Nutrition and Dietary Supplements
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ORIGINAL RESEARCH

Evaluation of energy, protein, and selected micronutrient density of homemade complementary foods consumed by children between 6 months and 23 months in food insecure woredas of Wolayita zone, Southern Ethiopia

This article was published in the following Dove Press journal:
Nutrition and Dietary Supplements
19 September 2016
Number of times this article has been viewed

Motuma Adimasu Abeshu[1,2]
Abdulaziz Adish[3]
Gulelat D Haki[4]
Azeb Lelisa[5]
Bekesho Geleta[6]

[1]John Snow, Inc, [2]Addis Ababa University, Center for Food Science and Nutrition, [3]Micronutrient Initiative Africa, Addis Ababa, Ethiopia; [4]Department of Food Science and Technology, University of Botswana, Gaborone, Botswana; [5]Micronutrient Initiative Ethiopia, [6]Ethiopian Public Health Institute, Addis Ababa, Ethiopia

Correspondence: Motuma Adimasu Abeshu
John Snow, Inc, PO Box 27236, Addis Ababa, Ethiopia
Tel +251 9 2146 2246
Email motumad4@gmail.com

Abstract: Complementary feeding should be timely, adequate, and given in a way that is appropriate for the age of the child, applying responsive feeding to fill the gap between what is provided by breastfeeding and the total nutritional requirements of the infant. The purpose of this study was to assess nutrient composition and evaluate adequacy of observed nutrient densities (energy, protein, calcium [Ca], iron [Fe], and zinc [Zn]) in homemade complementary foods for children of age 6–23 months, in comparison to the desired levels in food insecure woredas of the Wolayita zone, Southern Ethiopia. A cross-sectional weighed food record method was used to assess the energy and micronutrient compositions of homemade complementary foods and evaluate adequacy of observed nutrient densities in relation to the desired levels. Multistage sampling was used to locate the children. Observation and measurement of complementary food preparations throughout the day was made. Representative portions from the diets were sampled for further laboratory analysis and to evaluate adequacy of observed nutrient levels. More than 20 different complementary food types (mostly an extension of family foods) prepared from various food items were observed. Dietary diversity of the foods was very poor. The average dietary diversity score was only 2.54, while animal-source foods and vitamin A-rich fruits and vegetables were virtually absent. The energy and protein compositions of the diets, however, were sufficient. Energy density of 0.92 kcal/g, 1.24 kcal/g, and 1.41 kcal/g and protein density of 3.41 g/kcal, 2.18 g/kcal, and 2.48 g/kcal were observed in the diets of 6–8-month, 9–11-month, and 12–23-month age categories, respectively. The diets were poor in micronutrients. The observed nutrient density for Ca and Zn (mg/100 kcal) was significantly lower (P=0.000) than the desired levels. Similarly, the Fe level in the diets for 6–11 month old children was significantly lower than the desired nutrient density levels even when high bioavailability was accounted for. On the contrary, adequate nutrient density in the diets for 12–23 month old children was observed even when low bioavailability for Fe was accounted for. The complementary foods were energy dense. Micronutrients densities observed (Ca, Zn, and Fe), however, were very low as they continue to be the "problem nutrients".

Keywords: food insecure, nutrient density, homemade, estimated daily nutrient intake

Introduction

Complementary feeding has been defined as the process starting when breast milk alone is no longer sufficient to meet the nutritional requirements of infants, and therefore,

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http://dx.doi.org/10.2147/NDS.S112736

other foods and liquids are needed, along with breast milk.[1] It covers a period from 6 months to 23 months of age and is often characterized by an increased risk of malnutrition as infants and young children transit from highly nutritious breast milk as only/primary source of nutrients to transitional/family foods.[2–4] Complementary feeding should therefore be timely, adequate, and given in a way that is appropriate for the age of the child, applying responsive feeding.[1]

Complementary foods are expected to fulfill the following features: high energy content, low viscosity (ie, of an acceptable thickness or consistency), balanced protein (containing all essential amino acids) content, required vitamin and mineral (iron [Fe], folic acid, calcium [Ca]) contents, no (safe level) antinutritional components, and pleasant taste (palatable).[5]

Complementary foods usually are of two types: commercially prepared infant foods bought from the market and homemade complementary foods, which are prepared at the household (HH) level by the caregivers following traditional methods. In several parts of the developing world, complementary feeding continues as a challenge to good nutrition in children of age 6–23 months.[6] The challenges are context specific, but many are common across settings. They are often characterized by a combination of poor feeding practices and poor dietary quality of homemade complementary foods.[7–9] Commonly observed dietary quality problems include too little variety; inappropriate consistency; too few essential vitamins and minerals, especially vitamin A, Fe, zinc (Zn), and Ca; too few essential fatty acids; and too few calories among nonbreastfed infants.[8,10,11] Commercial, fortified food products on the other hand are often beyond the reach of the poor. A growing proportion of people in the developing countries do not have the physical access and economic capability to purchase fortified products.[12] Homemade complementary foods are prepared at the HH level by the caregivers following different traditional methods. The recommendation for specific food type to prepare depends on age appropriateness and development stage of infants and young children. The basic recipe food items used for the preparation of the complementary foods are commonly based on locally available staples, while the choice of specific food items differs considerably between populations, owing to tradition, availability, and ease of access.[13] In many developing countries, the staples are cereals, roots, and starchy fruits that mainly consist of carbohydrate and provide energy.[12] A commonly shared phenomenon about homemade complementary foods that are based on starchy roots and tubers or rice and available in many low-income countries is their frequent shortfall in composition of essential micronutrients such as Ca, Fe, and Zn. In contrast, the recipes prepared from maize and legumes or other cereal mixtures and legumes not only have higher Fe and Zn contents but also have considerably higher phytate contents.[14,15]

The net effect in both cases is that they would not meet the theoretical mineral requirements of young children due to either their low mineral content or as a result of low bioavailability, unless enriched with animal source foods (ASF) or fortified with appropriate micronutrients.[6,16,17] As a result, the World Health Organization designates Ca, Fe, and Zn as "problem nutrients", and deficiencies of these minerals can lead to adverse health consequences and restricted child growth and development.[6,16–18]

The recommendations for complementary feeding recipes for Ethiopian children of age 6–23 months are based on simple and locally available food items.[19] A review of the existing practice shows that homemade complementary foods are predominantly based on cereals and legumes (or other plant-derived products), and mostly an extension of family foods[16,20,21] which as such may fail to provide important nutrients.[22,23]

Starch-based complementary foods produce viscous porridges and gruels that are often known to be of low nutritive value and are characterized by low protein, low energy density, and high bulk.[24] For instance, traditional corn-based porridge consumed as a complementary food in rural villages of Sidama zone of Southern Ethiopia contains energy density of 53 kcal/100 g, while the kocho-based one contains 49 kcal/100 g, both of which contain very low energy levels.[25] In addition, mothers/caregivers usually dilute them to facilitate administration. However, this produces further reduction in the energy and nutrient density of the food.[9,16,26]

There is handful of literature available regarding the nutrient density of complementary foods and its adequacy. In Northern Wollo, Baye et al[21] assessed nutrient intakes from complementary foods, while the focus age groups were young children of age 12–23 months. By this age, most children are developmentally ready and are able to consume family foods of solid consistency compared to younger age groups.[27] Similarly, Gibson et al[16] assessed the energy and nutrient compositions of plant-based complementary foods (made from potato, kale, chickpea flour, oil, and water) used in Ethiopia and evaluated their adequacy for children of age 9–11 months as complementary foods. Even if a single set of recipes is used, gaps in key micronutrient composition have been reported.

Other studies based on 24-hour recall were also conducted, for instance, the Ethiopia Demographic and Health Survey study. Such methods use dietary diversity scores (DDSs) to predict nutrient density and assume serving sizes to predict adequacy of complementary foods,[28] which may be subject to measurement errors and recall biases.[29] In addition, there are limited studies conducted that target population groups with characteristics of chronic food insecurity.

For this study, therefore, a weighed food record method was used to assess the composition and evaluate whether the observed nutrient density (composition) would be adequate to be used as a complementary food when compared to the desired levels. The evaluation was conducted on homemade complementary foods for children of age 6–23 months in food insecure woredas of the Wolayita zone, Southern Ethiopia.

Materials and methods

Study area and period

Adequacy of daily energy, protein, and selected micronutrients intake from homemade complementary foods for children of age 6–23 months was evaluated in two of the five community-based nutrition woredas in the Wolayita zone. Dugna Fango and Kindo Koysha woredas are characterized by history of a high rate of severe acute malnutrition, high poverty, and chronic food insecurity.[30] Dugna Fango woreda has a population of 104,564, while Kindo Koysha has 96,480.[31] The major food crops in these woredas include, in order of importance, maize, sweet potato, *Ensete ventricosum* (false banana), teff (*Eragrostis tef*), haricot bean, sorghum, Irish potato, yam, and cassava.[31,32]

The study was conducted from October 2014 to April 2015.

Study design

A cross-sectional weighed food record method was used to assess the nutrient composition and evaluate adequacy of amount consumed per day to satisfy the nutrient requirement of children of age 6–23 months from homemade complementary feeding in selected food insecure woredas of the Wolayita zone.

Study population

All children of age between 6 months and 23 months, and their mothers/caregivers living in Kindo Koysha and Dugna Fango woredas of the Wolayita zone, who have been breastfed the first 6 months of life, and had a history of breastfeeding at the time of the study, respectively, were included in the study.

Samples and sampling design

Sample size

The sample size was determined after reviewing published articles that have employed weighed food record method as their study design. For instance, the sample size used in the article published by Baye et al[21] was 76 HHs, while Abebe et al[25] used 58 HHs. For this study, 68 child and mother/caregiver pairs were sampled.

Sampling design

From five community-based nutrition woredas in the Wolayita zone, two woredas with characteristics of food insecurity and severe malnutrition[30] were selected using the convenient sampling method. The kebeles (lowest administrative unit) in each woreda were then stratified into urban, semiurban, or rural. One representative kebele from the rural and semiurban kebeles in each woreda was then selected randomly using the lottery method. Urban kebeles were excluded from the sampling frame as preliminary assessments indicated mixed use of commercial and homemade complementary foods for child feeding. Subsequently, the size of HHs sampled per kebele was based on the proportionate sampling method as per their total population sizes. Individual HHs within the kebeles were finally picked from the list of eligible ones compiled from the health facility registry and health extension workers' report using the simple random sampling method.

Sample collection and handling

Sample collection tools

A semistructured questionnaire was customized from "guidelines for measuring HH and individual dietary diversity"[11] and "indicators for assessing infants and young child feeding practices",[33] piloted, and further enriched based on feedback obtained before its use, to collect data regarding homemade complementary foods. Daily food intakes were measured using high-precision digital balances. Weighed samples of the diets were sampled for nutrient analysis.

Implementation of tools

Four qualified and experienced nutritionists with knowledge of the study area were recruited and trained on the tool and data collection procedures for 2 days and dispatched for the data collection. One data collector per kebele and a supervisor per woreda were assigned to undertake the process.

Sample collection procedure

Mothers/caregivers were visited the day before to obtain their consent and asked to maintain regular feeding styles. One investigator per one to two HHs in the same neighborhood was assigned to cover the observation, measurement, and sampling of foods. Visits started early in the morning (7 am East Africa Time) and ended when the mother certified that the child would not consume anything except breast milk until the next day (8 pm East Africa Time).

The measurement involved the identification of food types served on the visit day, the food items used in recipes, and measurement of the quantity of complementary foods served and consumed by the child throughout the day. For dishes prepared from mixed recipes, food items used for preparing the complementary foods were identified and weighed separately before starting the mixing and cooking process. The final weight of the preparation was also measured later. From the food items included in the preparation, DDS was constructed.

Measurement to the nearest 0.1 g was made using SF-400 digital balances of 1–2,000 g capacity. The scales were calibrated every morning, and the same scales were used throughout. Individual servings were measured by weighing the plate and food both before and after the children were fed. Samples proportionate to individual servings were drawn throughout the day for further laboratory assays.

Other sociodemographic information, such as mother's/caregiver's age and level of education, HH size, parity, income, etc, was collected by interviewing the mothers/caregivers using the data collection tool.

Food sample handling

The complementary foods sampled were transferred to sample collection bottles, tightly closed, labeled, and placed in temperature-conditioned cold boxes. At the end of each day, the samples were transferred to and maintained in refrigerators until they were analyzed in laboratory assays.

Laboratory analysis

Preparation of samples

The primary food samples collected from HHs were sorted and grouped by the age of the children (6–8 months, 9–11 months, and 12–23 months) into sample categories 1, 2, and 3, respectively. Three composite samples were then prepared by crushing and mixing the primary samples to homogeneity using a mortar and pestle. Laboratory samples weighing 200 g were randomly sampled from each category for further assays.

Procedures for analysis

Assay of nutrient composition of the diets was conducted using established analytical procedures.[34]

The moisture content of the complementary foods was determined using (Association of Official Analytical Chemists) AOAC Official Method 925.10, while AOAC Official Method 920.39 was used to analyze the crude fat content. AOAC Official Methods 923.03, 962.09, and 986.11 and modified AOAC 985.35 were used to analyze crude ash, crude fiber, phytic acid, and the micronutrient (Ca, Fe, and Zn) contents, respectively. The crude protein content was determined following procedures under ES ISO 1871:213. The carbohydrate content was determined using the difference method as:

$$\% \text{ Carbohydrate} = 100 - (\% \text{ moisture} + \% \text{ fat} + \% \text{ protein} + \% \text{ ash} + \% \text{ crude fiber}) \quad (1)$$

The nutrient density of the diets was based on edible portions (as eaten) so as to allow comparison to the desired nutrient density levels.

Data analysis and interpretation

HH information and dietary nutrient levels were cleared, coded, and analyzed using SPSS Version 20. The findings were presented using tables, charts, and graphs, while proportion, mean, and standard deviation were the tools used to describe the data.

Statistical tests were employed to test whether the observed nutrient density for protein (g/100 kcal), Ca, Fe, and Zn (mg/100 kcal) in the homemade complementary foods would contain the minimum desired nutrient density as a complementary food.

The desired nutrient density from complementary foods for protein as 0.7 g/100 kcal; Ca as 123 mg/100 kcal, 78 mg/100 kcal, and 26 mg/100 kcal; and Zn as 1.6 mg/100 kcal, 1.0 mg/100 kcal, and 0.8 mg/100 kcal, for the 6–8-month, 9–11-month, and 12–23-month age categories, respectively, were used as true values. Similarly, the observed nutrient density for Fe was compared to the desired levels assuming for high, moderate, and low bioavailabilities. Accordingly, desired levels of 2.5 mg/100 kcal, 1.5 mg/100 kcal, and 0.5 mg/100 kcal for high bioavailability; 4.0 mg/100 kcal, 2.4 mg/100 kcal, and 0.8 mg/100 kcal for moderate bioavailability; and 7.7 mg/100 kcal, 4.6 mg/100 kcal, and 1.6 mg/100 kcal for low bioavailability were considered as true values for the 6–8-month, 9–11-month, and 12–23-month age categories, respectively.[6,18]

For differences observed, statistical significance was tested at $P<0.05$ using Student's *t*-test.

Ethical consideration

Ethical clearance from Addis Ababa University; Southern Nations Nationalities and Peoples Regional Health Bureau;

and Wolayita Zonal Health Department, and each woreda was secured before commencing the study. At the HH level, informed oral consent was obtained from mothers/caregivers to proceed with the data collection process. Utmost care was taken to maintain the confidentiality of the participants during analysis and dissemination of findings.

Results

Background characteristics of the respondents

Assessment of the nutrient composition and energy density of homemade complementary foods was conducted in a total of 68 HHs having children of ages between 6 months and 23 months in Dugna Fango and Kindo Koysha woredas.

The average HH size was 5.2 persons per HH. The age distribution of the population surveyed showed 98.8% of the total populations were younger than 49 years. Children between 6 months and 23 months of age, however, constituted only 19.89% of the total population surveyed. The great majority of the population were between 15 years and 49 years (42.90%), followed by the 5–14 years age group (28.41%). Almost all the respondents (98%) were of Wolayita ethnicity and were followers of Protestant religion (60.8%), followed by Orthodox (38.1%) and Muslim (1.1%). Table 1 provides a summary of selected sociodemographic characteristics of the HHs surveyed.

The literacy rate was very low (Table 1). Less than half (47.4%) of the total population were literate enough and capable of reading and writing. Out of these, 32.7% of them had attended elementary schools (1–8 grade), 11.9% had reached high school (9–12 grade), and only 0.9% had received some form of college training. Among the HH members, a majority (61.4%) of them had no formal jobs, while 11.9% of them were farmers (mostly, the heads of the HHs) and 8.2% of them were merchants (Figure 1).

A great majority (272, 77.27%) of the HH members surveyed had no regular source of income. The respondent's feedback regarding their average monthly income (in

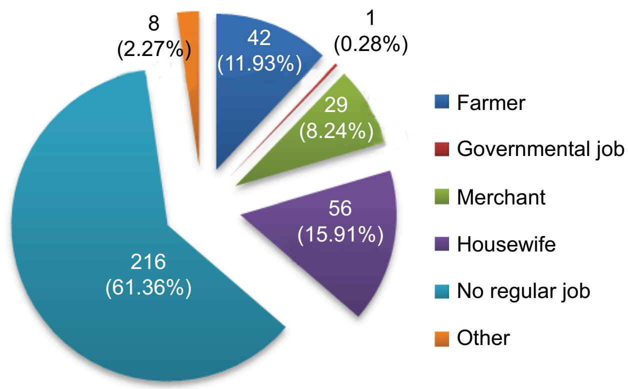

Figure 1 Occupational status of HH members.
Abbreviation: HH, household.

Table 1 Background characteristics of households

Background variable		Woredas					
		Dugna Fango		Kindo Koysha		Total	
		N	%	N	%	N	%
Sex	Male	79	53.74	97	47.32	176	50
	Female	68	46.26	108	52.68	176	50
	Total					352	100
Age ranges	<6 months	0	0	1	0.49	1	0.28
	6–23 months	29	19.73	41	20	70	19.89
	24–59 months	10	6.8	15	7.32	25	7.1
	5–14 years	44	29.93	56	27.32	100	28.41
	15–49 years	61	41.5	90	43.9	151	42.9
	50–64 years	3	2.04	2	0.98	5	1.42
	>65 years	0	0	0	0	0	0
	Total					352	100
Educational status	Illiterate	75	51.02	110	53.66	185	52.56
	Read and write	3	2.04	4	1.95	7	1.99
	Elementary (Grades 1–8)	49	33.33	66	32.2	115	32.67
	High school (Grades 9–12)	18	12.24	24	11.71	42	11.93
	College/university	2	1.36	1	0.49	3	0.85
	Total					352	100

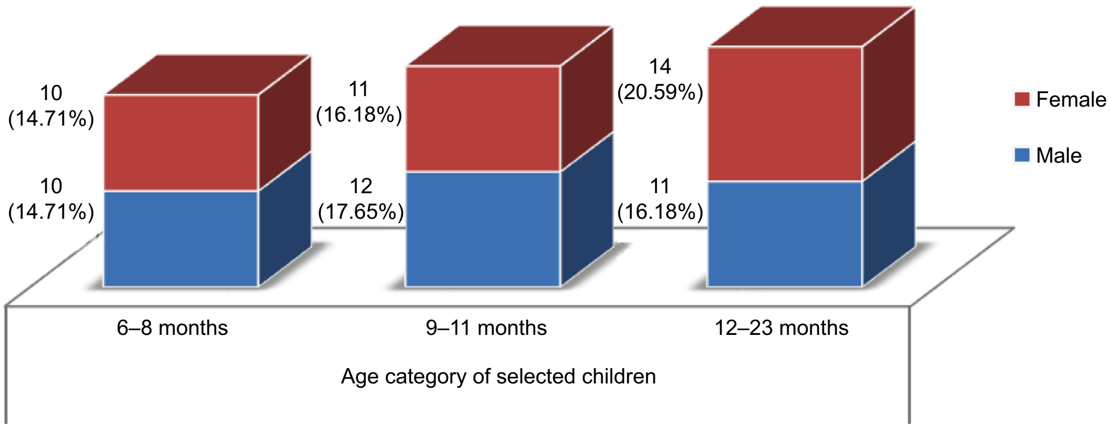

Figure 2 Age distribution and sex composition of the children included in the study.

Ethiopian birr) showed that 40 (11.36%) of them had monthly earning of <250, while 25 (7.1%) and 13 (3.69%) of them had monthly earning of 250–499 and 500–749, respectively.

Sixty-eight children/HHs were included in the study. Out of these, 28 (42.2%) HHs were selected from the Dugna Fango woreda, while the remaining 40 (58.8%) were from the Kindo Koysha woreda. Twelve (17.6%) HHs were selected from Dugna Sore and 16 (23.5%) were from Kercheche kebele of Dugna Fango. In addition, 29 (42.6%) of the HHs were from Sorto and the remaining eleven (16.2%) HHs were selected from Fechena kebele of the Kindo Koysha woreda.

The age distribution was devised in such a way that a sufficient number of children be included into one of the following three categories: 6–8 months, 9–11 months, and 12–23 months (Figure 2). Out of the total sampled, 20 (29.41%) of them were between 6 months and 8 months, while 23 (33.82%) and 25 (36.76%) were between 9 months and 11 months and 12 months and 23 months, respectively. Equal representation was given for children from both sexes during the selection of HHs. Out of the 68 children selected for the study, 33 (48.53%) were males and the remaining 35 (51.47%) were females.

Homemade complementary foods

Preparation of homemade complementary foods

The complementary foods under study were prepared at the HH level following traditional methods. Investigation into the daylong preparations shows that mothers/caregivers cook or prepare complementary foods at least once during the day, and a maximum of four was also observed. On average, complementary foods were prepared 2.26 times per HH per day.

Children are often fed multiple foods in a given day. A look at the number of food types used for feeding shows that a child is offered an average of 2.79 food types in a day. Along the spectrum of HHs, the number of food types used ranged from one to six per day. Twenty-one (30.9%) HHs served three food types, 20 (29.4%) served two, and nine (13.2%) served only one food type. The remaining 18 (26.5%) HHs served four or more food types to their child per day.

The food types served and items used to prepare them differ across HHs and among the different age groups. Some of the food types were prepared from multiple food items, as ingredients, while in other cases, only one food item was processed into various forms and presented to the child at different serving episodes. Among the food types prepared from multiple food items, kita/nifro (bread) was the commonest one with 29 (42.6%) of the HHs using them in their child's servings. Porridge (21, 30.9%) was the second most common food type, followed by injera/injera-containing preparations (17, 25.0%), beso (seven, 10.9%), soup made from oat (six, 8.8%), and shiro/misir wot (four, 5.9%).

Food types containing only single food items were also served at different times. Among these, milk/yogurt was served by 24 (35.3%) mothers/caregivers. This was followed by avocado and banana, each of which were served by 17 (25.0%) mothers/caregivers; cassava, served by 14 (20.6%) mothers/caregivers; and potato and yam, each been served by six (8.8%) mothers/caregivers. Figure 3 summarizes the most frequently served food types among the HHs.

Figure 3 shows that, from food types containing multiple food items, kita/nifro (bread), porridge, injera/injera-containing preparations, beso, and shorba (soup made from oat) were the top five frequently consumed food preparations observed among 29 (42.6%), 21 (30.9%), 17 (25.0%), seven (10.9%), and six (8.8%) of the HHs, respectively. Similarly, milk/yogurt, avocado, banana, cassava, potato, and yam were the most frequently observed, 24 (35.3%), 17 (25.0%),

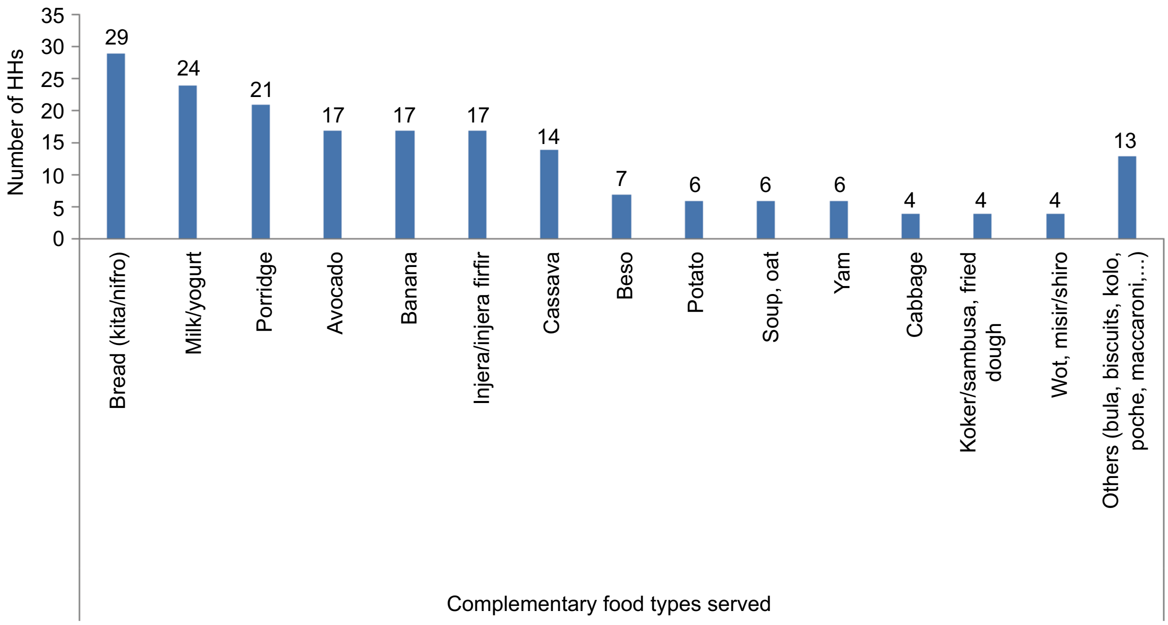

Figure 3 List and frequency of prevailing homemade complementary foods served.
Abbreviation: HH, household.

Table 2 Homemade complementary foods frequently observed

Prepared from multiple food items		
Name of food served	**Food items most frequently used by mothers/caregivers**	**Observation, n (%)**
Bread (kita/nifro)	Maize (bekolo), wheat (sinde), broad beans (bakela), teff, barley (gebs), butter/oils	29 (42.6)
Porridge	Maize (bekolo), wheat (sinde), barley (gebs), teff, oat, pea (ater), broad beans (bakela), lentils (misir), milk (wetet), butter, or some form of oil	21 (30.9)
Injera	Teff, maize (bekolo)	17 (25.0)
Injera-based preparation	Injera and stew made from garlic, onion, and butter/oil	
Beso	Barley (gebs) powder, milk (wetet), Teff, wheat (sinde), maize (bekolo), and oat	7 (10.9)
Soup (shorba)	Oat	6 (8.8)
Prepared from single food item		
Milk/yogurt		24 (35.3)
Avocado		17 (25.0)
Banana		17 (25.0)
Cassava		14 (20.6)
Potato and yam		6 (8.8) for both items

17 (25.0%), 14 (20.6%), 6 (8.8%), and 6 (8.8%), respectively, single food item preparations served.

The food items used to prepare such food types, however, show some variations among the HHs. Table 2 lists the most frequently used food items to prepare the top five frequently observed food types (in order of decreasing observation frequency).

In general, more than 20 different food items were used by the HHs during preparation of complementary foods at the HH level throughout the day. Among the locally available cereal and legumes, maize was the most commonly used food item being observed among 43 (63.24%) HHs, followed by wheat (29, 42.26%), teff (22, 32.35%), and barley (14, 20.59%). Butter or some form of oil was added to the complementary food preparations by 35 (51.47%) HHs. Among the dairy products, milk/yogurt was given to the children or added to the food preparations in approximately half (32, 47.06%) of the HHs. Avocado and banana, each (17, 25.0%), top the list of the most frequently used fruits as part/portion of daily feeding. The top frequently used ten food items are presented in Figure 4.

DDS for the food items used throughout the day was also constructed. Accordingly, the food items used were categorized

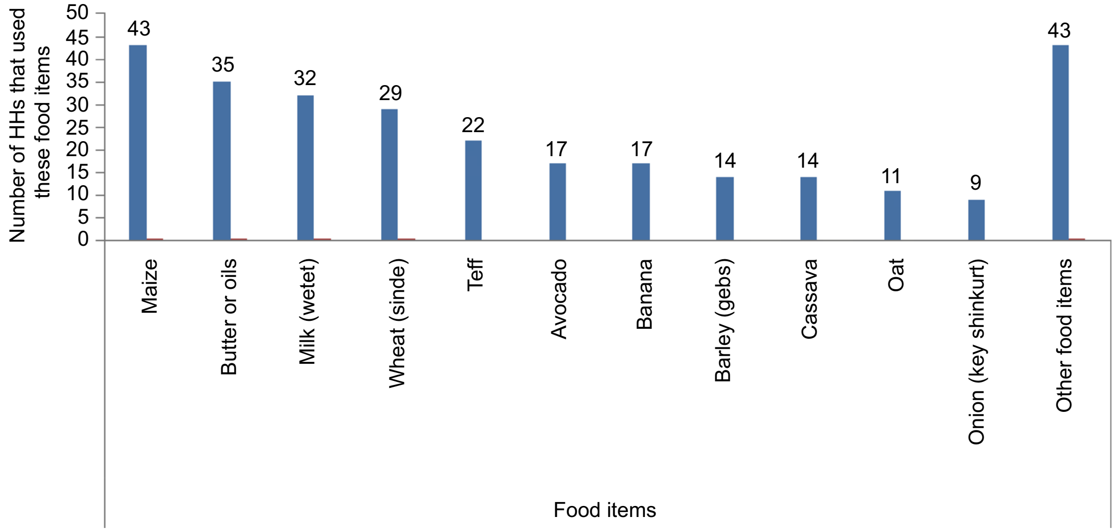

Figure 4 Top ten frequently used food items for complementary foods preparation.
Abbreviation: HH, household.

Table 3 Inclusion of various food categories to prepare complementary foods

		Responses		Remark
		n	% of respondents	
Food categories used in a day's preparation	Grain, roots, and tubers	67	98.50	
	Legumes and nuts	13	19.10	
	Dairy products	26	38.20	
	Flesh foods (meat, fish, poultry, and liver/organ meats)	32	47.10	Only oil/butter was used by all, except meat in one HH
	Fruits and vegetables	34	50.00	

Abbreviation: household, HH.

into one of the seven food categories (Table 3). These include grain, roots and tubers, legumes and nuts, dairy products, flesh foods (meat, fish, poultry, and liver/organ meats), eggs, and fruits and vegetables, and other orange-colored fruits and vegetables. Analysis of the most frequently utilized food category shows grains, roots, and tubers to have been, almost entirely, used by every HH (67, 98.5%). This is followed by fruits and vegetables (34, 50.0%), flesh foods (32, 47.1%), dairy products (26, 38.2%), and legumes and nuts (13, 19.1%). Among the six categories, none of the preparations contained egg.

Among the respondents included in the survey, only nine (13.2%) of them used food items from at least four different categories or more. On average, 2.54 food categories were used per day for the preparation of complementary foods. On a HH basis, 26 (38.2%) of them have used food items from three different categories, while 25 (36.8%) of them used two categories. Eight (11.8%) HHs used food items from four categories, while the same number of HHs (eight, 11.8%) used food items belonging to only one category (Figure 5).

Mothers/caregivers of children of age 12–23 months had used food items from three different categories (on average) to prepare complementary foods, when compared to those having children of age between 6 months and 8 months and 9 months and 11 months, who have used two categories on average. In addition, variation was observed in the number of food categories used in comparison to the sex of the child. Mothers/caregivers of female children more frequently used food items from three different categories when compared to male children where two categories were used (Table 4). This sex-based disparity is found to be valid irrespective of the age of the child.

Nutrient composition of homemade complementary foods

Laboratory assay of the sampled complementary foods was conducted to identify their nutrient compositions. From the macronutrients, assay of protein, fat, and carbohydrate composition was made. From the micronutrients, nutrient

Table 4 Average number of food categories used by sex and age category of the children

		Number of food categories used			
		6–8 months	9–11 months	12–23 months	6–23 months
Sex	Male	2	2	3	2
	Female	3	3	3	3
	Age average	2	2	3	2.54

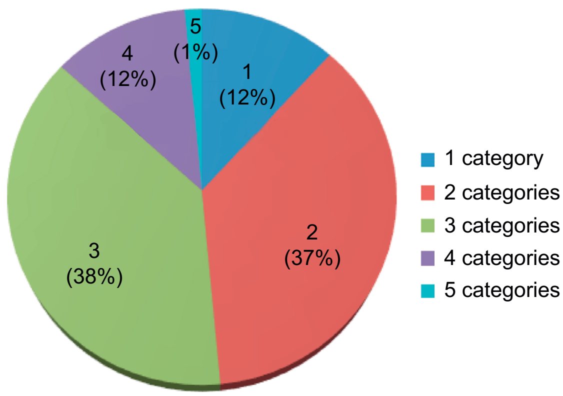

Figure 5 Number of food categories used to prepare complementary foods.

Table 5 Energy, nutrient, and antinutrient contents (per 100 g as EP) of homemade complementary foods

Nutrient profiles	Amount per 100 g (EP) by age category of children		
	6–8 months	9–11 months	12–23 months
Energy (kcal)[a]	91.28	124.24	141.16
Fat/lipid (g)	2.8	3.92	2.64
Protein (g)	3.11	2.66	3.5
CHO (g)[b]	13.41	19.58	25.85
Moisture (%)	75.63	69.59	64.07
Ca (mg)	22.79	9.22	11.66
Fe (mg)	1.96	2.04	2.87
Zn (mg)	0.58	0.59	0.76
Ash (g)	4.41	4.41	3.18
Fiber (g)	0.63	0.76	0.76
Phytate (mg)	23.31	59.31	10.50

Notes: [a]The energy content was calculated using the conversion factor for respective macronutrients. [b]The content of carbohydrates was calculated using % difference method.
Abbreviations: EP, eaten/edible portion; CHO, carbohydrates; Ca, calcium; Fe, iron; Zn, zinc.

analysis was conducted for the content of Ca, Fe, Zn, and ash, in general. In addition, the content of moisture, crude fiber, and phytic acid content was analyzed. The results of the assays are presented in Table 5.

Density and adequacy of energy and protein in the complementary foods

Energy density was calculated from the energy-yielding nutrients using their respective conversion factors. Accordingly, the energy density per 100 g of complementary foods served to the children of age between 6 months and 8 months was found to be 92.28 kcal, while 124.24 kcal and 141.16 kcal of energy was found per 100 g of foods served to the children of age between 9 months and 11 months and 12 months and 23 months, respectively. This result shows that energy density increased with the age of the children.

Water forms an important composition of any food. Assay of the moisture content of the complementary foods shows higher moisture level (75.63%) in the foods served to the 6–8-month olds (75.63%), followed by foods served to the 9–11-month olds (69.59%) and 12–23-month olds (64.07%). The moisture content declined as the age of the children increased.

A look at the relationship between the change in % moisture composition of the complementary foods among the different age categories and its energy density shows existence of a very strong, inverse linear relationship (Figure 6). An increase observed in the energy density of the complementary foods served with regard to the age of the children was, to a significant extent, due to the decrease in the moisture composition of the foods served to them (r^2=0.974, P=000).

The nutrient density (in g/100 kcal of complementary food) varied among the different age categories. The highest amount of protein (3.41 g/100 kcal) was observed among the 6–8 months age category, followed by 12–23 months age category (2.48 g/100 kcal) and 9–11 months age category (2.13 g/100 kcal). Compared to the minimum recommended protein density of 0.7 g/100 kcal (Table 6) in the diet of children of age between 6 months and 23 months, the complementary foods served to all age groups had significantly higher (P=0.000) protein composition. Fat density was highest (3.14 g/100 kcal) among the 9–11 months age category, while it was 3.07 g/100 kcal in the 6–8 months age category and 1.87 g/100 kcal in the 12–23 months age category.

Fats comprised 27.61%, 28.41%, and 16.83% of total energy consumed per day in 6–8-month, 9–11-month, and 12–23-month age groups, respectively. On the other hand, proteins comprised 13.62%, 8.56% and 9.91% of the energy among the 6–8-month, 9–11-month, and 12–23-month age groups, respectively.

The ratio of energy from protein to total energy contained in the complementary foods (protein:energy [PE] ratio) was

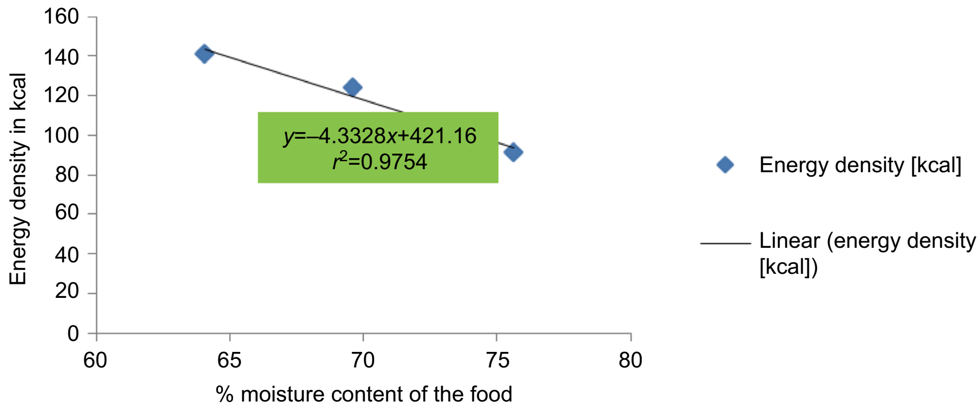

Figure 6 Relationship between the moisture level and energy density.

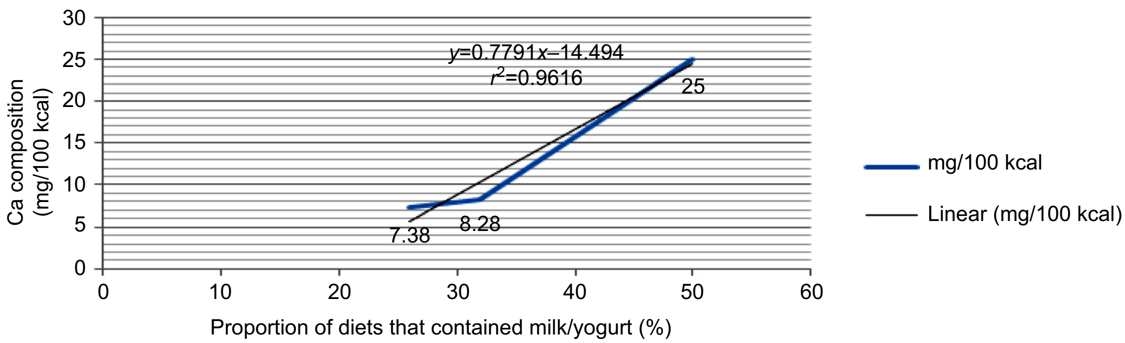

Figure 7 Difference in the Ca level among the diets of children of different age groups explained by the consumption of milk/yogurt.
Abbreviation: Ca, calcium.

13.6% for 6–8-month, 8.5% for 9–11-month, and 9.9% for 12–23-month age categories, all of which were significantly higher than the recommendations (Table 6).

Density and adequacy of Ca, Fe, and Zn in the complementary foods

Among the micronutrients, nutrient density (in mg/100 kcal) was analyzed for Ca, Fe, and Zn. In food consumed by the 6–8-month age group, Ca was found to be 24.97 mg/100 kcal, while Fe was 2.15 mg/100 kcal and Zn was 0.64 mg/100 kcal. In addition, the nutrient density in the foods consumed by the 9–11-month age group was 7.38 mg/100 kcal, 1.63 mg/100 kcal, and 0.47 mg/100 kcal for Ca, Fe and Zn, respectively. Similarly, 8.28 mg of Ca, 2.04 mg of Fe, and 0.54 mg of Zn were found per 100 kcal of foods consumed by the 12–23-month age groups.

Observed nutrient density for Ca was highest (25 mg/100 kcal) in the diets of 6–8-month-old infants compared to their older counterparts (7.38 mg/100 kcal for the 9–11-month-old infants and 8.28 mg/100 kcal for the 12–23-month-old infants). This difference in Ca composition is highly attributed to difference in preferential milk/yogurt use (Figure 7) in complementary food preparations (r^2=0.9616, P=0.000). Even if the use of cow's milk in complementary feeding is not recommended during the first 12 months of life, due to the ill health associated with consumption, this practice is rampant. Fifty percent and 26.1% of serving episodes for children of age 6–8 and 9–11 months, respectively, contained milk/yogurt as part of their daily food servings.

Comparison of the observed nutrient density for the three micronutrients to the desired nutrient density was also made (Table 6). The observed nutrient densities for Ca and Zn (in mg/100 kcal) were found to be significantly lower (P=0.000) than the desired nutrient density across all the age groups. As a result of this, the children may fail to obtain sufficient micronutrients that can satisfy their nutritional requirements even if they consume adequate quantity of food for their age.

Observed Fe density (mg/100 kcal) was also compared to the desired nutrient density, assuming for low, medium, and high bioavailabilities. Accordingly, diet of children between 6 months and 8 months had significantly lower Fe density (P=0.000) compared to the desired amount, even assuming

Table 6 Comparison of observed nutrient density to desired levels in complementary foods by age of the children

Age category	Nutrient density for protein (g/100 kcal)		PE ratio (%)	
	Observed	Recommended [a]	In foods consumed	Minimum recommendation[b]
6–8 months	3.41*	0.7	13.62*	5.1–6.3
9–11 months	2.13*	0.7	8.50*	4.8–6.0
12–23 months	2.48*	0.7	9.90*	4.3–5.7

Notes: [a]Desired value adapted from World Health Organization/United Nation Children's Fund[6]. [b]Value adapted from Reeds and Garlick[43]. *The mean for observed nutrient density is significantly higher than the recommended nutrient density at $P<0.05$ ($P=0.000$).
Abbreviation: PE, protein:energy.

for high bioavailability. On the other hand, diet of children between 12 months and 23 months contained a quantity of Fe (mg/100kcal) greater than the desired Fe density, even when accounting for low bioavailability. For the 9–11-month age group, the diets contained Fe density comparable to the desired value only when assuming high bioavailability.

Discussion

The present study assessed nutrient composition of homemade complementary foods and evaluated adequacy of protein, energy, and selected micronutrients (Fe, Zn, and Ca) for children of age 6–23 months in Dugna Fango and Kindo Koysha woredas of the Wolayita zone, Southern Ethiopia.

Complementary food should fill gaps in nutritional requirement from breastfeeding alone, starting from the age of 6 months.[35] In the case of homemade complementary foods, caregivers should prepare appropriate complementary food a reasonable number of times per day using an appropriate mix of food items. Literature suggests that the frequency should be in such a way that it minimizes holding over prepared food from one meal to the next, and minimizes the risk of microbial contamination, and optimizes the time and effort required by caregivers to prepare such foods.[35] Among the subjects observed in this study, the caregivers cook complementary foods an average of 2.26 times per day, which is in line with the recommended average levels.

Caregivers should also choose suitable food items and cook them in a way that maximizes their nutritional value.[11] In addition, the diets should be appropriate to the developmental stage of the child.[6,35,36] During this study, more than 20 different homemade complementary food types were observed throughout the study. While some of the complementary foods were prepared using recipes containing multiple food items, the others were made simply from single food items processed into different forms.

A peculiar observation was that most of the complementary foods prepared/served were the same as family foods, for instance, the preparation and composition of kita/nifro, injera/injera firfir, shiro/misir wet, and potato. Similar observations were also noted in other parts of the country.[19,20] Such transition directly to "family foods", however, may put the infant at risk of multiple micronutrient deficiencies. Dewey[23] indicated that family foods usually fall short of providing adequate Fe, Zn, and sometimes Ca, even if based on improved food recipes.

It is only by ensuring acceptable dietary diversity in children's diets can sufficient amounts of nutrients be consumed. Complementary foods should, therefore, be diverse enough to encompass food items from four or more food categories.[11,26,35,37] According to findings of this study, however, the average number of food categories used per day was only 2.54, while the DDSs for most of the diets were in the low (0–2) to medium (3–4) range. Food items from four or more food categories were used in only 13.2% of the respondents. Even if a slight improvement was observed compared to the national figure of 4%,[38] the diet of a significant majority of the children failed to comply with the recommendations.[39]

Food items belonging to grains, roots, and tubers were used ubiquitously to prepare complementary foods. Almost all diets (98.5%) contained, per day, food items from this category. Literature suggests that cereal grains provide a substantial proportion of dietary energy, protein, and micronutrients for much of the world's population.[36] The level of use of food items in this category was higher than the national level of 60.0%,[38] although similar studies in Ethiopia and other developing countries reported an equivalent level.[16,19,20,35]

The level of use of food items from the legumes and nuts category (19.1%) was equivalent to the national data (20.0%).[38] The use of legumes, however, is rarely recommended because of the problems of indigestibility, flatulence, and diarrhea associated with their consumption; introduction at later ages is recommended.[40]

The use of butter or some form of oil was seen in 51.47% of HHs. Addition of oil makes diets softer and easier to eat. It also affects the overall nutrient density of the diet. Addition of one teaspoon of vegetable oil to 100 g of a typical maize pap used in West Africa increased the energy density from 0.28 kcal/g to 0.73 kcal/g. It also reduced protein density from 8.9% to 3.3% of energy and Fe density from 0.5 mg/100 kcal to 0.2 mg/100 kcal.[6,40]

Half of the diets served per day contained food items belonging to the fruits and vegetables group. In comparison to the national trend, where only 15.0% of diets do, consumption of fruits and vegetables was very high.[38] Yet, diets containing vitamin A, however, were rarely consumed.

One of the most conspicuous limitations of the homemade complementary foods was the fact that none of the diets contained ASF, even when compared with the national figure.[38] Diet containing meat was seen in only 1.47% of HHs. Plant-based complementary foods by themselves are insufficient to meet the needs for selected micronutrients generally classified as problem nutrients.[6,16,17] In addition, the inclusion of ASF is a well-documented intervention to improve the quality of complementary foods using high-quality locally available foods.[41]

Consumption of milk/yogurt was observed in as many as 37.2% of children of age 6–11 months. Even if its inclusion in diet significantly improves the Ca level, such practice might be accompanied with grave risks. Feeding unheated cow's milk to children younger than 12 months is associated with fecal blood loss and lowered Fe status.[36]

Complementary foods are expected to have sufficient energy density to provide a growing child with adequate daily energy requirement. The recommended minimum energy density in complementary foods is, at least, 0.8 kcal/g, thus greater than the energy density in breast milk (0.7 kcal).[2] In reality, the energy density in complementary foods is more variable and usually contains between 0.6 kcal/g and 1.0 kcal/g, and it even may be as low as 0.3 kcal/g in foods that are watery and dilute.[26]

In this study, the energy density per gram of complementary foods consumed was found to be 0.92 kcal, 1.24 kcal, and 1.41 kcal for 6–8-month, 9–11-month, and 12–23-month age categories, respectively. Compared to the minimum recommended energy density of 0.8 kcal/g, all the diets had good energy density. The energy density in the diets of 9–11-month and 12–23-month age categories, in fact, was excellent compared to the arbitrary cutoff level of 1.0 kcal/g of food.[35] This may be due to the prevailing practice of adding butter/oil observed in more than half of the HHs surveyed. This is also in line with the result reported by Gibson et al[16] for complementary food preparations (1.23 kcal/g as eaten) that are based on starchy roots, tubers, and similar items for children of 9–11-month age category.

Proteins and fats are important nutrients in complementary foods. In this regard, both the nutrient density and amount consumed per day were adequate. Protein density (g/100 kcal) in all the diets exceeded the desired level of 0.7 g/100 kcal.[6] Similar findings were reported for protein density in homemade complementary foods prepared in other parts of Ethiopia.[16,20]

The PE ratio, which is the ratio of energy from protein to total energy contained in a certain amount of food, is one of the indicators used to assess the quality and adequacy of protein in complementary foods. The minimum recommended PE ratio, to come from complementary foods, of children between 6 months and 23 months of age lies between 4.3% (for foods with high protein quality, such as milk, and for a child of age 23 months) and 6.3% (for foods with low protein quality, such as plants, and for a child of age 6 months).[36,42] In congruence with these recommendations, the PE ratio in the complementary foods was found to be 13.62%, 8.5%, and 9.90% for the 6–8-month, 9–11-month, and 12–23-month age categories, respectively.

Fe, Zn, and Ca are limiting nutrients in unfortified plant-based complementary foods commonly used in the developing countries.[6,17] The findings of this study also show similiar patterns. Nutrient densities for Ca and Zn were very low (P=0.000), in diets of all age groups, compared to the desired levels. Given the poor diversity of the diets served and virtual absence of ASF with improved nutrient bioavailability, this finding is not very surprising. In another study, a similar conclusion has been reached by Gibson et al.[16] According to Baye et al,[21] however, Zn met desired values when moderate bioavailability was assumed.

Adequacy for Fe, however, differs based on the level of bioavailability accounted for. For the diet of 6–8-month infants, the observed level was very low (P=0.000) even when high bioavailability was assumed, while adequacy was ensured assuming high bioavailability only for the 9–11-month age groups.

Contrary to these two age groups, the observed Fe level was adequate for 12–23 months even when low bioavailability was assumed. Previous studies have shown that adult Fe intake in Ethiopia surpasses recommended values and this was attributed to the high Fe contents of most cereals grown in the country.[43,44] However, a large proportion of this Fe was attributed to soil contamination.[15] Further investigations are required to evaluate the bioavailability of both intrinsic and contaminant Fe.

As these problem nutrients are also relatively low in breast milk, possible deficiencies of these micronutrients inadvertently lead to adverse health consequences and restricted child growth and development.[14–16]

Conclusion

The homemade complementary foods were often an extension of family foods. As such, their energy density and protein composition were adequate enough to be used as complementary foods. The nutrient density for the selected problem nutrients, such as Ca, Fe, and Zn, however, was very poor. Very low dietary diversity was observed in a significant majority of HHs, while ASF and vitamin A-rich fruits and vegetables were virtually absent. Further research should be conducted to assess the nature, appropriateness, and adequacy of homemade complementary foods in larger catchment areas and bigger sample bases.

Limitation of the study

In spite of the interesting findings this study has brought forward, the following limitations should also be noted.

1. The cross-sectional nature of this study did not allow seasonal variation in food intakes to be considered.
2. Although caregivers were instructed not to alter their children's complementary food preparations and dietary patterns, this does not warrant the absence of deliberate changes in their diets.
3. This study only looked into the dietary nutrient compositions of the complementary foods. It did not assess nutritional status of the children investigated.

Acknowledgments

The authors are grateful for the financial support provided by the Micronutrient Initiative Ethiopia (award number: 10-1314-ADIMAS-29). The authors would like to acknowledge the support of the Southern Nations Nationalities and Peoples Regional Health Bureau and Wolayita Zonal Health Department for allowing them to conduct this study at the woredas. The authors thank Bekuman Olani, Biniam Tesfay, Sorome Admassu, and Mestayit Gebru for assisting in the data collection process.

Disclosure

The authors report no conflicts of interest in this work.

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