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Development of Affordable, Nutrient-Dense Complementary Foods Using Indigenous Ingredients for Children Aged 6–24 Months

Harsha Choube
School of of Humanities & Social Sciences Sabarmati University, Ahmedabad, Gujrat, India

Corresponding Author; **Harsha Choube**

Abstract
The period from 6 to 24 months is critical for child growth and development because breast milk alone becomes insufficient to meet the increasing nutritional requirements of infants and young children. In many low- and middle-income communities, complementary diets are dominated by cereal-based foods and are frequently inadequate in energy, protein, fat, iron, zinc, calcium, vitamin A, and other essential micronutrients. The high cost of commercially formulated complementary foods further limits their accessibility to economically vulnerable households. The present study proposes the development of affordable, nutrient-dense complementary foods using locally available indigenous ingredients such as cereals, legumes, oilseeds, fruits, vegetables, and other appropriate nutrient-rich foods. Selected ingredients would be processed through cleaning, roasting, milling, blending, and appropriate cooking or drying techniques to improve nutritional quality, digestibility, acceptability, and storage stability. Different formulations would be developed by combining complementary plant ingredients to improve protein quality and increase energy and micronutrient density. The formulations would be evaluated for proximate composition, selected micronutrients, energy value, functional properties, microbiological safety, sensory acceptability, shelf stability, and cost per serving. Previous research indicates that locally produced complementary foods can improve dietary quality, while recent evidence demonstrates the feasibility of developing nutrient-dense infant foods from indigenous ingredients. The proposed approach could provide a culturally acceptable and economically feasible alternative to expensive commercial complementary foods and contribute to improved infant and young-child nutrition.

Keyword: Complementary Feeding, Indigenous Ingredients, Nutrient Density, Infants, Young Children, Affordable Foods, Dietary Diversity, Malnutrition, Local Foods, 6–24 Months

Introduction

Complementary feeding refers to the introduction of foods and liquids in addition to breast milk when breast milk alone can no longer satisfy the nutritional requirements of the growing infant. The World Health Organization recommends that complementary foods be introduced at approximately 6 months while breastfeeding continues. The period from 6 to 23 months represents a particularly important window for preventing growth faltering, micronutrient deficiencies, and other forms of malnutrition.

During this period, children require foods with relatively high nutrient density because their stomach capacity is limited while their requirements for energy and essential nutrients increase rapidly. Complementary foods therefore need to provide adequate energy, protein, essential fatty acids, iron, zinc, calcium, vitamin A, folate, and other micronutrients. Evidence shows that inadequate dietary diversity and poor nutrient density remain important challenges in many developing countries.

In low-resource communities, cereal-based porridges are commonly used as complementary foods because cereals are inexpensive, familiar, and readily available. However, cereal-based foods alone may have insufficient protein quality and inadequate amounts of certain micronutrients. Research on complementary foods has demonstrated deficiencies in energy, protein, fat, and calcium in commonly consumed preparations, emphasizing the need to improve the nutritional composition of traditional complementary foods.

Affordability is another major challenge. Evidence from South Asia indicates that although several affordable sources of vitamin A and folate are available, affordable sources of some nutrients, particularly zinc, remain limited. Strategies involving locally available foods, household production, food processing, and improved dietary combinations may therefore help reduce the economic barriers to nutrient-adequate complementary feeding.

Indigenous foods offer an important opportunity in this context. Cereals can provide energy; legumes can increase protein; oilseeds can supply protein and healthy fats; vegetables and fruits can contribute vitamins, minerals, and bioactive compounds; and appropriate animal-source foods can provide highly bioavailable nutrients where culturally and economically feasible. A recent 2026 study demonstrated that complementary foods formulated from indigenous ingredients such as rice, carrots, soybeans, peanuts, cowpeas, and milk powder could achieve substantial protein, fat, iron, calcium, and vitamin A content while maintaining acceptable sensory and functional properties.

Consequently, development of affordable complementary foods based on indigenous ingredients represents a promising food-based strategy for improving dietary adequacy among children aged 6–24 months.

Problem Statement

Poor-quality complementary feeding remains a major nutritional concern in many low- and middle-income settings. Families with limited economic resources frequently depend on inexpensive cereal-based preparations that may not provide adequate amounts of protein, fat, iron, zinc, calcium, and vitamin A. Commercial complementary foods may offer improved nutrient density but can be unaffordable for many households.

The central problem addressed by this research is therefore the lack of low-cost, culturally acceptable, nutrient-dense complementary food formulations prepared from locally available indigenous ingredients.

Rationale of the Study

The study is based on five major considerations:

Nutritional need: Children aged 6–24 months have high nutrient requirements relative to their small stomach capacity.

Economic accessibility: Commercial complementary foods may be financially inaccessible to low-income households.

Local availability: Indigenous cereals, pulses, legumes, oilseeds, fruits, and vegetables can often be obtained locally.

Cultural acceptability: Foods based on familiar local ingredients are more likely to be accepted by caregivers and children.

Sustainability: Local production can reduce dependence on expensive imported or commercially processed foods.

Food-based complementary-feeding interventions have been identified as potentially sustainable approaches for addressing nutrient deficiencies during this vulnerable developmental period.

Research Hypotheses

$H_0 1$: There is no significant difference in the nutritional composition of complementary foods developed using different indigenous ingredient combinations.

$H_1 1$: There is a significant difference in the nutritional composition of complementary foods developed using different indigenous ingredient combinations.

$H_0 2$: There is no significant difference in sensory acceptability among the developed complementary food formulations.

$H_1 2$: There is a significant difference in sensory acceptability among the developed complementary food formulations.

$H_0 3$: The incorporation of legumes and oilseeds does not significantly improve the nutrient density of cereal-based complementary foods.

$H_1 3$: The incorporation of legumes and oilseeds significantly improves the nutrient density of cereal-based complementary foods.

Materials and Methods

Research Design

An experimental food-development design will be employed. Several complementary food formulations will be prepared using different proportions of selected indigenous ingredients. A cereal-based formulation may be used as the control, while experimental formulations will contain combinations of cereals with legumes, oilseeds, vegetables, and/or fruits.

Selection of Indigenous Ingredients

Ingredients should be selected according to:

- Local availability;
- Affordability;
- Nutritional value;
- Seasonal accessibility;
- Cultural acceptability;
- Ease of processing;
- Digestibility;
- Food safety;
- Storage characteristics.

Potential ingredient categories include:

Ingredient group	Examples	Major contribution
Cereals	Rice, maize, millet, sorghum	Energy, carbohydrate
Legumes	Lentils, chickpeas, cowpeas, beans, soybean	Protein, iron, folate
Oilseeds	Sesame, groundnut, sunflower seed	Fat, protein, energy
Vegetables	Carrot, pumpkin, leafy vegetables	Vitamin A, minerals, fibre
Fruits	Banana, mango, papaya	Vitamin A, vitamin C, carbohydrate
Animal-source foods, where culturally appropriate	Egg, fish, milk	Protein, iron, zinc, vitamin B12
Healthy fats	Vegetable oils	Energy and essential fatty acids

Ingredient selection should be adapted to the geographical study area

Processing of Ingredients

The selected raw materials will be sorted and cleaned to remove foreign materials and damaged grains or seeds. Depending on the ingredient, processing may include washing, soaking, germination, roasting, drying, dehulling, milling, or cooking.

Roasting and germination may be considered because appropriate processing can improve flavour, digestibility, and functional characteristics while reducing some antinutritional factors. However, processing conditions should be standardized so that excessive heat does not unnecessarily reduce heat-sensitive nutrients.

The processed ingredients will be milled separately and passed through an appropriate sieve. The resulting flours will be stored in clean, airtight food-grade containers until formulation.

Development of Complementary Food Formulations

Different formulations may be prepared by varying the proportions of cereals, legumes, oilseeds, and micronutrient-rich plant ingredients.

A conceptual formulation design is presented below

Formulation	Cereal	Legume	Oilseed	Vegetable/Fruit component
F0 – Control	High	—	—	—
F1	High	Moderate	Low	Low
F2	Moderate	Moderate	Moderate	Low
F3	Moderate	High	Moderate	Moderate
F4	Moderate	Moderate	High	Moderate

The exact proportions should be determined using nutrient-composition data and dietary requirements rather than arbitrarily assigned.

Nutritional Analysis

The developed formulations will be analysed for

- Moisture;
- Crude protein;
- Crude fat;
- Crude fibre;
- Ash;
- Carbohydrate;
- Energy;
- Iron;
- Calcium;
- Zinc;
- Vitamin A or carotenoid equivalents;

Selected B-group vitamins where resources permit.

Standard analytical procedures such as those of AOAC or validated national/international laboratory methods should be used.

The energy value may be estimated using Atwater conversion factors where appropriate.

Protein Quality

Protein quality is an important consideration when predominantly plant-based ingredients are used. Cereals and legumes should therefore be combined strategically because their amino-acid profiles can complement one another.

For example, cereal proteins tend to be relatively limited in lysine, whereas legumes generally provide more lysine. Appropriate cereal–legume combinations can therefore improve the overall amino-acid balance of the formulation.

Functional Properties

- The formulations may be evaluated for:
- Bulk density;
- Water absorption capacity;
- Water solubility;
- Dispersibility;
- Viscosity;
- Swelling capacity;
- Reconstitution characteristics.

These properties are particularly important for complementary foods because excessive viscosity can limit the amount of energy and nutrients that a young child can consume in a small volume.

Sensory Evaluation

Sensory acceptability should be assessed using an appropriate caregiver/food sensory panel and a validated hedonic scale where ethically and methodologically appropriate.

The following characteristics may be evaluated:

- Colour;
- Aroma;
- Taste;
- Texture;
- Mouthfeel;
- Consistency;
- Overall acceptability.

Because the products are intended for young children, sensory evaluation should be designed carefully and should not expose infants to unsafe foods or procedures.

Microbiological Analysis

Microbiological safety is essential for complementary foods. Samples should be tested for appropriate indicators and pathogens according to applicable food-safety standards.

- Possible analyses include:
- Total viable count;
- Yeast and mould;
- Coliforms;
- Escherichia coli;
- Salmonella spp.;

Other relevant pathogens according to local regulatory requirements.

Recent research on indigenous complementary-food formulations has demonstrated the importance of combining nutritional evaluation with microbiological safety assessment; one 2026 formulation study reported acceptable microbial stability and absence of tested major pathogens.

Shelf-Life Study

The developed formulations should be packed in suitable moisture- and oxygen-resistant packaging and stored under controlled conditions.

Samples may be evaluated periodically for:

- Moisture;
- Rancidity;
- Microbial growth;
- Sensory changes;
- Colour changes;
- Nutrient retention;
- Packaging integrity.
- The storage period should be determined experimentally rather than assumed.

Cost Analysis

- Affordability will be evaluated by calculating the cost of:
- Raw ingredients;
- Processing;
- Packaging;
- Labour;
- Energy;

- Transportation;
- Storage.
- The cost per 100 g and cost per serving will then be calculated.
- A useful indicator will be:

Cost per serving = Total production cost ÷ Number of servings produced

The developed formulation may subsequently be compared with locally available commercial complementary foods.

Statistical Analysis

- Data will be expressed as mean ± standard deviation where appropriate. Statistical analysis may include:
- One-way analysis of variance (ANOVA);
- Tukey's or another appropriate post-hoc test;
- descriptive statistics;
- correlation analysis where relevant.
- Statistical significance may be established at $p < 0.05$.

Expected Results

The study is expected to demonstrate that appropriately selected combinations of indigenous ingredients can improve the nutritional quality of traditional cereal-based complementary foods.

The formulations containing a combination of cereals, legumes, and oilseeds are expected to show improved protein and energy density compared with cereal-only formulations. Addition of vegetables and fruits may improve carotenoid, vitamin C, folate, and mineral contributions.

A successful formulation is expected to demonstrate:

- Improved protein content;
- Adequate energy density;
- Improved fat content;
- Increased mineral contribution;
- Acceptable consistency;
- Good sensory acceptability;
- Microbiological safety;
- Satisfactory storage stability;

Lower or competitive cost compared with commercial alternatives

Recent experimental evidence supports the feasibility of this approach. A 2026 study using indigenous ingredients developed formulations with substantial protein, fat, iron, calcium, and vitamin A levels and reported good functional and sensory characteristics.

Discussion

The development of complementary foods from indigenous ingredients addresses both nutritional and socioeconomic dimensions of child nutrition. During the complementary-feeding period, children have high nutrient requirements but limited gastric capacity. Therefore, simply increasing the quantity of food is insufficient; the nutrient density and diversity of the diet must also be improved.

Cereal-based complementary foods are inexpensive and widely accepted but may provide inadequate amounts of some nutrients. Combining cereals with legumes and oilseeds provides a practical method for increasing protein and energy density. Additional nutrient-rich ingredients can help address micronutrient gaps.

Evidence from South Asia indicates that affordability of nutritious foods varies substantially by nutrient and food category. Vitamin A-rich vegetables and dark green leafy vegetables can be relatively affordable, whereas some nutrients, particularly zinc, remain difficult to obtain from inexpensive plant foods alone. Therefore, complementary-food formulation should focus not merely on total calories or protein but on the overall nutrient profile.

The use of indigenous ingredients can also strengthen food-system resilience. Local ingredients are generally more familiar to households and may be easier to obtain than imported commercial products. However, indigenous formulations should not automatically be considered nutritionally adequate. Plant-based complementary foods may remain insufficient in highly bioavailable iron, zinc, calcium, vitamin B12, and other nutrients unless carefully formulated or appropriately fortified.

Dietary diversity is also important. Evidence indicates that interventions involving fortified blended foods, locally produced complementary foods, and other nutrient-dense approaches can improve nutritional outcomes during complementary feeding.

Thus, the most effective formulation should combine affordability, nutrient density, safety, digestibility, sensory acceptability, and cultural suitability rather than optimizing a single nutritional parameter.

- **Food and Nutrition Programmes:** The findings could inform community-based complementary-feeding interventions.
- **Researchers:** The study can provide a basis for further investigations into nutrient composition, bioavailability, processing, acceptability, and shelf stability of indigenous complementary foods.
- **Policy Makers:** Evidence on affordable locally produced complementary foods may support food-based nutrition strategies.

Ethical Considerations

If the study involves infants or young children, ethical approval should be obtained from the appropriate institutional ethics committee before recruitment or feeding trials. Written informed consent should be obtained from parents or legally authorized caregivers.

Food safety must be established before any product is offered to children. Particular attention should be given to allergenic ingredients, choking hazards, contamination, hygiene, and age-appropriate food texture.

The developed product should be considered a complementary food and not a replacement for breastfeeding. WHO guidance should be followed when designing feeding interventions for children 6–23 months.

Conclusion

The development of affordable complementary foods using indigenous ingredients represents a promising food-based approach to improving the nutritional quality of diets among children aged 6–24 months. Strategic combinations of cereals, legumes, oilseeds, fruits, vegetables, and, where appropriate, animal-source foods can increase nutrient density while maintaining affordability and cultural acceptability.

The success of such products should be evaluated comprehensively through nutritional, functional, sensory, microbiological, shelf-life, and economic assessments. Importantly, affordability alone should not be the principal criterion; the formulation must also provide meaningful amounts of essential nutrients in a safe and age-appropriate form.

The proposed research could therefore contribute to the development of locally appropriate complementary foods capable of supporting improved dietary diversity and nutrient intake among infants and young children, particularly in resource-constrained communities.

Recommendations

Based on the proposed research framework, the following recommendations are made:

- Local cereals should be combined with legumes or other complementary protein sources to improve protein quality.
- Oilseeds or appropriate edible oils should be considered to increase energy density.
- Locally available fruits and vegetables should be incorporated to improve micronutrient diversity.
- Processing methods such as roasting, soaking, germination, and cooking should be optimized rather than applied indiscriminately.
- Nutrient composition should be verified through laboratory analysis.
- Microbiological safety should be established before products are recommended for infant feeding.
- Cost per serving should be included as a core outcome of product development.
- Products should undergo sensory and caregiver acceptability testing.
- Shelf-life studies should be conducted under realistic household storage conditions.
- Further studies should evaluate nutrient bioavailability and, where ethically justified, the effectiveness of the developed food in improving dietary adequacy or nutritional status.

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