Acceptability and safety of novel infant porridges containing lyophilized meat powder and iron-fortified wheat flour

Helena Pachón, María Reyna Liria Domínguez, Hilary Creed-Kanashiro, and Rebecca J. Stoltzfus

Abstract

Background. *Lyophilized meat powder with iron-fortified wheat flour can be used to produce an infant porridge with bioavailable iron, but its acceptability and safety are unknown.*

Objective. *To evaluate the acceptability and safety of porridges containing lyophilized meat powder and iron-fortified wheat flour.*

Methods. *Peruvian mothers' input was used to develop porridges without (no meat) and with meat powder (low or high chicken liver, low or high chicken thigh). Acceptability was determined by maternal hedonic scoring, 9-day infant intake, and videotape analysis of how well infants liked each porridge. Dry and cooked porridges and meat ingredients were tested for microorganisms; meats were tested for pesticides.*

Results. *Mothers gave higher acceptability scores to the no-meat porridge, followed in order by low and high quantities of meat powder (e.g., mean ± SD "taste" scores were 4.5 ± 0.9 for the no-meat, 3.7 ± 1.1 for the low-liver, and 3.3 ± 1.1 for the high-liver porridges,* $p = .0001$*). Infants' porridge intake did not differ: 61.4 ± 47.1 g of no-meat, 62.1 ± 44.9 g of low-thigh, and 67.5 ± 42.0 g of low-liver (*$p = .7$*), as supported by the video analysis. Microbiologic safety was acceptable except for marginally acceptable molds and yeasts in dry ingredients. No pesticide residues were detected.*

Conclusions. *Despite mothers' clear preference for no-meat porridges, infants consumed equal amounts of porridges with and without meat. Thus, if mothers can be convinced to feed the meat-containing porridges to the infants despite their own preferences, the infants will consume these porridges. The mold and yeast content of the porridge ingredients must be reduced.*

Key words: Acceptability, bioavailability, complementary feeding, complementary food, infant feeding, intervention, iron, Peru, porridges, sensory characteristics

Introduction

Anemia, resulting from iron deficiency or other causes, affects an estimated 2 billion people around the world [1]. Anemia is of concern in infants because it has been associated with impaired mental and motor development [2] and retarded growth [3]. Infants 6 months of age and older in developing countries are especially vulnerable because the complementary foods offered to them are often not iron dense, and breastmilk alone does not provide sufficient quantities of iron to meet infants' requirements. Thus, the challenge in improving the iron status of infants from 6 months onward is to regularly provide them with *bioavailable* iron in sufficient quantities at mealtimes. This could be achieved by feeding infants iron-fortified foods coupled with an iron-absorption enhancer [4].

High-quality and low-cost iron-fortified infant foods are not common in developing countries [5]. Nevertheless, food-fortification efforts have made iron-fortified staple foods, not necessarily directed at children, available and at relatively low cost. A study from Peru has demonstrated the effectiveness of ferrous sulfate–fortified wheat products on iron status among 41 stunted and moderately anemic children 3 to 4 years of age [6]. These children were given wheat products (biscuits or noodles) with ferrous sulfate (3 mg iron per 100 g wheat product), plus or minus zinc fortificant, daily for 7 weeks. In the iron-only group, hemoglobin increased from 106.0 to 129.6 g/L ($p < .001$) and no child was

Helena Pachón and Rebecca J. Stoltzfus are affiliated with the Division of Nutritional Sciences, Cornell University, Ithaca, New York, USA; María Reyna Liria Domínguez and Hilary Creed-Kanashiro are affiliated with the Instituto de Investigación Nutricional, Lima, Peru.

Please direct queries to the corresponding author: Helena Pachón, Centro Internacional de Agricultura Tropical (CIAT), Apartado Aéreo 6713, Cali, Colombia; e-mail: h.pachon@cgiar.org.

anemic at the endpoint. In addition to 100 g of fortified wheat products daily, children ate their baseline diet throughout the study. The authors commented that it is "notable that children's hemoglobin concentrations increased in response to the dietary treatments with iron-fortified foods, even though these foods delivered a net increase of only ~1 mg/d [of iron]."

With any type of fortified food, the type of fortificant used can limit the amount of ingested iron that is absorbed; promoters such as meat or ascorbic acid must also be present to enhance iron absorption [4]. Meat, in addition to being an excellent enhancer of iron absorption, contributes nutrients that are lacking in the diets of infants in developing countries: iron, zinc, and vitamin B_{12} [7–9]. Meats are available in developed and developing countries [10]; however, in most settings, meats are given to young children infrequently and only in small quantities [11–18]. This is probably due to a combination of parents' beliefs and perceptions of appropriate first foods [19–20], the recommendations of health personnel [21] and family members [22] about what foods to introduce, cost [23], availability in the home [24], and infants' innate preference for sweet foods [25].

Recent research in human adults [26] has shown that adding lyophilized meat powder to an iron-fortified food increases by 85% the intake of absorbable iron from the diet. Further, these substantial improvements in iron absorption were observed with small amounts of lyophilized meat (equivalent to 20 g of meat) combined with small amounts of an iron-fortified food (48 g). Compared with nonlyophilized meat, lyophilized meat powder has a longer shelf life and is a more concentrated source of nutrients [27].

Before recommending that infants eat such a combination, it needs to be determined whether parents will feed these meat-fortified food combinations, infants will consume the combinations if offered them, and these foods are safe for infants to consume. Therefore, the objectives of this study were to evaluate mothers' and infants' acceptance of recipes containing lyophilized meat powder and iron-fortified wheat flour and assess the microbiologic and pesticide safety of the lyophilized meat powder and meat-flour recipes.

Methods

To meet the study objectives, five activities were carried out in June to August 2003 and September to December 2004: recipe-creation exercises, maternal acceptability trial, infant acceptability trial, infant video taping, and microbiological and pesticide-residue testing. The study activities were approved by the institutional review boards of the Instituto de Investigación Nutricional in Peru and Cornell University in the United States. Written informed consent was obtained from all women who participated in any study activity. All participants received a token gift.

Study setting

Study activities were carried out in an urban shanty town in southern Lima, Peru. Approximately 8,000 families live in the community, which was founded in January 2000. The community lacks basic services such as running water, indoor plumbing, paved roads, and a reliable electricity supply.

Recipe-creation exercises

Recipe-creation exercises [19] were held in 2003 and 2004. The purpose of the first exercise was for mothers of infants to create recipes that combined meats as they are sold in the community (Nestlé beef with vegetables, alpaca *charqui* (dried meat), chicken thigh, chicken liver, chicken spleen, chicken blood) with locally available iron-fortified food (Gerber infant rice cereal, Papimás infant wheat cereal, iron-fortified pasta, iron-fortified wheat flour). The purpose of the second exercise was for mothers to create porridges that combined lyophilized meat powder (chicken thigh, chicken liver) with iron-fortified wheat flour (donated by Alicorp SA, Peru); other ingredients were also provided (powdered whole milk (Leche Anchor, Nestlé Peru), brown sugar, cinnamon sticks or powder, whole or powdered cloves, vanilla extract). Mothers' input was used to develop the recipes tested during the maternal and infant acceptability trials.

Preparation of lyophilized meat powder

Raw chicken liver and heart and chicken thigh were purchased from a local chicken producer (San Fernando, Lima, Peru). At the Instituto de Investigación Nutricional (IIN), visible fat and the heart were removed from the chicken liver, and visible fat, skin and bone were removed from the chicken thigh. The chicken liver and thigh were cut into small cubes, and 1 kg of each was cooked for 12 minutes in 50 mL of water in a microwave oven (LG model MS-114YFA). After cooling at room temperature for 30 minutes, the cooked chicken was packaged in 0.5-mm-thick polyethylene bags and stored at −180°C with dry ice.

The cooked meat was transported to a commercial lyophilization plant (Liofilizadora Pacífico) where the meat was processed in a lyophilizer (Leybold Hereaus, Model GT12) at platen temperature of 38°–42°C at a pressure of 0.3 mBARS for 23 hours. The lyophilized meat was then ground to a fine powder with a company-made hammer mill using a 600-micron mesh.

Energy and nutrient profile of porridges

The porridges used during the maternal and infant acceptability trials contained ingredients available in Lima: fortified powdered whole milk, fortified wheat flour, brown sugar, meat, and vanilla powder (SD 18798 donated by Montana SA). The reported energy and nutrient contents of these ingredients were used to develop isocaloric recipes.

According to the label, the milk contains 500 kcal of energy, 16.2 g of protein, 26.6 g of fat, 9.2 mg of iron (as ferric pyrophosphate; Rudy Campos, Nestlé Perú, personal communication), 1.7 mg of zinc, 350 μg RE of vitamin A and 50 mg of ascorbic acid per 100 g. The donated wheat flour was formulated with the iron (5.5 mg as ferrous fumarate/100 g), thiamin (0.5 mg/100 g), riboflavin (0.4 mg/100 g), niacin (4.8 mg/100 g), and folic acid (120 μg/100 g) levels recently enacted by Peruvian national decree [28]; other values were taken from the IIN food composition table [29]: 359 kcal of energy, 10.5 g of protein, 2.0 g of fat, 0.7 mg of zinc, 0 μg RE of vitamin A, and 1.8 mg of ascorbic acid per 100 g. According to the IIN food composition table, the brown sugar contains 380 kcal of energy, 0 g of protein, 0 g of fat, 1.7 mg of iron, 0.2 mg of zinc, 0 μg RE of vitamin A, and 0 mg of ascorbic acid per 100 g. Given that the final weight of lyophilized liver powder is 19.5% of the weight of raw liver, and assuming that no nutrients were lost during the cooking and lyophilization process, the IIN food-composition table values for liver were multiplied by 5.13 (100/19.5) to obtain the liver powder values. By a similar process, the energy and nutrient profile of the chicken thigh powder was obtained (multiplication factor of 4.57). In summary, the liver powder was estimated to have 641 kcal of energy, 92 g of protein, 20 g of fat, 44 mg of iron, 16 mg of zinc, 31,626 μg RE of vitamin A, and 173 mg of ascorbic acid per 100 g and the thigh powder to have 544 kcal of energy, 90 g of protein, 18 g of fat, 5 mg of iron, 9 mg of zinc, 91 μg RE of vitamin A, and 14 mg of ascorbic acid per 100 g. No energy or nutrient contribution was estimated for the vanilla powder. The energy and nutrient profile of the porridges was estimated from these ingredient values (**table 1**).

TABLE 1. Energy and nutrient profile and ingredients (per 100 g of cooked porridge) of five recipes tested during the acceptability trials with mothers and infants[a]

Component	Porridge[b]				
	No meat	Low liver	High liver	Low thigh	High thigh
Energy and nutrients					
Energy (kcal)	115.1	115.0	115.1	115.5	115.4
Protein (g)	2.9	3.5	3.8	5.0	5.6
Fat (g)	3.4	3.1	3.0	3.2	3.0
Calcium (mg)	120.9	107.3	98.2	98.1	84.4
Iron (mg)[c]	1.5	1.8	2.0	1.4	1.3
Zinc (mg)	0.3	0.4	0.5	0.5	0.5
Vitamin A (μg RE)	42.0	353.0	507.6	36.0	31.7
Ascorbic acid (mg)	6.2	7.1	7.5	5.3	4.7
Ingredients					
Fortified whole milk powder (g)	12.0	10.5	9.5	9.5	8.0
Fortified wheat flour (g)	9.0	8.0	8.0	7.0	7.0
Brown sugar (g)	6.0	7.2	7.7	7.0	7.5
Vanilla powder (g)	0.02	0.06	0.08	0.04	0.06
Liver powder (g)	0	1.0	1.5	0	0
Thigh powder (g)	0	0	0	3.0	4.0

a. The energy and nutrient values for these foods were obtained from multiple sources: the food label for milk powder; the national decree for wheat flour iron, thiamin, riboflavin, niacin, and folic acid levels [28]; and the Instituto de Investigación Nutricional (IIN) food-composition table for other nutrients [29]. No energy or nutrient contribution was estimated for the vanilla powder.

b. The no-meat porridge contained ferrous fumarate-fortified wheat flour, ferric pyrophosphate-fortified whole milk powder, brown sugar, and vanilla powder. The liver and thigh porridges contained the same ingredients plus lyophilized meat powder, as follows: low liver (1.0 g liver powder/100 g cooked porridge), high liver (1.5 g liver powder/100 g cooked porridge), low thigh (3.0 g chicken thigh powder/100 g cooked porridge), and high thigh (4.0 g chicken thigh powder/100 g cooked porridge).

c. Iron-fortified whole milk powder, iron-fortified wheat flour, meat powders, and brown sugar contributed the iron in the porridges. Specifically, for the no-meat porridge, the iron came from the milk (1.2 mg), flour (0.3 mg) and sugar (0.1 mg). For the low-liver porridge, the iron came from the milk (1.0 mg), liver powder (0.4 mg), flour (0.3 mg), and sugar (0.1 mg). For the high-liver porridge, the iron came from the milk (0.9 mg), liver powder (0.7 mg), flour (0.3 mg), and sugar (0.1 mg). For the low-thigh porridge, the iron came from the milk (0.9 mg), flour (0.3 mg), thigh powder (0.1 mg), and sugar (0.1 mg). For the high-thigh porridge, the iron came from the milk (0.7 mg), flour (0.3 mg), thigh powder (0.2 mg), and sugar (0.1 mg).

Maternal acceptability trial

From a master list of community families with infants, all women with an infant 5 to 11 months of age ($n = 274$) were assessed for eligibility to participate in the acceptability trial. Mothers were excluded ($n = 80$) if their children were < 6 months or > 11 months old ($n = 67$) or had a condition that interfered with their ability to eat such as cleft lip ($n = 1$), or if the mother lived outside the community ($n = 12$). Among the women eligible to participate ($n = 194$), 43 were not located; therefore, 151 women were invited to participate. Of these, 61 did not participate because of refusal ($n = 9$), because they did not show up on the testing date ($n = 44$), or for an unknown reason ($n = 8$). A total of 90 women participated in the acceptability trial.

Women were randomly divided into two groups (liver-tasters and thigh-tasters); each woman tasted and evaluated three porridges: liver tasters tried the no-meat, low-liver (1.0 g liver powder/100 g cooked porridge), and high-liver (1.5 g liver powder/100 g cooked porridge) porridges, and the thigh tasters tried the no-meat, low-thigh (3.0 g chicken thigh powder/100 g cooked porridge), and high-thigh (4.0 g chicken thigh powder/100 g cooked porridge) porridges.

The acceptability form had been used previously with women living in a Lima shantytown. The form required that the woman be able to write. For any woman who requested help ($n = 10$), a member of the study team sat with her and filled out the form with her. The form asked women to evaluate with numbers and words the smell, taste, texture, color, consistency, and overall characteristics of each porridge. The numerical scales included a five-item Likert-type scale where cartoon faces and words ranged from "dislike very much" (1) to "like very much" (5). In addition, the women were asked to rank the porridges from most to least liked. It took the women about 30 minutes to complete the form.

The trial was carried out in the large living room of a home located near the entrance to the community. Two pieces of plywood were arranged on top of a picnic-size table to create cubicles for four women. The cubicles were created on the two large tables in the room, creating space for eight women to carry out the trial simultaneously, without influence from the other women.

The porridges were prepared at the testing site; all three porridges were served at one time to each woman. There were six possible combinations for serving three porridges to each woman: no meat, low meat, high meat; no meat, high meat, low meat; low meat, high meat, no meat; low meat, no meat, high meat; high meat, low meat, no meat; and high meat, no meat, low meat. Each of these combinations was randomly counterbalanced among the women. Food samples of about 30 g were served to women in 90-ml transparent, disposable plastic cups that were marked with a three-digit code that identified the porridge and another three-digit code that identified the mother.

Infant acceptability trial

An updated list of community women with an infant 5 to 11 months of age ($n = 277$) was reviewed to identify eligible participants for the infant acceptability trial. For a variety of reasons, 208 women were excluded: mother did not participate in recipe exercise or acceptability trial ($n = 82$), infant < 6 months or > 9 months ($n = 81$), no date of birth for infant ($n = 34$), no address ($n = 6$), infant with birthweight < 2.5 kg ($n = 3$), infant with Down syndrome ($n = 1$), and infant with cleft palate ($n = 1$). Among the eligible women ($n = 69$) with infants 6 to 9.9 months of age, 8 were not located. Therefore, 61 women were invited to participate; of these, 12 declined to participate. A total of 49 mother–infant pairs participated in the home-based, 9-day, infant acceptability trial.

In the trial, the infants were given three porridges for 3 days each in their homes. The three porridges were each fed at one sitting on 3 consecutive days to the infant. The six possible orders of presenting the porridges (e.g., no meat, low liver, and low thigh) were randomly counterbalanced among the participants.

On days 1 and 9, a qualitative 24-hour dietary recall was administered to capture the infant's dietary pattern. At the first visit, the infant's health status in the previous week was also ascertained. In subsequent home visits, the infant's health status was determined prospectively by the mother's report.

Infants sick with diarrhea, vomiting, fever, or cough with phlegm that affected their appetite (by maternal report) were not fed porridge that day. They were visited daily (up to 6 days/week) and fed the porridge on the 9 days when not sick (although the infant could be recuperating). Some infants were visited up to 18 days to obtain the 9 days of intake data.

Prior to preparing the porridge, mothers were asked the last time the baby was fed (any drink, food, or breastmilk), and an attempt was made to wait at least 30 minutes from the previous feeding to the feeding of the baby. Mothers were also asked to assess the infant's appetite on that day. Mothers were instructed to mix the dry ingredients with 180 ml of water in a pot, remove lumps, and cook for about 3 minutes until the porridge had boiled and thickened. They were then asked to serve and feed the porridge to the infant. The weight of the cooked porridge and the amounts served and fed to the baby were weighed on a digital scale (Soehnle DC and Vera scales). When the mother noted that the baby was full, she was asked to wait about 5 minutes and to try feeding the baby again. At the end of the feeding session, the mothers were asked how well they thought the baby ate the porridge and whether or not this was the amount the baby typically consumed. Using a four-item scale, the fieldworker also independently evaluated how the infant ate the porridge (i.e., rejected, accepted with dislike, accepted with indifference, accepted with pleasure).

Videotaping infant acceptability trial

On the basis of logistics (when the camera and camera operator were available), a subset of 10 mother–infant pairs were selected to have their nine feeding sessions videotaped for subsequent analysis of how well the infant liked each of the recipes. The sessions were videotaped with a Hi-8 video camera (Sony CCD-TRV608 NTSC). Only the mother's code and the porridge code were written on the tapes so that the scorers would be blind to the day of the feeding session and the porridge being fed to the infant. In the United States, three scorers reviewed in real time the first 2 minutes of each feeding session to ascertain initial acceptance, as done by Mennella et al. [30]. The scorer coded the infant's acceptance of the porridge on a scale of 1 (infant consistently rejects food) to 5 (infant always accepts food), following the coding of Sullivan and Birch [31].

Microbiological and pesticide residue testing

Three groups of food were microbiologically tested: raw meat and cooked meat powder, porridge dry ingredients, and cooked porridge. Raw meat (chicken thigh, chicken liver) was refrigerated at 4°–8°C and sampled at one time point within approximately 24 h of purchase of the meat. The cooked, lyophilized, and ground meat powder was analyzed at days 5, 30 and 60 after having been cooked, lyophilized, ground, and stored at 4–8°C. The meat samples were tested at the IIN microbiological laboratory for *Escherichia coli*, *Clostridium perfringens*, and *Salmonella* by standard assays [32]. The dry ingredients for the porridges tested in the infant acceptability trial were packaged in 0.5-mm-thick polyethylene bags and stored at room temperature in the study community for 3 weeks. The dry ingredients were tested for aerobic mesophiles, molds and yeast, and *Salmonella* upon packaging and after 3 weeks of storage. The porridges tested during the infant acceptability trial were cooked and stored with a plate covering them (a common practice in the study community) at room temperature in the IIN laboratories and tested for aerobic mesophiles and *E. coli* at 2, 3, 5, and 7 hours post-cooking.

After about 1 year of cold storage, chicken liver and chicken thigh powders were sent to Covance Laboratories (Madison, WI, USA) for pesticide residue testing (FDA PAM 304 screen). The presence of organochlorinated or organophosphate compounds was assessed.

Statistical methods

For the maternal acceptability trial, the numerical scores women gave to the six sensory characteristics of three porridges were compared by ANOVA and the rank data were analyzed by rank-ordered logistic regression (Stata version 8.2). For the infant acceptability trial, the amount consumed in grams and the acceptability score assigned by the video coders to the three different porridges were compared by a repeated-measures ANOVA (SAS version 9). To assess intra- and interscorer reliability prior to video coding, a weighted kappa coefficient was calculated by Stata, which allowed for concordant scoring to include a deviation of ± 1 unit (e.g., scoring the same video as 3 and 4).

Results

Recipe-creation exercises

For the recipe-creation exercises, the convenience samples consisted of 25 women with infants 5 to 8 months in 2003 and 21 women with infants 4 to 17 months in 2004. In 2003, the participants did not combine savory foods (such as meats) with sweet foods (such as the Gerber and Papimás infant foods). However, they did combine the meats with iron-fortified pasta; the consistency of these combinations varied between liquid (such as soups) and thick (such as purées). Further, because infants about 5 to 8 months of age do not have teeth and because of fear of infants choking, the mothers preferred to feed them easily mashed food such as chicken liver and not sinewy food such as muscle tissue (e.g., chicken, beef).

With the use of mothers' input obtained through the recipe-creation exercises, five isocaloric recipes were developed in 2004: one porridge without meat and two recipes each for the chicken liver powder and the chicken thigh powder (**table 1**). A commercially produced vanilla powder (Vanilla SD 18798) made of natural ingredients (as required for cereal-based infant foods per Codex Alimentarius and Peruvian norms [33, 34]) was donated by a local producer (Montana SA).

On the basis of a previous study carried out in a Lima shantytown with 6-month-old infants consuming a wheat-flour-based infant porridge, infants could be expected to consume about 100 g per serving (Nelly Zavaleta, IIN, personal communication). For 100 g of the final cooked porridge, the goal was to maintain the vitamin A content below 600 μg RE, which is the tolerable upper intake level (UL) recommended for infants 7 to 12 months of age [35], and to have an energy density of at least 1 kcal/g of cooked porridge [36]. The vitamin A UL substantially limited the amount of liver powder that could be added to the porridge.

Participants in 2004 recipe exercise and maternal and infant acceptability

In the maternal acceptability trial in 2004, 90 women with infants 3 to 12 months of age participated. A total of 49 mother–infant pairs participated in the infant acceptability trials; the infants were 6 to 9 months old. The pairs yielded 504 infant-days of data. Of these, 151 infant-days were excluded from the analyses because the infant was sick with fever, cough with phlegm, diarrhea, loose stools, vomiting, or stomach infection or was convalescing ($n = 66$), the time since the last feeding was ≤ 30 minutes ($n = 52$), the infant was not at home ($n = 26$), the amount of porridge served was greater than the amount cooked ($n = 2$), the type of porridge served was unknown ($n = 2$), or the time since the last feed was unknown ($n = 2$). A total of 353 infant-days were analyzed. Since some women participated in multiple research activities (recipe exercise, maternal acceptability, infant acceptability), a total of 111 different women participated in 2004.

In 2004 the infants were 8.0 ± 2.4 (SD) months old on average, 45.1% were girls, 94.4% were currently breastfeeding, and 80.3% had eaten meat at least once prior to the study. On average, the women who participated in 2004 were 25.9 ± 5.9 years old, had a husband or partner (87.4%), had 2.1 ± 1.2 living children, and had 7.8 ± 3.4 years of formal education. Few (18.9%) reported working. The participants' homes primarily had dirt or sand floors (62.2%), plywood walls (76.6%), and tin roofs (80.2%).

Maternal acceptability

Of the 90 women, 39 tasted thigh-containing recipes and 51 tasted liver-containing recipes. The same numeric score was used by 39 women each for liver and thigh. All 90 used the same scale to rank their preferred porridges.

With the exception of porridge consistency, the women who tasted the liver-containing recipes gave the highest characteristic scores to the no-meat porridge, followed by the low-liver and the high-liver porridges (**table 2**). Similarly, the women who tasted the thigh-containing recipes gave the highest taste, texture, and overall scores to the no-meat porridge, followed by the low-thigh and the high-thigh porridges.

After factors that could influence the scores women gave to the porridge characteristics had been controlled for (order in which porridge was tested, woman's birthplace, whether or not the child had been fed meat already, whether or not the woman participated in the recipe-creation exercise), the porridge type consistently emerged as an important factor (data not shown). These covariates did not alter the conclusion that porridge type significantly influenced most of the women's sensory scores.

By simple rank-ordering, it was clear that addition

TABLE 2. Unadjusted scores (range, 1 to 5) of porridges tested during the maternal acceptability trial[a]

	No meat	Low liver	High liver	Unadjusted p
Liver tasting ($n = 39$)				
Smell	4.46 ± 0.96	3.64 ± 1.20	3.28 ± 1.32	.0001
Taste	4.51 ± 0.88	3.74 ± 1.12	3.38 ± 1.09	< .0001
Texture	4.10 ± 1.13	3.53 ± 1.27	3.11 ± 1.27	.0025
Color	4.28 ± 1.17	3.62 ± 1.18	3.56 ± 1.17	.0125
Consistency	4.05 ± 1.15	3.82 ± 1.14	3.82 ± 1.17	.6000
Overall	4.44 ± 1.07	3.90 ± 1.14	3.62 ± 1.21	.0069
Thigh tasting ($n = 39$)				
Smell	3.85 ± 1.20	3.49 ± 1.34	3.28 ± 1.23	.1393
Taste	4.41 ± 0.88	3.44 ± 1.35	3.00 ± 1.26	< .0001
Texture	4.24 ± 0.94	3.50 ± 1.08	3.05 ± 1.15	< .0001
Color	4.00 ± 1.10	3.85 ± 1.16	3.51 ± 1.32	.1885
Consistency	4.00 ± 1.08	4.03 ± 0.93	3.63 ± 1.24	.2118
Overall	4.33 ± 0.90	3.61 ± 1.26	3.38 ± 1.31	.0014

a. All values are means ± SD. Unadjusted p values were calculated by analysis of variance (ANOVA). Among 90 women, 39 tasted thigh-containing recipes and 51 tasted liver-containing recipes. Among the liver tasters, 39 used the same numeric scales to evaluate the porridge characteristics as the thigh tasters and 12 did not. Therefore, for the thigh- and liver-containing recipes, the porridge characteristics are based on 39 women each. The no-meat porridge contained iron-fortified wheat flour, whole milk powder, brown sugar and vanilla powder. The liver and thigh porridges contained the same ingredients plus lyophilized meat powder, as follows: low liver (1.0 g liver powder/100 g cooked porridge), high liver (1.5 g liver powder/100 g cooked porridge), low thigh (3.0 g chicken thigh powder/100 g cooked porridge), and high thigh (4.0 g chicken thigh powder/100 g cooked porridge). Estimate of texture was based on how the porridge felt on the tongue. Estimate of consistency was based on observation of a spoonful of porridge lifted out of the cup and allowed to drop back into the cup.

of either meat decreased mothers' ranking of the porridges. Thigh-tasters (n = 39) ranked the no-meat porridge as the porridge they liked the most (84.6%), followed by the low-thigh (12.8%) and the high-thigh (2.6%) porridges ($p < .001$). The liver-tasting women (n = 51) ranked the porridge they liked the most as follows: no meat (76.5%), low liver (19.6%), and high liver (3.9%) ($p < .001$).

Infant acceptability

Infants' unadjusted daily intake of the porridges was not statistically significantly different ($p = .7$): 61.4 ± 47.1 g of the no-meat, 62.1 ± 44.9 g of the low-thigh, and 67.5 ± 42.0 g of the low-liver. Porridge remained a statistically nonsignificant predictor ($p = .69$) of infant's intake when adjusted for time since last feed, mother's report of infant's appetite prior to feeding, infant's age, percentage of the final cooked porridge that was fed to the infant, the fieldworker, whether or not the infant had eaten meat before, mother's age, and the energy density of the porridge. Mothers' and field workers' assessments of how the infants liked the porridge were statistically significantly correlated with infant intake (Spearman's rho = −0.52, $p < .0001$; Spearman's rho = 0.49, $p < .0001$, respectively).

Infant videotaping

Intraobserver and interobserver reliability was high (the kappa coefficient ranged from 0.74 to 1.0). Unadjusted video scores (ranging from 1 to 5) given to infants' acceptance by scorers did not significantly differ according to porridge type ($p = .99$): 3.8 ± 1.0 for the no-meat, 3.8 ± 1.2 for the low-thigh, and 3.8 ± 0.8 for the low-liver porridge. After controlling for position of the feeder with respect to the infant, the number of spoonfuls offered to the infant in the 2-minute video segment, and the proportion of spoonfuls offered that the infant consumed, porridge type remained a nonsignificant predictor of the video score ($p = .85$). To explore relationships between intake by the infant (in grams) and the mothers' and fieldworkers' assessment of acceptance by the infant, the sample size was reduced to 57 child-days due to exclusions for infant intake described earlier. Infant intake and video score were not associated (Spearman's rho = 0.19, $p = .16$). Mothers' assessments of how well the infants liked the porridge were not associated with video acceptance scores (Spearman's rho = −0.20, $p = .14$); fieldworker assessments were associated with video scores (Spearman's rho = 0.35, $p < .01$).

Microbiological and pesticide residue testing

At all four time points (0 [raw meat], and days 5, 30, and 60 post-lyophilization), the chicken liver and chicken thigh had < 10 CFU/g of *C. perfringens* and no *Salmonella* present/25 g. The raw meat had higher *E. coli* counts (most probable number [MPN] 49/g and 71/g for chicken liver and chicken thigh, respectively) than the lyophilized meat powder that had been stored for 5, 30, or 60 days at 4°–8°C (MPN < 3/g). According to the Codex Alimentarius [33], supplementary foods for older infants and young children should be free of pathogenic microorganisms. The meat powders met this standard, since *C. perfringens* and *E. coli* were not detectable and *Salmonella* was absent.

In a three-class sampling plan, two values are used to distinguish acceptable from unacceptable microbiological quality: m and M, where > M is unacceptable, > m and < M is marginally acceptable, and < m is acceptable [37]. The porridge dry ingredients at packaging and after 3 weeks of room-temperature storage had no detectable *Salmonella* and met the Peruvian standards for acceptable aerobic mesophiles (< $m = 10^4$ CFU/g where m differentiates good quality from marginally acceptable quality) [38, 39] (**table 3**). In contrast, the porridge dry ingredients were marginally acceptable for molds and yeast ($m = 10^2$ CFU/g, M = 10^4 CFU/g where M distinguishes marginally acceptable from unacceptable quality) [38, 39].

The cooked porridges met Peruvian standards for

TABLE 3. Microbiological results from assay of porridge dry ingredients immediately after packaging and after 3 weeks of storage at room temperature in the study community

Porridge[a]	Aerobic mesophiles (CFU/g)[b]	Molds and yeasts (CFU/g)[b]	*Salmonella* (present or absent/25 g)
Standards used[c]			
m	10^4	10^2	Absent
M	10^6	10^4	
After packaging			
No meat	3×10^2	1.7×10^2	Absent
Low liver	4×10^2	3.6×10^2	Absent
Low thigh	3×10^2	1.7×10^2	Absent
After 3 wk storage			
No meat	2×10^2	2.3×10^3	Absent
Low liver	2×10^2	6×10^2	Absent
Low thigh	2×10^2	4.7×10^2	Absent

CFU, colony-forming unit

a. The no-meat porridge contained iron-fortified wheat flour, whole milk powder, brown sugar, and vanilla powder. The liver and thigh porridges contained the same ingredients plus lyophilized meat powder, as follows: low liver (1.0 g liver powder/100 g cooked porridge) and low thigh (3.0 g chicken thigh powder/100 g cooked porridge).

b. The assay cannot detect values < 10 CFU/g.

c. In a three-class sampling plan, two values are used to distinguish acceptable from unacceptable microbiological quality: m and M, where > M is unacceptable, > m and < M is marginally acceptable, and < m is acceptable [37]. The standards were obtained from the International Commission on Microbiological Specifications for Foods [39].

aerobic mesophiles ($< m = 10^4$ CFU/g) [39] **(table 4)** and had undetectable levels of *E. coli* after 2, 3, 5, and 7 hours of standing at room temperature after cooking.

No pesticide residues were detected in the chicken liver powder or the chicken thigh powder (< 0.2 ppm of organochlorinated residues and < 0.05 ppm of organophosphates).

Discussion

Porridges containing lyophilized meat powder were evaluated for safety and for acceptability by mothers and infants living in an urban shantytown in Lima, Peru. Consistently, mothers gave higher acceptability scores to organoleptic characteristics (smell, taste, texture, color, consistency, and overall acceptability) of the porridge containing no meat, followed by porridges containing low quantities of meat powder and higher quantities of meat powder. In comparison, infants' intake (used as a proxy of acceptance) was the same for porridges containing no meat, low quantities of chicken liver powder, and low quantities of chicken thigh powder. The infants' lack of a preference for a porridge was supported by the video analysis. The lyophilized meat powder was microbiologically safe up to 2 months after it was processed. Similarly, the cooked porridge met microbiological standards for up to 7 hours of storage at room temperature. However, the dry porridge ingredients had only marginal acceptability with respect to molds and yeasts upon packaging and 3 weeks post-storage at room temperature. No pesticide residues were detected in the meat powders.

TABLE 4. Microbiological results of porridges cooked and stored at room temperature for 2, 3, 5, and 7 hours after cooking

Porridge[a]	Storage time (h)	Aerobic mesophile (CFU/g)[b]	*Escherichia coli* (MPN/g)[c]
No meat	2	2×10^3	< 3
	3	1.5×10	< 3
	5	1.7×10^2	< 3
	7	5×10^2	< 3
Low liver	2	1.2×10^3	< 3
	3	< 10	< 3
	5	7.5×10	< 3
	7	2.5×10^2	< 3
Low thigh	2	2.5×10^2	< 3
	3	8×10	< 3
	5	1.7×10^2	< 3
	7	2.2×10^3	< 3

CFU, colony-forming unit; MPN, most probable number

a. The no-meat porridge contained iron-fortified wheat flour, whole milk powder, brown sugar, and vanilla powder. The liver and thigh porridges contained the same ingredients plus lyophilized meat powder, as follows: low liver (1.0 g liver powder/100 g cooked porridge) and low thigh (3.0 g chicken thigh powder/100 g cooked porridge).

b. The assay cannot detect values < 10 CFU/g. These results were compared against standards from the International Commission on Microbiological Specifications for Food [39]: $m = 10^4$ CFU/g and $M = 10^6$ CFU/g.

c. The assay cannot detect values < 3 MPN/g. These results were compared against standards from the International Commission on Microbiological Specifications for Food [39]: $m = < 3$ MPN/g and M = 10 MPN/g.

Recipe-creation exercises

A key insight from the recipe-creation exercises was that mothers did not mix savory with sweet foods, which is what was done to create the meat-containing porridges that were evaluated in this study. However the alternative, creating an infant food mixing iron-fortified pasta with meat in a soup, was not nutritionally acceptable to the researchers because of the low energy density. Therefore, mothers' preference for non-meat-containing porridges during the acceptability trial was not surprising. That this preference did not extend to infants is promising; these meat-containing sweet porridges could be promoted as a nutritious food that infants like.

Nutrient contribution of porridges

Because of the changes in the organoleptic properties of the base porridge caused by adding the chicken liver and thigh powders and because of the vitamin A UL for infants, smaller amounts of the meat powders were added to the porridge than originally planned. Subsequent analysis of the energy, macronutrient, and vitamin A contents of the meat powders by Covance Laboratories resulted in vitamin A values that were considerably lower for chicken liver powder than we had estimated (6,690 vs. 31,626 µg RE/100 g), within 8% of the energy, protein, and fat values that we had estimated for chicken liver and chicken thigh powders, and within 8% of the vitamin A value for chicken thigh powder. The vitamin A discrepancy was due to the value for raw chicken liver in the IIN food-composition table [29], which is about twofold larger (6,165 vs. 3,296 µg RE) than in the USDA nutrient database [40]. Whether the vitamin A UL level of 600 µg RE is accurate or too low for this age group is debatable [41].

The iron contribution of the porridges is small relative to international recommendations (1.3–2.0 mg/27 g dry product vs. 7.4 mg/27 g dry product recommended [42]). However, previous work in Peru suggests that these porridges could provide an important bioavailable source of iron to infants, and the addition of lyophilized meat powder would increase bioavailability.

In a poor community in Lima, Peru, 6-month-old infants were served approximately 200-g portions of porridge containing wheat flour, milk, sugar, and oil twice a day for 9 months (Nelly Zavaleta, IIN, personal communication). These infants were fed a porridge similar to the "no-meat" porridge that we evaluated, with one exception: the earlier study was conducted when the wheat flour in Peru was fortified with 3.0 mg of iron per 100 g as ferrous sulfate [43], and we used wheat flour fortified with 5.0 mg of iron per 100 g as ferrous fumarate (in addition to thiamin, riboflavin, niacin, and folic acid), as allowed by new Peruvian legislation [28]. No baseline hemoglobin data were available on the Peruvian infants who consumed a porridge comparable to the "no-meat" porridge for 9 months; however, another study in a similar Peruvian community revealed that 72.7% of infants 6 months old had a hematocrit < 33%, indicative of anemia (Mary Penny, IIN, personal communication). At the end of the 9-month study, the prevalence of anemia was about 25%, which is about one-third of what could have been expected at baseline and one-third of that in a national sample of children 12 to 15 months of age [44].

As described earlier, daily consumption of ferrous sulfate–fortified wheat products (3 mg of iron per 100 g of wheat product) for 7 weeks eliminated anemia among 41 stunted and moderately anemic children 3 or 4 years of age [6].

Maternal acceptability trial

Mothers preferred porridges with low or no meat to porridges with a higher meat content. Nevertheless, scores for the organoleptic properties of the porridges averaged 3.4 to 4.4 (ranging from 3, "neither like nor dislike," to 5, "like very much"), suggesting that all porridges were within an acceptable range for women. When the proportion of women giving porridges the lowest scores (1, "dislike very much," and 2, "dislike some") was compared among the porridges, the same trend was seen as for other analyses: the proportion disliking the porridges was highest for the porridges with most meat, followed by those with less meat and no meat (data not shown).

Infant acceptability trial and videotaping

Despite differing maternal perceptions of the foods, infants consumed the same amount of the three porridges offered to them (no meat, low liver, low thigh), suggesting that they had no preference for one over the other, even after factors that influence infants' intake of any food had been controlled for. In contrast, the mothers expressed a preference for the no-meat porridge over the meat-containing porridges. This difference is supported by the lack of association between the overall score women gave to the porridges and the amount of porridge the infants ate (data not shown). Because an infant's intake is influenced by so many factors beyond his or her preference for a particular food, we videotaped a subset of children to try to objectively determine their porridge preference. The videotape analysis supports the findings from the intake data: there was no difference in infants' initial (2 minutes) preference for the porridges based on blinded coding. Correspondence between infants' total intake and 2-minute video coding has been observed in another study [30].

Comparison with acceptability of porridges used in public health programs

Several porridges used in public health programs in different countries have undergone acceptability trials [45–50]. The methods used in Mexico for the national PROGRESA program are most comparable with those of our study [49, 50]. In Mexico, the acceptability of three PROGRESA porridges (vanilla, banana, and chocolate flavored) to children was evaluated with hedonic scores (how trained enumerators judged the child's acceptance) and total intake over 14 days (grams consumed); acceptability of the porridges by the caregiver was not assessed. Acceptability and consumption were evaluated with 108 children (75% were < 2 years old, and 25% were moderately underweight and 2 or 3 years old). For acceptability, the enumerators scored children's acceptance of each porridge on a scale of 1 to 5. The average score for the three PROGRESA porridges was 3.7 to 4.2, and the differences between porridges were not statistically significantly different. These results are comparable to the unadjusted overall scores (on a five-point scale) mothers gave the porridges tested in Peru: 4.4 ± 1.0 (SD) for the no-meat porridge, 3.9 ± 1.1 for the low-liver porridge, 3.6 ± 1.2 for the high-liver porridge, 3.6 ± 1.2 for the low-thigh porridge, and 3.4 ± 1.3 for the high-thigh porridge.

Consumption in Mexico was measured over 14 days when the children's favorite porridge (based on acceptability) was provided daily at a feeding center. On each day, 69 g of the porridge was offered to the child; the average daily intake of the porridges was 57.6 to 65.2 g, which represents 83.4% to 94.3% of the porridge served. Children ate more of the chocolate porridge than the vanilla porridge, and more of the vanilla porridge than the banana flavor ($p < .05$). Among breastfed children < 2 years of age, the mean consumption of any porridge was 56.5 ± 15.0 g (82% of the amount served). The amount of porridge consumed by breastfeeding children < 2 years of age in Mexico is comparable to the amount consumed by Peruvian infants 6 to 9 months of age; however the Peruvian children were offered a larger amount (up to 200 g) than the Mexican children (69 g). It is not surprising that more than 83% of the porridge fed to the Mexican children was consumed; these children in the second year of life probably could have consumed more than the 69 g offered to them in one sitting.

The hedonic scale used to evaluate children's acceptance in Mexico was similar to the videotape analysis we completed. In both cases, coders observed children during a feeding and scored acceptability according to predefined categories, with 1 representing the lowest acceptability and 5 representing the highest acceptability. However, in our case, the observation was recorded and scoring was limited to the first 2 minutes of the feeding, whereas in Mexico, the observation was made in real time and covered the entire feeding episode.

Microbiological and pesticide residue testing

These data show that it is possible to develop meat-containing porridges that are pathogen-free for up to 7 hours after cooking and storage at room temperature. In addition, the lyophilized meat powder alone was microbiologically safe for 60 days when refrigerated at 4°–8°C. However, upon packaging, the dry ingredients had marginally acceptable levels of mold and yeast, and these values increased after 3 weeks of room-temperature storage. Allthough these results are not surprising, given the humid conditions in Lima, they suggest that the porridge ingredients need to be stored in conditions that prevent or decrease mold and yeast growth *prior* to mixing and packaging, that refrigeration of the packaged dry ingredients may be warranted to slow mold and yeast growth, and that other packaging material needs to be explored. With respect to pesticide residues, neither organophosphate nor organochlorinated compounds were detected in the meat powders after approximately 1 year of cold storage.

The microbiological safety of a processed complementary food used in Ghana (Weanimix) was evaluated under two conditions: fermentation and storage in a vacuum flask [51]. The main outcome was the presence of coliforms (≥ 100/mL), an indicator of fecal contamination, in the cooked maize–peanut-soybean porridge approximately 9 hours after preparation. A strength of this study is that foods were prepared and stored in homes under real-life conditions by women with children 6 to 18 months of age ($n = 50$). Both experimental conditions reduced coliform contamination of the food (fermentation and storage in vacuum flask if the food temperature was > 50°C). In the public health setting, however, neither condition is presumably used by families. In fact, the unfermented, non-vacuum-stored food had the highest proportion of contaminated samples (48%).

Simplified methods to assess food acceptability among young children

Rapid and accurate methods to assess food acceptability could promote their more regular use in public health programs and research. The results of this study indicate that in lieu of measuring infants' intake as a proxy for acceptability, other less resource-intensive methods could be used. For example, we found that mothers' and field workers' assessments of how much infants liked the porridge was strongly correlated with the infants' porridge intake. In a subset of infants with real-time video analysis of the first 2 minutes of each feeding, the coders' scores yielded similar conclusions as the infant intake data, but the scores were not associated with infant intake. These data suggest that a fieldworker needs to observe only the first 2 minutes of a feed and not the feeding session in its entirety. Notably, the mean length of feeding sessions for the 67 infant-days videotaped was 13.7 ± 6.1 minutes. Alternatively or in addition, maternal assessment of how the infant liked the porridge can be used. In summary, these "subjective" measures do not require training of mothers, use of food scales, or extensive data collection in the field and may be sufficient to determine infant acceptability of a new or modified food.

Conclusions

With maternal input, we developed infant porridges containing fortified wheat flour, fortified powdered milk, brown sugar, vanilla powder, and lyophilized meat powder; the porridges were tested for maternal and infant acceptability, microbiological, safety and pesticide residues. According to hedonic rating of sensory characteristics, mothers preferred the porridge with no meat to any of the porridges with meat. Even so, their overall ratings of the meat-containing porridges ranged from "neither like nor dislike" to "like." In comparison, infants consumed the same amount of the meat-containing and non-meat-containing porridges. The acceptability data suggest that if mothers can be convinced to feed the meat-containing porridges to the infants despite their own preferences, the infants will consume them. Pesticide residues were not detected in the meat powders. The microbiological quality of the lyophilized meat powder, dry ingredients, and cooked porridge was acceptable, except for the numbers of molds and yeasts in the dry ingredients. Measures need to be taken to reduce the mold and yeast content of the porridge ingredients.

Acknowledgments

We acknowledge the contributions to the fieldwork of Katiushka Vaccari Silva, Liliana Cutipa Quispe, Liz Espinoza Oré, Sara Livia Echía, Carolina Yong Ruiz, Roberto Carlos Renjifo Silva, and students from the Universidad Nacional Mayor de San Marcos and the Cordon Bleu Institute. We thank the community and Ministry of Health leaders for facilitating our entry into the community, the staff of the IIN laboratories for conduct of the microbiological analyses, and Dr. Kathryn Boor of Cornell University for interpretation of the microbiological results. We also thank Ruben Frescas, Jr., Akua Gyamerah, and Julia Raymond for development of the video coding system and for coding the videos, and Drs. Patricia Kariger and Richard Canfield for assistance with the coding system. Funding was provided by Cornell University (Division of Nutritional Sciences, Latin American Studies Program/Tinker Foundation, Program in International Nutrition, Mario Einaudi Center for International Studies, Marion Fish Cox Fellowship); Gerber Foundation Predoctoral Fellowship; American Society for Nutritional Sciences; Hispanic Scholarship Fund/Pfizer Inc. Fellowship; National Institutes of Health Training Grant in Nutrition (5 T32 K07158-28); and Scientific Cooperation Research Program, USDA (58-3148-4-071). Fortified wheat flour was donated by Alicorp SA, Peru, and vanilla powder by Montana SA, Lima, Peru.

References

1. Stoltzfus RJ, Dreyfuss ML. Guidelines for the use of iron supplements to prevent and treat iron deficiency anemia. Washington, DC: International Life Sciences Institute, 1998:1. Available at: http://inacg.ilsi.org/file/b2_VUHUQ8AK.pdf. Accessed 22 December 2006.
2. Grantham-McGregor S, Ani C. A review of studies on the effect of iron deficiency on cognitive development in children. J Nutr 2001;131(2S-2):649S–68S.
3. Rivera JA, Hotz C, Gonzalez-Cossio T, Neufeld L, Garcia-Guerra A. The effect of micronutrient deficiencies on child growth: A review of results from community-based supplementation trials. J Nutr 2003;133(11 suppl 2):4010S–20S.
4. Lynch SR, Stoltzfus RJ. Iron and ascorbic acid: Proposed fortification levels and recommended iron compounds. J Nutr 2003;133:2978S–84S.
5. Lutter CK. Macrolevel approaches to improve the availability of complementary foods. Food Nutr Bull 2003; 24:83–103.
6. López de Romaña D, Salazar M, Hambidge KM, Penny ME, Peerson JM, Krebs NF, Brown KH. Longitudinal measurements of zinc absorption in Peruvian children consuming wheat products fortified with iron only or iron and 1 of 2 amounts of zinc. Am J Clin Nutr 2005; 81:637–47.
7. Dewey KG, Brown KH. Update on technical issues concerning complementary feeding of young children in developing countries and implications for intervention programs. Food Nutr Bull 2003;24:83–103.
8. Allen LH. Folate and vitamin B_{12} status in the Americas. Nutr Rev 2004;62(6 pt 2):S29–33.
9. Murphy SP, Allen LH. Nutritional importance of animal source foods. J Nutr 2003;133(11 suppl 2):3932S–5S.
10. Delgado CL. Rising consumption of meat and milk in developing countries has created a new food revolution. J Nutr 2003;133(11 suppl 2):3907S–10S.
11. Cowin I, Emond A, Emmett P; ALSPAC Study Group. Association between composition of the diet and haemoglobin and ferritin levels in 18-month-old children. Eur J Clin Nutr 2001;55:278–86.
12. Faber M. Complementary foods consumed by 6–12-month-old rural infants in South Africa are inadequate in micronutrients. Public Health Nutr 2005;8:373–81.
13. Fox MK, Pac S, Devaney B, Jankowski L. Feeding infants and toddlers study: What foods are infants and toddlers eating? J Am Diet Assoc 2004;104:S22–30.
14. Fox MK, Reidy K, Karwe V, Ziegler P. Average portions of foods commonly eaten by infants and toddlers in the United States. J Am Diet Assoc 2006;106(1 suppl 1): S66–76.
15. Hotz C, Gibson RS. Participatory nutrition education and adoption of new feeding practices are associated with improved adequacy of complementary diets among rural Malawian children: A pilot study. Eur J Clin Nutr 2005;59:226–37.
16. McConahy KL, Smiciklas-Wright H, Birch LL, Mitchell DC, Picciano MF. Food portions are positively related to energy intake and body weight in early childhood. J Pediatr 2002;140:340–7.
17. Ntab B, Simondon KB, Milet J, Cissé B, Sokhna C, Boulanger D, Simondon F. A young child feeding index is not associated with either height-for-age or height velocity in rural Senegalese children. J Nutr 2005;135:457–64.
18. Yeung GS, Zlotkin SH. Efficacy of meat and iron-fortified commercial cereal to prevent iron depletion in cow milk-fed infants 6 to 12 months of age: A randomized controlled trial. Can J Public Health 2000;91:263–7.
19. Creed Kanashiro H, Fukumoto M, Bentley ME, Jacoby E, Verzosa C, Brown KH. Use of recipe trials and anthropological techniques for the development of a home-prepared weaning food in the Central Highlands of Peru. J Nutr Educ 1991;23:30–5.
20. Graham MA. Food allocation in rural Peruvian households: Concepts and behavior regarding children. Soc Sci Med 1997;44:1697–709.
21. Serra-Majem LL, Calvo JR, Male ML, Ribas L, Lainez P. Population attitudes towards changing dietary habits and reliance on general practitioners in Spain. Eur J Clin Nutr 1999;53(suppl 2):S58–61.
22. Aubel J, Touré I, Diagne M. Senegalese grandmothers promote improved maternal and child nutrition practices: The guardians of tradition are not averse to change. Soc Sci Med 2004;59:945–59.
23. Gittelsohn J, Vastine AE. Sociocultural and household factors impacting on the selection, allocation and consumption of animal source foods: Current knowledge and application. J Nutr 2003;133(11 suppl 2): 4036S–41S.
24. Liria MR, Bartolini R, Abad MF, Creed-Kanashiro HM. Mothers' perceptions towards the feeding of animal source foods to infants, Lima, Peru. FASEB J 2005;19(4): A460 (abstract 285.6).
25. Desor JA, Maller O, Greene LS. Preference for sweet in humans: Infants, children, and adults. In: Weiffenbach JM, ed. Taste and development: The genesis of sweet

preference. DHEW Publication No. (NIH) 77-1068. Bethesda, MD, USA: US Department of Health, Education, and Welfare, Public Health Service, 1977:161–72.
26. Hallberg L, Hoppe M, Andersson M, Hulthén L. The role of meat to improve the critical iron balance during weaning. Pediatrics 2003;111(4 pt 1):864–70.
27. Gailani MB, Fung DY. Critical review of water activities and microbiology of drying of meats. Crit Rev Food Sci Nutr 1986;25:159–83.
28. El Peruano. Normas legales, 3 febrero 2005. Aprueban Reglamento de la Ley N 28314 que dispuso la fortificación de la harina de trigo con micronutrientes. Lima, Peru: El Peruano, 2005:286087–286089.
29. Instituto de Investigación Nutricional (IIN). Food composition tables IIN, 2001. Lima, Peru: Instituto de Investigación Nutricional, 2001.
30. Mennella JA, Jagnow CP, Beauchamp GK. Prenatal and postnatal flavor learning by human infants. Pediatrics 2001;107(6):e88. Available at: http://www.pediatrics.org/cgi/content/full/107/6/e88. Accessed 10 December 2006.
31. Sullivan SA, Birch LL. Infant dietary experience and acceptance of solid foods. Pediatrics 1994;93:271–7.
32. Food and Drug Administration. Bacteriological analytical manual, 7th ed. Arlington, VA, USA: AOAC International, 1992:17–234.
33. Codex Alimentarius. Guidelines on formulated supplementary foods for older infants and young children, CAC/GL 08-1991. Available at: http://www.codexalimentarius.net/web/standard_list.do?lang = en. Accessed 10 December 2006.
34. Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual (INDECOPI). Norma técnica Peruana, Alimentos cocidos de reconstitución instantánea, Papillas, Requisitos. NTP 209.260:2004. Lima, Peru: INDECOPI, 2004:15.
35. Institute of Medicine. Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium and zinc. Washington, DC: National Academies Press, 2001:144.
36. Pan American Health Organization/World Health Organization (PAHO/WHO). Guiding principles for complementary feeding of the breastfed child. Washington, DC: PAHO, 2003:21. Available at: http://www.paho.org/English/AD/FCH/NU/Guiding_Principles_CF.htm. Accessed 22 December 2006.
37. Huss HH, Ababouch L, Gram L. Assessment and management of seafood safety and quality. FAO Fisheries Technical Paper No. 444. Rome: Food and Agriculture Organization, 2004:8. Available at: http://www.fao.org/DOCREP/006/Y4743E/Y4743E00.htm.. Accessed 22 December 2006.
38. Institute of Medicine. Scientific criteria to ensure safe food. Washington, DC: National Academies Press, 2003:142. Available at: http://www.nap.edu/books/030908928X/html. Accessed 22 December 2006.
39. International Commission on Microbiological Specifications for Foods (ICMSF). Microorganismos de los alimentos. Métodos de muestreo para análisis microbiólogicos: Principios y aplicaciones específicas, volumen II. Zaragoza, Spain: Editorial Acribia, 1981:110–3.
40. US Department of Agriculture (USDA). National nutrient database for standard reference, release 18. Available at: http://www.ars.usda.gov/main/site_main.htm?modecode=12354500. Accessed 10 December 2006.
41. Zlotkin S. A critical assessment of the upper intake levels for infants and children. J Nutr 2006;136:502S–6S.
42. Lutter CK, Dewey KG. Proposed nutrient composition for fortified complementary foods. J Nutr 2003; 133:3011S–20S.
43. Hertrampf E. Iron fortification in the Americas. Nutr Rev 2002;60(7 pt 2):S22-5.
44. Instituto Nacional de Estadística e Informática (INEI). Encuesta demográfica y de salud familiar 2000. Lima, Peru: INEI, 2001:186.
45. Tartanac F. Incaparina and other Incaparina-based foods: Experience of INCAP in Central America. Food Nutr Bull 2000;21:49–54.
46. Barenbaum M, Pachón H, Schroeder DG, Hurtado E. Use, acceptability, and cost of Incaparina, a commercially processed food in Guatemala. Food Nutr Bull 2001; 22:71–80.
47. Rozo C. Complementary foods in Colombia. Food Nutr Bull 2000;21:55–60.
48. Lartey A, Manu A, Brown KH, Peerson JM, Dewey KG. A randomized, community-based trial of the effects of improved, centrally processed complementary foods on growth and micronutrient status of Ghanaian infants from 6 to 12 mo of age. Am J Clin Nutr 1999;70:391–404.
49. Rosado JL, Rivera J, Lopez G, Solano L, Rodriguez G, Casanueva E, Garcia-Aranda A, Toussaint G, Maulen I. Desarrollo y evaluación de suplementos alimenticios para el Programa de Educación, Salud y Alimentación. Salud Publica Mex 1999;41:153–62. Available at: http://www.scielosp.org/pdf/spm/v41n3/41n3a02.pdf. Accessed 22 December 2006.
50. Rosado JL, Rivera J, Lopez G, Solano L. Development, production and quality control of nutritional supplements for a national supplementation programme in Mexico. Food Nutr Bull 2000;21:30–4.
51. Kimmons JE, Brown KH, Lartey A, Collison E, Mensah PP, Dewey KG. The effects of fermentation and/or vacuum flask storage on the presence of coliforms in complementary foods prepared for Ghanaian children. Int J Food Sci Nutr 1999;50:195–201.