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ARTICLE

# The use of linear programming to determine whether breastfed infants can achieve a nutritionally adequate complementary feeding diet: a case study of 6–11-month-old infants from KwaMashu, KwaZulu-Natal, South Africa

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**Objectives:** The objectives of this study were to ascertain whether the nutrient requirements of 6–11-month-old infants can be met with a food-based approach, and to identify the nutrients of which it is difficult to achieve adequate intakes.
**Design, setting and subjects:** A cross-sectional survey and interviews with mothers and caregivers from the KwaMashu Community Health Centre were conducted. One hundred and thirty-four interviews were completed. This information provided the food consumption input for the model using Optifood software.
**Results:** The results revealed that with the current food pattern of infants from the study group in KwaMashu, iron, zinc and calcium are nutrients whose requirements are likely not to be met in the diet. The percentage RNI (recommended nutrient intake) for iron was 25.2%, zinc 51.3% and calcium 77%. Nutrient intakes for these nutrients of concern improved in the 'No pattern' diet but iron and zinc intakes remained below the RNI. According to the best diets modelled by Optifood, it appears that infants in KwaMashu would be able to achieve the recommended intakes of energy, protein, and 8 of the 11 micronutrients, as long as breastfeeding on demand continues during the complementary feeding phase.
**Conclusions:** This study calls into question the continued food-based focus to ensure nutrient adequacy in infants. In conjunction with efforts to improve household food security and continued support and promotion of breastfeeding for the first 2 years of life, targeted micronutrient supplementation may be needed to ensure the optimal growth and development of infants in South Africa.

**Keywords:** Optifood, complementary feeding, nutrient requirements, infant nutrition, South Africa

## Introduction

Public health nutrition decision-making relies on current and reliable data. Conducting research to provide the information to enable evidence-based decisions is a challenge in resource-limited settings (with limited funding for example). Research tools that allow the investigation and the assessment of options at a lower cost, and in a shorter time, are valuable. One such tool in the field of nutrition is modelling. Modelling various scenarios based on specific inputs will allow researchers to weigh up various courses of action and their possible outcomes in a timely and financially efficient manner. For complementary feeding in South Africa, it would be useful to model whether available foods in a community can help achieve recommended nutrient intakes, and to test specific food-based recommendations that could be promoted.

The World Health Organization/London School of Hygiene and Tropical Medicine (WHO/LSHTM) Optifood linear programming software assists in formulating and evaluating a food-based approach, testing various food-based recommendations, and assessing the cost of various dietary patterns.[1] This can facilitate better decision-making and advocacy for the assessed complementary feeding efforts. Furthermore, Optifood has greater objectivity and provides stronger evidence for actions than other assessments.[1] This software is presently only made available to users once they have received training in its use as no comprehensive user manual is currently available. The first author of this paper was trained by Dr Elaine Ferguson from the LSHTM on how to use the software (August 2017). This linear programming approach has been used to assess the complementary feeding diet in other countries as outlined in Table 1.

## Objectives

The objectives of this study were to:

1. describe the current food consumption patterns of 6–11-month-old infants attending a well-baby clinic in KwaMashu, KwaZulu-Natal;
2. ascertain if the nutrient requirements of 6–11-month-old infants can be met with a food-based approach (as a case study for South Africa); and
3. highlight the nutrients of which it is difficult to achieve adequate intakes.

The study made use of the WHO/LSHTM Optifood linear programming software. As the use of linear programming is relatively new to nutrition decision-making in South Africa, it was the first time it was used in South Africa to assess complementary feeding diets.

## Method

One hundred and thirty-four interviews were completed with mothers and caregivers from KwaMashu in South Africa, and this provided the input for the modelling exercise. The study was a cross-sectional survey with data collected using questionnaires for sociodemographic and dietary information at the

**Table 1:** Recently published research on the complementary feeding diet that used Optifood

| Country | Year of publication | Age of children in study population | Sample size | Dietary intake methodology |
|---|---|---|---|---|
| Cambodia | 2014[2] | 6–11-month-old infants | 78 | Single 24 hour recall |
| Ghana | 2017[3] | 6–23-month-old infants | 705 | Multiple-pass 24 hour recall, repeated in 20% of subsample |
| Guatemala | 2017[4]<br>2018[5] | Breastfed 6–11-month-old infants and 12–23-month-old infants<br>Non-breastfed 12–23-month-old infants<br>6–11-month-old infants | 73<br>91<br>26<br>94 | Household consumption and expenditure data, 24 hour recall and food frequency data from an older study<br>Single 24 hour recall |
| Indonesia | 2016[6]<br>2014[7] | 12–23 month-old infants<br>6–23 month-old infants | >8000 | 1 day weighed diet records, single 24 hour recall, 5 day food tally |
| Kenya | 2016[8]<br>2015[9] | 6–23-month-old infants<br>6–23-month-old infants | 882<br>401 | Multiple-pass 24 hour recall with weighing of foods, recipe information collected |
| Myanmar | 2016[10] | 12–23-month-old infants | 106 | 12 hour weighed diet records, single 24 hour recall, 5 day food record |

KwaMashu Community Health Centre. KwaMashu is a suburb of Durban in KwaZulu-Natal with 175 663 residents according to Stats SA.[11] The KwaMashu Community Health Centre (KMCHC) is a referral site for six clinics and has a catchment population of about 750 000.[12] The KMCHC treats about 169 000 patients a year, including approximately 9 500 under five-year-old children (personal communication 2018). Ethics approval for this study was obtained from the University of Pretoria Faculty of Natural and Agricultural Sciences Ethics Committee (reference number 180000016). Permission was also granted by the KwaZulu-Natal Health Research Ethics Committee (reference number: KZ_201809_018).

The methodology described in this article is specific to the nutrition modelling conducted. Optifood software version V4.0.14.0 (16 June 2015) was used to conduct the nutrition modelling. Tables 2–5 detail the input used in the modelling in Optifood. The modelling conducted by Optifood aims to model the best seven-day diet within the given parameters that comes closest to mathematically achieving greater than or equal to 100% of the RNI (recommended nutrient intakes) for the selected nutrients. Optifood models the 'two best diets', i.e. a 'Food pattern' diet, which is the best diet closest to the target population's average food pattern, while the 'No food pattern' diet is the best diet that can deviate from average food group patterns but remains within upper and lower food group constraints set for the modelling exercise.

Table 2 summarises the information for the nutrition modelling exercise for Optifood and the rationale behind the decisions made. The main source of information for the input that was required was the information collected with the questionnaires on feeding practices and the quantified food frequency questionnaires regarding the previous 7-day dietary intake of the infants. The South African Food Quantities Manual (SA FQM)[13] was used to translate household descriptions of foods to grams; and the South African Food Composition Tables (SA FCT)[14] were used for the input of the food composition data of South African foods into the Optifood software.

In Table 3, the consumption information on the 14 food items used in the modelling exercise is provided. Table 4 outlines the food group level input required for the modelling exercise, and the source of food quantities information and food composition data is detailed in Table 5. South Africa has mandatory food fortification regulations for maize meal and wheat flour to be fortified with vitamin A, thiamine, riboflavin, niacin, folic acid, pyridoxine (vitamin $B_6$), iron and zinc.[19]

## Results

The modelling conducted by Optifood aims to model the best seven-day diet within the given parameters that comes closest to mathematically achieving greater than or equal to 100% of the RNI for the selected nutrients. Optifood models the 'two best diets', i.e. a 'Food pattern' diet, and a 'No food pattern' diet as described in the previous section. Table 6 describes the number of servings of food from each food group in the two best diets that had been modelled by Optifood, i.e. the 'Food pattern' and the 'No food pattern' diet as described in the methodology section. Table 7 outlines the energy and nutrient content of the two best diets that had been modelled and includes the percentage of the RNI.

The number of servings in the two best diets that had been modelled shows that the 'No pattern' diet minimises most foods and selects the use of the fortified infant cereal, chicken and banana in preference to other foods to meet nutrient requirements (Table 6).

The nutrients for which the percentage RNI is less than 100% are shaded in Table 7. With the current foods most commonly consumed in the study group in KwaMashu, the diet modelled according to current food patterns identifies iron, zinc and calcium as the nutrients whose requirements are likely not to be met in the diet of infants (nutrients of concern). The percentage RNI for iron was 25.2%, for zinc 51.3% and for calcium 77%. Nutrient intakes for these nutrients of concern improve in the 'No pattern' diet but iron and zinc intakes still remain below the RNI.

Table 8 depicts the top three food sources of each nutrient in the food pattern diet as portrayed by Optifood.

Breastmilk continues to be the main source of energy, macronutrients, and 9 of the 11 micronutrients in the modelled diet, highlighting the important contribution of continued breastfeeding when foods are introduced to the diets of infants. Breastmilk and animal-source foods provided 71% of the protein intake. Fortified foods (infant cereal, margarine) and starchy plant foods (butternut) stood out as main contributors to nutrient intakes in this modelled diet. Even though processed meat appears in the table of main nutrient sources, it should be

**Table 2:** Summary of data inputs required for linear programming for Optifood modelling (adapted from Ferguson *et al.* 2008[1]) and the parameters selected

| Information required for the Optifood modelling | Input (modelling parameters) |
|---|---|
| 1. Foods that the target population typically consumes, including the typical portion sizes of foods, and frequency of consumption per week | The top 14 food items consumed by more than 40% of the 6–11-month-old infants in the past 7 days were selected for the modelling exercise.<br>If more foods were selected then the food items would not represent what might be available to households in the community.<br>The servings per week of each food were determined from the category most commonly selected in the quantified food frequency recall, i.e. daily consumption, most days (consumed on 4 or more days), some days (consumed 2–3 times), and consumed once in the previous 7 days. Where a range of intake was most commonly cited the upper limit in the range was selected as the consumption amount.<br>The typical portion size of each of the foods was determined by using the most frequently described portion and translating it into grams.<br>The food quantities manual[13] was used to translate portions into grams and this was confirmed with a shop visit by the first author to determine typical serving unit weights of the 14 items as declared on food labels.<br>The minimum servings per week for all foods were indicated as 1, except for 2 food items where the typical consumption was 1 times a week. In these cases the minimum consumption was set to 0.1 times per week.<br>Maximum consumption for each of the food items was set to 0.1 higher than the typical consumption. |
| 2. Food consumption patterns of the target group (defined as the number of times foods from a selected food group were consumed) | Table 3 describes the typical, minimum (low consumption level) and maximum servings (high consumption level) per week of each food item.<br>Table 4 outlines the food group level input required for the modelling exercise. |
| 3. Energy and nutrient requirements of the target population | The Optifood default energy and nutrient requirements for 6–11-month-old infants was used as the reference for daily energy and nutrient intakes. A weight of 9 kg was used in calculations based on infant weight after consultation of the WHO 50th percentile weight for boys and girls at 9 months.[15]<br>The reference energy per day in Opifood was 693 kcal (about 2897 kJ) and protein was 10.26 g per day. Daily micronutrient requirements were: calcium 400 mg per day, vitamin C 30 mg per day, thiamine 0.3 mg per day, riboflavin 0.4 mg per day, niacin 4 mg per day, vitamin $B_6$ 0.3 mg per day, folate 80 µg per day, vitamin $B_{12}$ 0.7 µg per day, and vitamin A 400 µg retinol equivalents per day. These nutrient intakes will be referred to as recommended nutrient intakes (RNI).<br>For iron, the Optifood user can select bioavailability of 5%, 10%, 12% or 15% to determine the requirement. For zinc the Optifood user can select low, moderate or high bioavailability to determine the requirement. A selection was made based on which value best matched the nutrient requirement specified by the South African government for infant food labelling purposes for 6–12-month-old infants,[16] i.e. 11 mg for iron (10% bioavailability gives 9.3 mg/day) and 3 mg for zinc (moderate bioavailability gives 4.1 mg/day). |
| 4. Nutrient composition of foods per 100 g | Nutrient information for the 14 food items was mainly selected from the South African Food Composition Tables.[14] This was also checked against current food label information for the selected nutrients in Optifood. Some of the nutrient data for yogurt, processed meats and hard margarine were updated with product label information (as products changed due to new legislation). The nutrient information for the infant cereal was calculated from on-pack directions for preparation and using the as sold nutrient data from the SAFCTs. Table 6 details the information on food composition and food quantities information. |
| 5. Target population breastfeeding status | Forty-nine (36.6%) 6–11-month-old infants in this study were still receiving breastmilk, 63 (47.0%) were receiving formula milk and it was reported that 22 (16.4%) were mixed feeding (breastmilk and formula milk).<br>Just over half (52.9%) of the infants were still receiving some breastmilk and as breastmilk is the ideal, the target population breastfeeding status was selected as 'yes'. |
| 6. Energy and nutrient contribution from breastfeeding | The Optifood food composition values for the energy and nutrient contribution from breastmilk were used. In Optifood breastmilk provides 66 kcal (or 276 kJ) per 100 g. Optifood uses kcal but kJ is used in South Africa, and so both units are reported.<br>Breastmilk consumption was estimated at 600 g per day. This is the average of 626 and 574 g – calculated from the energy provided by breastmilk and the WHO reference values for the amount of energy provided by average breastmilk intake by 6–8-month-old infants providing 413 kcal or 1 726 kJ), and of 9–11 month-old infants (providing 379 kcal or 1 584 kJ).[17]<br>These WHO references values were also used by Skau *et al.* (2014)[2] in an estimation of 576 g for 6–8-month-old infants and 541 g for 9–11-month-old infants (with breastmilk energy values of 70 kcal/100 g (293 kJ/100 g) in their calculation of the contribution of breastmilk to use in the Optifood modelling exercise).<br>Six hundred grams (600 g) of breastmilk will provide 396 kcal (or 1655 kJ) (57% of total daily energy), with energy from complementary foods contributing the remaining 297 kcal (or 1242 kJ) to meet total energy needs of 693 kcal (or 2897 kJ) per day. The 2002 WHO Complementary Feeding Summary of Guiding Principles Report references that complementary food should provide about 200 kcal (or 836 kJ) for 6–8-month-old breastfed infants and 300 kcal (or 1254 kJ) for 9–11-month-old breastfed infants.[18]<br>The calculated estimate used in this study falls within these acceptable limits. |

remembered that the modelled diet does not take into consideration the levels of nutrients such as sodium and saturated fat in the diet of infants. Government fortified maize meal, which is widely used in South Africa as a complementary food, only features as a key source of folate for infants in this modelled diet. A report compiled by the South African food

**Table 3:** Consumption details of the 14 food items used in the modelling exercise (x denotes 'times' a week)

| | Food item | Percentage of infants consuming the food item in past 7 days | Most frequent amount consumed | Percentage of infants consuming most frequent amount | Weekly consumption: typical (the upper limit in a range was used) | Weekly consumption: minimum | Weekly consumption: maximum |
|---|---|---|---|---|---|---|---|
| 1 | Soft maize porridge* | 91.00% | 200 ml | 69% | Daily or 7 x a week | 1 x a week | 7.1 x a week |
| 2 | Commercial/ shop bought infant cereal* | 88.10% | 200 ml | 69% | Daily or 7 x a week | 1 x a week | 7.1 x a week |
| 3 | Butternut* | 80.60% | 200 ml | 51% | 2–3 x a week | 1 x a week | 3.1 x a week |
| 4 | Potato* | 77.60% | 200 ml | 44% | 2–3 x a week | 1 x a week | 3.1 x a week |
| 5 | Chips/crisps** | 66.40% | 1 small packet | 74% | 1 x a week | 0.1 x a week | 1.1 x a week |
| 6 | Sweetened yogurt** | 64.90% | 1 small tub | 79% | 2–3 x a week | 1 x a week | 3.1 x a week |
| 7 | Banana** | 63.40% | 1 small banana | 53% | 2–3 x a week | 1 x a week | 3.1 x a week |
| 8 | Hard margarine | 62.70% | 5 ml | 74% | Daily or 7x a week | 1 x a week | 7.1 x a week |
| 9 | Sugar | 56.00% | 5 ml | 65% | Daily or 7x a week | 1 x a week | 7.1 x a week |
| 10 | Boiled egg | 55.20% | 1 egg | 95% | 2–3 x a week | 1 x a week | 3.1 x a week |
| 11 | Peanut butter | 54.50% | 5 ml | 67% | daily or 7x a week | 1 x a week | 7.1 x a week |
| 12 | Biscuits** | 52.20% | 1½ biscuits | 83% | 1 x a week | 0.1 x a week | 1.1 x a week |
| 13 | Chicken | 46.30% | ¼ cup | 37% | 2–3 x a week | 1 x a week | 3.1 x a week |
| 14 | Polony/ viennas | 42.50% | 1 vienna | 70% | 2–3 x a week | 1 x a week | 3.1 x a week |

Footnote:
*Designated as a starchy staple in Optifood analysis.
**Designated as a snack in Optifood analysis.

fortification programme attributed the reduction of neural tube defects in South Africa to food fortification with folic acid.[19]

## Discussion

According to the best diets modelled by Optifood, it appears that infants in KwaMashu would be able to achieve adequate energy, protein and micronutrient intakes for 8 of the 11 micronutrients, as long as breastfeeding on demand continues during the complementary feeding phase. Although foods consumed in the diets of infants in other countries are very different from those consumed by infants in KwaMashu, iron, zinc and calcium were also identified as problem nutrients by Optifood modelling exercises conducted in countries such as Cambodia, Ghana, Guatemala, Indonesia, Kenya and Myanmar.[2–10]

**Table 4:** Food group level input required for the modelling exercise

| Food group and subgroup | Foods in each group | Low servings/ week | Average servings/week | High servings/ week |
|---|---|---|---|---|
| Added fats: margarine, fortified | Margarine | 1 | 7 | 7.1 |
| Added sugars: sugar, unfortified | Sugar | 1 | 7 | 7.1 |
| Bakery and breakfast cereals: sweetened bakery product, unfortified | Biscuits | 0.1 | 1 | 1.1 |
| Breastmilk | | 6.9 | 7 | 7.1 |
| Dairy product: yogurt | Sweetened yogurt | 1 | 3 | 3.1 |
| Fruit | Banana | 1 | 3 | 3.1 |
| Grain and grain products: fortified products | Soft maize porridge<br>Commercial infant cereal | 2 | 14 | 14.2 |
| Legumes, nuts and seeds: sweetened product | Peanut butter | 1 | 7 | 7.1 |
| Meat fish and eggs: Eggs, Poultry or Processed meat | | 3 | 9 | 9.3 |
| | Boiled egg | 1 | 3 | 3.1 |
| | Chicken | 1 | 3 | 3.1 |
| | Polony/viennas | 1 | 3 | 3.1 |
| Savoury snacks: Savoury snacks | Chips/crisps | 0.1 | 1 | 1.1 |
| Starchy roots and other starchy veg: Starchy plant foods | Butternut/potato | 2 | 6 | 6.2 |
| Snacks | | 3 | 9 | 9.3 |
| Staples | | 2 | 14 | 14.2 |

**Table 5:** Source of food quantities information and food composition data

| No. | Food item | Most frequent amount consumed (in grams) | Source of food quantities information | Source of food composition data and rationale when country data not used |
|---|---|---|---|---|
| 1 | Soft maize porridge | 200 g | SA FQM[13] – footnote (a) | SA FCT[14] – footnote (b) |
| 2 | Commercial infant cereal | 246 g | Weighed | Calculated – footnote (c) |
| 3 | Butternut | 168 g | SA FQM | SA FCT |
| 4 | Potato | 200 g | SA FQM | SA FCT |
| 5 | Chips/crisps | 14 g | Product label | SA FCT |
| 6 | Sweetened yogurt | 100 g | Product label | Product label – footnote (d) |
| 7 | Banana | 25 g | SA FQM | SA FCT |
| 8 | Hard margarine | 5 g | SA FQM | Product label – footnote (e) |
| 9 | Sugar | 4 g | SA FQM | SA FCT |
| 10 | Boiled egg | 50 g | SA FQM | SA FCT |
| 11 | Peanut butter | 5 g | SA FQM | SA FCT |
| 12 | Biscuits | 9 g | Product label | SA FCT |
| 13 | Chicken | 55 g | SA FQM | SA FCT |
| 14 | Polony/viennas | 42 g | Product label | Product label – footnote (f) |

Footnotes:
[a]SA FQM is the South African Food Quantities Manual.[13]
[b]SA FCT is the South African Food Composition Tables.[14]
[c]The 'as consumed' data for the infant cereal was calculated as only the 'as sold' data was available in the SA FCT.
[d]The yogurt categories have changed,[20] the small-tub yogurt is now a medium-fat yogurt and not a low-fat yogurt as published in the SA FCT.
[e]The margarine formulation has changed,[21] and the fat content in the market products is different from that in the SA FCT.
[f]There is large discrepancy in the fat and energy content in the SA FCT versus product label data for these processed meats in the market, which is probably due to salt reduction legislation[22] (and resultant product reformulation).

A recent GAIN/UNICEF nutrient gap assessment of 6–23-month-old infants in South Africa found best evidence for vitamin A and calcium to be nutrients of concern, but the iron and zinc gap burden was found to be low (this was based on moderate certainty evidence for iron and low certainty evidence for zinc).[23] The GAIN/UNICEF brief called for more quality data on those micronutrients for which conclusions were based on low certainty evidence. The GAIN gap analysis was based on various pooled data and it is possible that infants in different areas in South Africa have different challenges in meeting the requirements for different nutrients. Butternut availability in KwaMashu is usually seasonal and consequently infants residing

**Table 6:** Number of servings of each food in the 'two best diets'

| Food | Serving size (grams) | Food pattern (#servings per week) | No food pattern (#servings per week) |
|---|---|---|---|
| Banana | 25 | 3 | 1.8 |
| Sugar | 4 | 7 | 1 |
| Sweetened yogurt | 100 | 3 | 1 |
| Hard margarine | 5 | 7 | 1 |
| Chips/crisps | 14 | 1 | 0.1 |
| Biscuits | 9 | 1 | 0.1 |
| Butternut | 168 | 3.1 | 1 |
| Potato | 200 | 1 | 1 |
| Boiled egg | 50 | 1 | 1 |
| Chicken | 55 | 1 | 3.1 |
| Polony/ viennas | 42 | 2.7 | 1 |
| Commercial infant cereal | 246 | 1 | 4.3 |
| Soft maize porridge | 200 | 1 | 1 |
| Peanut butter | 5 | 7 | 1 |
| Breastmilk | 600 | 6.9 | 6.9 |

**Table 7:** Energy and nutrient content of the two best diets that had been modelled and %RNI

| Nutrient | Food pattern | No food pattern | Food pattern (%RNI) | No food pattern (%RNI) |
|---|---|---|---|---|
| Energy (kcal) | 693 | 693 | 100 | 100 |
| Protein (g) | 16.8 | 21.9 | 164 | 213.6 |
| Fat (g) | 34.1 | 30.1 | N/A | N/A |
| Carbohydrate (g) | 76.6 | 81.3 | N/A | N/A |
| Calcium (mg) | 308.1 | 403.3 | 77 | 100.8 |
| Vitamin C (mg) | 40.1 | 60.4 | 133.8 | 201.4 |
| Thiamine (mg) | 0.4 | 0.6 | 129.7 | 182.2 |
| Riboflavin (mg) | 0.4 | 0.5 | 108 | 115.6 |
| Niacin (mg) | 5.2 | 5.1 | 130.3 | 127.4 |
| Vitamin $B_6$ (mg) | 0.4 | 0.4 | 150.6 | 135.8 |
| Folate (µg) | 97.3 | 95 | 121.6 | 118.8 |
| Vitamin $B_{12}$ (µg) | 1 | 1.1 | 145.2 | 156.6 |
| Vitamin A RE (µg) | 649.7 | 584.9 | 162.4 | 146.2 |
| Iron (mg) | 2.4 | 5.2 | 25.2 | 55.6 |
| Zinc (mg) | 2.1 | 2.7 | 51.3 | 65.6 |

**Table 8:** Top three food sources of each nutrient

| Nutrient | Food source 1 | Food source 2 | Food source 3 |
|---|---|---|---|
| Energy | Breastmilk | Butternut | Infant cereal |
| Protein | Breastmilk | Chicken | Peanut butter |
| Fat | Breastmilk | Margarine | Peanut butter |
| Carbohydrate | Breastmilk | Butternut | Infant cereal |
| Calcium | Breastmilk | Yogurt | Infant cereal |
| Vitamin C | Breastmilk | Infant cereal | Potato |
| Thiamine | Breastmilk | Infant cereal | Margarine |
| Riboflavin | Breastmilk | Yogurt | Margarine |
| Niacin | Breastmilk | Peanut butter | Chicken; margarine |
| Vitamin $B_6$ | Butternut | Margarine | Processed meat |
| Folate | Breastmilk | Margarine | Maize meal |
| Vitamin $B_{12}$ | Breastmilk | Yogurt | Eggs |
| Vitamin A RE | Breastmilk | Butternut | Infant cereal |
| Iron | Infant cereal | Processed meats | Butternut |
| Zinc | Breastmilk | Chicken | Butternut |

in KwaMashu could experience challenges in meeting their Vitamin A needs if this food is left out of their diets. The affordability of fortified infant cereal at different times of the month and the year could also impact on micronutrient intakes. Nutrient intakes will also be negatively impacted by suboptimal breastfeeding practices.

When the low absolute amount of iron and zinc in the modelled two best diets is considered, it is probable that the intake of these micronutrients will still remain lower than recommendations, even when compared with lower revised recommendations for diets based on foods that have a higher bioavailability.

The results from this study emphasise the continued promotion of breastfeeding alongside nutrient-dense complementary foods such as fortified infant cereal and adding fortified margarine to foods being consumed. Food-based strategies and their communication need to be relevant and based on the actual food consumption and availability in a community, and not a generic message. Nutrition communication should also discourage infant consumption of unhealthy options, such as processed meats and chips, found regularly consumed by infants in this study. Healthier affordable options should be promoted.

GAIN/UNICEF have highlighted chicken, fish, peanut butter, dried beans, beef liver, chicken liver, carrots and milk as the most affordable foods to fill nutrient gaps in the diets of children.[24] These are all foods that were being consumed by some infants in this study. It may be that while households purchased these nutritious food items, the quantity that is consumed is not adequate to meet infant needs, due to lack of knowledge or food insecurity, or both, or that these foods may not be available throughout the month or year. Attention to making nutritious foods more affordable in South Africa is warranted, but GAIN/UNICEF emphasise that even with price reductions, 20–35% of households would still be unable to afford the foods they need to be able to feed their children a diet meeting all nutrient requirements.[24]

A 2019 Cochrane review[25] on the value of animal-source foods for growth and development of infants found limited quality evidence and some uncertainty regarding the impact of animal-source foods when compared with cereal products or no intervention. Nevertheless, in this study, animal-source foods were an important contributor to nutrient intakes in infants' diets in KwaMashu. An IFPRI report[26] highlighted the fact that animal-source food energy derived from eggs and dairy products is relatively more expensive than food energy obtained from other animal-source foods, which may restrict their consumption. Consequently, these foods are most sensitive to prices impacting on their consumption.[26] This IFPRI report also suggests that promoting household production of animal-source foods is likely to not have an impact on intakes, as these foods are valued for the high prices they can generate if they are sold. Research has been conducted on the addition of South African green leafy vegetables to maize meal, which showed that regular consumption could contribute to iron intakes.[27]

If it holds true that the problem nutrients identified in this study are also difficult to achieve in other infant diets, it would give direction to product formulation for infants and for biofortification of foods with iron, zinc and calcium. Promising research on potatoes biofortified with zinc and iron has been conducted, with bioavailability studies currently under way.[28] Targeted fortification and supplementation of infants, e.g. with micronutrient sprinkles containing specific nutrients, appear to be the more pressing option to be considered alongside food-based strategies that include the promotion of breastfeeding.

The output from data modelling is only as useful as the consideration given to the input parameters. The nature of this type of exercise requires deliberated decisions on a number of input parameters, each of which relies on logical and substantiated decision-making. While due care and deliberation has gone into this exercise, it is plausible that the errors in selection of each of the parameters affects the results presented here. These results are applicable only to infants residing in KwaMashu and are based on a relatively small sample of respondents, without consideration of monthly or seasonal variation in intake and types of foods consumed by infants. One key assumption which was made in the estimation of nutrient composition of foods in this study was that they were prepared in such a way that the products had the appropriate consistency and were not overdiluted.

One of the limitations experienced with the use of Optifood was the inflexibility in real-time manipulation and not being able to customise the output in any way. Nevertheless, with training Optifood is easy to use and it facilitates quick assessments and produces results that are easy to export for further analysis. With the availability of this type of software, further testing using infant food consumption information from other regions in South Africa should be conducted to obtain a better picture of nutrients of concern in infants. It would also be useful to assess the diets of other age groups in South Africa using recently published national data.

## Conclusion

The results from the modelling exercise reveal that the current food pattern of infants from the study group in KwaMashu, identified iron, zinc and calcium as the nutrients whose requirements are likely not to be met in the diet of these infants (nutrients of concern). This study calls into question the continued food-based focus to ensure nutrient adequacy in infants. Together with efforts to improve household food security and the continued support and promotion of breastfeeding for the first two years of life, other targeted interventions such as micronutrient supplementation may be needed to ensure the optimal growth and development of infants in South Africa. The availability of new software for analysis in the field of nutrition such as Optifood heralds an exciting phase in research and more should be done to train individuals in the use of these tools. In addition, these tools should be made available globally at no/low cost.

## Disclosure of interest

No potential conflict of interest was reported by the authors.

## Author contributions

The first author was a PhD student and the second author the PhD supervisor. The first author conceptualised and designed the study, led the data collection, performed the data analysis and drafted the manuscript. The second author gave input into the study, checked all results and edited the manuscript. Both authors reviewed and approved the manuscript for submission.

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