (kg) (n=1101)			0.01 (-0.10, 0.12)				-0.02 (-0.13, 0.09)
HC (cm) (n=1101)	43.99 (1.37)	44.12 (1.36)	0.12 (-0.04, 0.28)		44.05 (1.33)	44.06 (1.39)	0.01 (-0.15, 0.17)
Adjust birth HC (cm) (n=1101)			0.01 (-0.13, 0.15)				0.02 (-0.12 0.16)
MUAC (cm) (n=1101)	13.61 (1.03)	13.59 (1.03)	-0.02 (-0.14, 0.10)		13.61 (1.04)	13.59 (1.01)	-0.02 (-0.14, 0.10)
Adjust Birth MUAC (cm) (n=1101)			-0.04 (-0.16, 0.08)				-0.03 (-0.15 0.09)
LAZ (n=1100)	-1.01 (1.11)	-1.00 (1.05)	0.01 (-0.12, 0.13)		-0.98 (1.08)	-1.03 (1.08)	-0.05 (-0.18, 0.08)
Adjust birth LAZ (n=1100)			-0.05 (-0.17, 0.06)				-0.05 (0.16, 0.08)
WAZ (n=1101)	-1.38 (1.03)	-1.32 (1.05)	0.05 (-0.07, 0.17)		-1.34 (1.01)	-1.36 (1.06)	-0.02 (-0.14, 0.11)
Adjust birth WAZ (n=1101)			-0.01 (-0.12, 0.11)				-0.03 (-0.14, 0.08)
WLZ (n=1100)	-1.15 (1.02)	-1.09 (1.09)	0.06 (-0.07, 0.19)		-1.12 (1.05)	-1.12 (0.07)	0.02 (-0.11, 0.15)
Adjust birth WLZ (n=1100)			0.05 (-0.08, 0.18)				0.01 (-0.12, 0.13)
Relative risk of undernutrition at 12 mo postpartum							
	n(%)	n(%)	PR (95%CI)		n(%)	n(%)	PR (95%CI)
Stunting (n=1100)	95 (17.7)	103 (18.3)	1.04 (0.81, 1.34)		102 (18.3)	96 (17.7)	0.97 (0.75,1.25)
Adjust birth stunting (n=1100)			1.07 (0.83, 1.36)				1.00 (0.78, 1.28)
Wasting (n=1100)	111 (20.7)	102 (18.2)	0.89 (0.70, 1.13)		106 (19.1)	107 (19.8)	1.03 (0.81,1.31)
Adjust birth wasting (n=1100)			0.89 (0.70, 1.13)				1.04 (0.82, 1.33)
Underweight (n=1101)	133 (24.7)	137 (24.4)	0.99 (0.80, 1.22)		135 (24.2)	135 (24.9)	1.04 (0.84, 1.27)
Adjust birth underweight (n=1100)			0.99 (0.81, 1.21)				1.08 (0.88, 1.33)

LAZ, length-for-age z-score; WAZ, weight-for-age z-score; WLZ, weight-for-length z-score, MUAC, mid-upper arm circumferences; HC, Head circumference; PR, Prevalence ratio

1 Linear regression analysis was used to derive the intervention effect
2 Multi-level mixed-effects model estimated the monthly change in growth outcomes (95%CI). Program exposure was included as a fixed effect, while individual participant was treated as a random intercept and time of visit as a random slope to account for repeated measures. Interaction terms between time to assessment (month) and supplementation allocation presented the intervention effect.
3 Differences (95% CI) in monthly change of growth outcomes between control and supplementation group were derived using contrasts of average marginal effects.
4 Generalized linear regression models with a Poisson distribution and robust standard errors were used to derive relative risk (95%CI).

Data Safety Monitoring Board

The purpose of the Data and Safety Monitoring Board is to provide external, objective advice to the Executive Committee regarding the safety and efficacy of the interventions being evaluated. This committee will be responsible for reviewing the study protocol, and results of the study on a regular basis, summarizing their conclusions and advice in a written set of minutes, and communicating this information to the Executive Committee. The PI will then forward these minutes to the Institutional Review Boards at the George Washington University and the Nepal Health Research Council.

The DSMB has specific responsibility to determine if there are problems relating to the safety of the intervention, to the degree that the trial should be stopped, and to determine if the study should be stopped early because the benefit of the interventions has proved to be stronger than originally anticipated. The Data and Safety Monitoring Board will meet just prior to the onset of field operations to review the final protocol, and once a year after the beginning of data collection to review the accumulated data. Voting membership on the Data Safety and Monitoring Board is limited to persons external to the investigative team. Senior members of the investigative team will serve as ex-officio members without voting rights. The composition of the DSMB will include expertise in biostatistics, pediatrics, OB/GYN, epidemiology, and research ethics. At least one member (non-voting) will be from the Nepal Health Research Council. In addition to the voting members of the DSMB, study investigators will act as resources to the DSMB in a non-voting capacity.

The DSMB members for this trial were as follows:

1. Prof. Dr. Sudha Basnet (Chairperson), Professor, Department of Pediatrics, Institute of Medicine (IoM), Tribhuvan University
2. Prof. Dr. Meeta Singh, Head, Department of Gynecology and Obstetrics, Nepalgunj Medical College
3. Dr. Ram Krishna Chandyo, Associate Professor, Department of Community Medicine, Kathmandu Medical College
4. Dr. Chakra Budhathoki, Associate Professor, Biostatistician, Johns Hopkins University School of Nursing

The DSMB members met a total of five times during this study period with the first meeting held on December 12, 2021 and the final meeting held on December 9, 2025.

Dissemination

Results of the study were disseminated in Kathmandu on December 12, 2025 that included forty-one participants with expertise and experience in maternal, newborn, and child health and nutrition from the National Planning commission, Family Welfare Division of the Ministry of Health and Population, Nepal Health Research Council, academia (University College London, CAFODAT college, Kathmandu University) and development partners (UNICEF Nepal, UNICEF regional office of South Asia, World Food Programme, Eleonor Crooke Foundation). On January 14, 2026, the results were disseminated at the district level in

Malangwa, Sarlahi district where stakeholders from the district and municipalities were invited and attended. A total of 48 stakeholders were invited out of whom 34 attended the meeting.

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Supplementary table 1: Balanced energy-protein supplement nutritional composition

Formula 1 ingredients: Vegetable oils (rapeseed, palm, soy in varying proportions), defatted soy flour, skimmed milk powder, peanuts, sugar, maltodextrin, soy protein isolate, vitamin and mineral complex, stabilizer (fully hydrogenated vegetable fat, mono and diglycerides). Allergens warning: peanuts, soy and dairy products. May contain traces of gluten.

Formula 2 ingredients: Vegetable oils (rapeseed, palm), skimmed milk powder, defatted soy flour, peanuts, sugar, maltodextrin, vitamin and mineral premix, fully hydrogenated vegetable oil (palm). Allergens warning: peanuts, soy and dairy products. May contain traces of gluten.

Formula 3 ingredients: Peanuts, vegetable oil (rapeseed), skimmed milk powder, sugar, whey protein concentrate, maltodextrin, premix of vitamins and minerals, fully hydrogenated vegetable oil (palm), flavor. Allergens warning: peanuts and dairy products. May contain traces of soy.

		Formula 1		**Formula 2**		**Formula 3**	
		RUSF P&L 72g		**Reformulation 1 RUSF P&L 72g**		**Reformulation RUSF 2 P&L 72**	
Nutrients	**Unit**	**Mean / 100g**	**Mean / dose 72g**	**Mean / 100g**	**Mean / dose 72g**	**Mean / 100g**	**Mean / dose 72g**
Energy	**kcal**	546	393	544	391	557	401
Protein	**g**	20.2	14.5	20.4	14.7	20.2	14.5
Lipids	**g**	36	26	36	26	37.3	26.9
Linoleic Acid	**g**	5.4	3.9	5.4	3.9	6.2	4.5
alpha- Linolenic Acid	**g**	1.8	1.3	1.9	1.4	1.8	1.3
Calcium	**mg**	694	500	776	559	695	500
Zinc	**mg**	21	15	21	15	21	15

Copper	**mg**	1.8	1.3	1.8	1.3	1.8	1.3
Iron	**mg**	31	22	30	22	31	22
Iodine	**ug**	347	250	360	260	348	250
Selenium	**ug**	90	65	91	65	94	68
Manganese	**mg**	2.9	2.1	2.9	2.1	2.9	21
Magnesium	**mg**	102	73	108	78	99	72
Free phosphorus	**mg**	580	418	638	459	664	478
Potassium	**mg**	781	562	892	642	800	576
Vitamin A	**ug RE**	1069	770	1069	770	1,069	770
Vitamin B1	**mg**	1.9	1.4	1.9	1.4	1.9	1.4
Vitamin B2	**mg**	1.9	1.4	1.9	1.4	1.9	1.4
Niacin	**mg**	21	15	21	15	21	15
Vitamin B5	**mg**	9.7	7	9.7	7	9.7	7.0
Vitamin B6	**mg**	2.6	1.9	2.6	1.9	2.6	1.9
Folic Acid	**ug**	556	400	556	400	556	400
Vitamin B12	**ug**	3.6	2.6	3.6	2.6	3.6	2.6
Vitamin C	**mg**	139	100	139	100	139	100

Vitamin D (Cholecaciferol)	**ug**	21	15	21	15	21	15
Vitamin E (alpha tocopherol)	**mg**	25	18	25	18	25	16
Vitamin K	**ug**	100	72	100	72	100	72

Reference: Erchick DJ, Lama TP, Khatry SK, Katz J, Mullany LC, Zavala E, LeClerq SC, Christian P, Tielsch JM. Supplementation with fortified balanced energy-protein during pregnancy and lactation and its effects on birth outcomes and infant growth in southern Nepal: protocol of a 2×2 factorial randomised trial. BMJ Paediatr Open. 2023 Nov;7(1):e002229. doi: 10.1136/bmjpo-2023-002229.