Formulation and Sensory Evaluation of Complementary Foods from Low-Cost, Locally-Available and Nutrient-Dense Ingredients using Linear Programming

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Abstract

Meeting energy and micronutrient requirements during complementary feeding period especially in developing countries is limited by many factors one of them being poverty. This study was carried out in Rombo district, Kilimanjaro region with the aim of developing low-cost complementary foods using locally available ingredients by linear programming. Frequently used complementary foods and their ingredients were identified by using 24-hour dietary-recall questionnaire. Market and field survey was done to identify available ingredients and their monetary values. Linear programming was used to identify the cheapest possible combination of food ingredients that meet a set of nutritional requirements. Data was analysed by one-way analysis of variance (ANOVA) model using R software (Ri386) version 3.3.1. Means and standard deviations were calculated for acceptability of the sensory attributes of the complementary foods and for categorical variables frequencies and percentages were used. Seven recipes (banana puree with either minced beef, fish, pumpkins or milk as well as maize and composite flour porridges) were developed, prepared and then subjected to sensory evaluation using 5-point Likert scale. Banana porridge with minced beef was highly acceptable. There was no significant difference in terms of acceptability between banana porridge with fish, maize porridge, composite flour porridge and banana porridge with pumpkins. Banana porridge with milk had the least score. Linear programming was found to be a good method to improve nutrient content of complementary foods using low cost, locally available and culturally acceptable ingredients.

Keywords: Complementary foods, linear programming, formulation, sensory attributes

Introduction

Under nutrition among children aged 0-5 years has been a significant health problem in many developing countries including Tanzania. It is an impediment to global poverty eradication, productivity and economic growth (Dukhi, 2020). According to World Health Organization (2020), about 47 million children under 5 years of age are wasted, 14.3 million are severely wasted and 144 million are stunted globally. In Tanzania, about 31.8% of children under five years of age are stunted, 3.5% are wasted and 14.6% are underweight (TNNS, 2018).

Several efforts have been taken by the government of Tanzania to protect a child's health and these include antenatal care, care during childbirth, care of obstetric emergencies, new born care, postpartum care as well as formulation of various nutrition-related policies such as agriculture policy, food and nutrition policy. Other steps taken to improve nutrition in Tanzania include integration of nutrition-related activities in other sectors, supporting nutrition related researches as well the presence of the Ministry of Health, Community Development, Gender, Elderly and Children (MoHSW, 2007; TFNC, 2014).

Direct measures that have been taken to fight malnutrition include universal fortification in salt with iodine and cooking oils with vitamin A, iron as well as vitamin A supplementation to children, immunization, promotion of home gardening and keeping small animals provision of nutrition education specifically during prenatal and growth monitoring clinic visits (TDHS-MIS, 2016). Food fortification and supplementation may be effective in reducing the levels of under nutrition but they are questionable in terms of sustainability (Heidkamp *et al.,* 2021).

During the first six months of a child's life, breast milk alone can satisfy all the nutritional needs. From the age of six months, an infant's need for energy and nutrients starts to exceed what is provided by breast milk, and complementary feeding becomes necessary to fill the energy and nutrients' gap (Dewey, 2003). Several studies conducted in Tanzania reported low energy and nutrient contents in complementary foods (Muhimbula *et al.,* 2011, Kulwa, *et al.,* 2015). Despite the presence of so many complementary food formulations in Tanzania, most of them do not meet the recommended dietary allowance for a child (Muhimbula *et. al.,* 2011; Ogbo, *et. al.,* 2018).

Linear programming is a powerful approach for identifying and formulating low-cost, locally available, culturally acceptable and nutritionally adequate diets avoiding a "trial and error" approach (Briend *et al.,* 2001; Dibari *et al.,* 2012). It is an algorithm for maximising or minimising a given (linear) objective function subject to a set of linear constraints on a list of decision variables (Parlesak *et al.,* 2016). In complementary food formulations, linear programming helps to find the lowest-cost mix to fulfil a set of nutritional requirements (Calvalho *et al.,* 2015). This study was carried out with the aim of developing low-cost complementary foods using locally available ingredients by linear programming method.

Methodology

Study area

This study was conducted in Rombo district in Kilimanjaro Region, Tanzania. This district was selected by simple random sampling. The district receives annual rainfall ranging from 500 to 1000 mm per annum and the mean monthly temperature is 22–26°C with maximum temperatures of 35°C. The main economic activity practiced in Rombo District is agriculture. This carries about 90% of the total activities while 7% of the residents are doing small businesses and 3% are the employed workers (Rombo DC Profile, 2013). The common food crops include banana, maize, sorghum, sweet potatoes, cassava legumes, fruits and vegetables; whereas the main cash crop is coffee. Most of the residents in the study area consume banana, grain and legume-based foods.

Study design and sample size

The study adopted a cross-sectional research design where data was collected at one point in time. The study subjects were mothers/caregivers and their children aged 6 to 23 months. The study subjects were selected by simple random sampling method using a table of random numbers. Children who were under special nutritional therapies and those with medical disorders or chronic health conditions were excluded from the study. The sample size was obtained using the prevalence formular whereby the stunting prevalence (18.3%) for children less than 5 years in Kilimanjaro region (TFNC, 2014) was used. This formula was adopted from SMART (2012) and a total of 230 respondents were involved in this study.

Data collection

The questionnaire for data collection had both open and close ended questions divided in three sections. Section A was about social and demographic characteristics of the mother/ caregiver. Section B inquired information on the frequently used complementary foods while section C covered 24-hour dietary recall. The questionnaires were administered through face-to- face interview. Market survey was also done to identify what was available in the market and their unit price. The foods were recorded based on their names, measurement units, weight, price and place they were obtained (Table 3)

Step 1: Generation of the list of locally available foods

A list of locally available foods both processed, unprocessed or semi-processed was generated from the questionnaires, market survey and opportunistic observation of what was available in the farms and retail shops as well as data from the 24-hour dietary recall.

Step 2: Price of food ingredients

The prices for food ingredients were collected from Tarakea, Kikelelwa and Usseri markets, butcheries, retail shops and from the street vendors. If some of the foods were sold per item (for example 3 bananas for 200 or 5 fish for 1000), they were weighed on-site and the average weight (kg) was used to calculate the price. For the foods with price range (same product but different prices) based on the market/seller, the lowest price was selected. Also, all the processing costs, such as washing, milling, drying, sieving and grinding were included in the ingredient cost.

Step 3: Nutritional composition of the selected foods

Both Tanzania food composition table (Lukmanji *et al.,* 2008) and Nutri Survey databases (MOH, 2007) were used to obtain food composition values. The values given by NutriSurvey during the formulation of recipes were compared with that of Tanzania food composition tables to see if there is a difference in nutrients composition. The values for prepared (cooked, baked, boiled, roasted and simmered) foods were used where appropriate (For example the energy value of raw rice is higher than that of cooked rice) (MOH, 1992).

Step 4: Recipe development

Linear Programming Module of Nutri-Survey was used to identify the cheapest possible combination of food ingredients that meet a set of nutritional requirements based on the age of the child taking into account safety, amount consumed, cultural acceptability and the sensory attributes (WHO, 2001; Dibari *et al.,* 2012). Seven complementary food recipes were designed by using linear programming module of NutriSurvey (2004) and each food was characterised by its price and its nutrient content taking into account maximum and minimum values. The decision variables were whether a food was selected and at what weight while the objective function was to minimize the total cost of the recipe while improving nutrient contents. The food was considered culturally acceptable and safe if it was within the list generated from local market survey.

Preparation and sensory evaluation of the formulated complementary food recipes

After formulation of seven complementary food recipes by linear programming method, the ingredients were purchased from Tarakea market and local retail shops around the market and transported to the Department of Food Technology, Nutrition and Consumer Sciences laboratory at Sokoine University of Agriculture-Morogoro for processing and sensory evaluation process. The ingredients purchased were bananas, pumpkins, salt, cooking oil, pumpkin seeds, sunflower seeds, sesame seeds, yellow maize, amaranth seeds, baobab flour, amaranth seeds, onions, tomatoes, green peppers, carrots, cowpea leaves, rice, milk, lemons, fish, yellow soya bean and eggs.

In order to reduce anti-nutritional factors and increase digestibility and bioavailability of vitamins, minerals, amino acids and proteins, processes such as boiling, soaking, germination, grinding, milling and peeling were done. Yellow maize (*Zea mays*) were sorted, washed with distilled water and dried in the oven set at 65ºC overnight and then milled into flour. The soya beans (Glycine max) were sorted, poured in boiling water and boiled for 45 minutes, peeled, washed, dried in an oven set at 65ºC overnight, roasted and then milled into flour. Pumpkin, sesame, amaranth and sunflower seeds were sorted, washed and soaked overnight for germination and on the next day they were dried in an oven for six hours, roasted to improve the flavour of the porridge, blended/ground to course flour and then sieved to obtain the fine flour. Bananas and pumpkins were peeled, washed and sliced. Onions, tomatoes, green pepper and tomatoes were washed and sliced into small pieces.

Sensory evaluation

The nine-point hedonic scale (ranging from 1= dislike extremely through 5=neither like nor dislike to 9= like extremely') and five point hedonic scale (5= like extremely, 4 = like moderately, 3 = neither like nor dislike, 2 = dislike moderately and 1 = dislike extremely) developed by Peryam and Pilgrim (1957) were used to measure consumer's responses to the formulated complementary food recipes. The parameters studied included appearance, odour, texture, taste and general acceptability. A total of 102 panellists were used in this study whereby 49 were semi-trained final year undergraduate students of the Department of Food Technology, Nutrition and Consumer Sciences at Sokoine University of Agriculture, Morogoro, Tanzania and 53 were mothers who attended clinic at Tarakea Health Centre, RCH Unit. The use of mothers instead of the target recipients (children) was necessary because of their ability to objectively evaluate the sensory characteristics of the formulations (Muhimbula *et al.,* 2011).

Data analysis

Data were cleaned to adjust for inconsistency, conflicting and implausible responses and carefully subjected to the descriptive analyses using the computer software Statistical Products and Service Solution (SPSS) version 20.0. Means were calculated for continuous variables and for categorical variables frequencies and percentages were used.

For sensory evaluation, data was analysed by the one way analysis of variance (ANOVA) model using R software (Ri386) version 3.3.1 for windows. The means and standard deviations (mean ± standard deviation) were calculated for acceptability of the sensory attributes of the complementary foods. Turkeys Honest Significant Difference (HSD) test was used to determine the significance of mean differences of scores for all the sensory attributes. The level of statistical significance was set at $p<0.05$.

Ethical aspects

The study protocol was approved by the National Institute for Medical Research (NIMR/HQ/R.8a/Vol.IX/2362), Sokoine University of Agriculture and Rombo District Executive Director. Written informed consent was obtained from all mothers/caregivers who took part in this study. All the participants were ensured of confidentiality and autonomy and that the information obtained will not be misused.

Results

Social and demographic characteristics of the study participants

Table 1 shows the socio-demographic characteristics of the 230 mothers/caregivers who met the inclusion criteria and were included in this study. They were from three villages namely Kikelelwa (30.4%), Kibaoni (38.7%) and Urauri (30.9%). Majority of the respondents (62.2%) were aged between 20-35 years at the time of data collection. About 72.6% were married, 63.9% had completed primary school education and 50.9% were involved in agriculture.

Table 1: Socio-demographic characteristics of the study participants

V ariable	Frequency	%
Age of mothers (years)		
<20	31	13.5
20-35	143	62.2
> 36	56	24.3
Marital status		
Single	63	27.4
Married	167	72.6
Education level		
Informal	10	4.3
Primary school	147	63.9
Secondary school	67	29.1
Post-secondary school	6	2.6
Occupation		
Home maker	33	14.3
Agriculture	180	78.3
Employed in formal and informal sectors	17	7.4
Religion		
Christian	196	85.3
Muslim	34	14.8

Types and amounts of frequently used complementary foods

Based on the data collected using 24-hour dietary recall, the types of frequently used complementary foods identified are shown in Table 2. Also, average portion size in grams of each food consumed for the previous 24 hours based on the child's age is shown. The results shown that none of the mothers reported giving vegetables to their children and only few were given fruits

recipes creation obtained from 24-hour dietary recall and market survey are summarized in Table 3. This list includes both frequently and rarely consumed foods selected due to their high nutrient contents. Foods such as carbonated drinks and black tea were frequently mentioned but they were of low nutritive value and for this reason they were excluded from the list. During the interview, most of the mothers reported to give their children beef soup instead of beef (included in the list). Relevant nutrition

Table 2: Types and amount (per day) of complementary foods consumed (Results of 24-hour dietary recall)

Type of food	6-8 months (N=60)		9-11months (N=52)		12-23 months (N=112)	
	n (%)	Amount (g)	n (%)	Amount (g)	n (%)	Amount (g)
Banana puree with beef soup	19(31.7)	97.1	29 (55.8)	177.2	78 (66.1)	165.4
Banana puree with fish soup	12 (20)	126.8	14 (26.9)	117.2	45 (38.1)	148
Banana puree with milk	18 (30)	88.9	24 (46.2)	126.5	43 (36.4)	150.5
Composite flour porridge	21 (35)	147.8	32 (61.5)	257.1	80 (67.8)	319.2
Maize porridge	34(56.7)	171.2	19 (36.5)	236.2	31 (26.3)	319.3
Rice porridge with milk	5 (8.3)	88.4	4 (7.7)	108	18 (15.3)	140.5
Banana puree with pumpkin	2 (3.3)	112	*	*	4 (3.4)	155.5
Banana puree with beans	2 (3.3)	53.5	7 (13.5)	120	5 (4.2)	143.6
Black tea	4 (6.7)	61.75	10 (19.2)	98.3	38 (32.2)	158.1
Ugali with fish stew	1 (1.7)	38	5 (9.6)	50.8	12 (10.2)	110.3
Bread	1 (1.7)	60	*	*	3 (2.5)	48.7
Cow's milk (Fresh milk)	32 (53.3)	141.9	25 (48.1)	200.7	49 (41.5)	233.7
Rice with carrots	*	*	*	*	3 (2.5)	140
Mixed fruits juice	5 (3)	98.6	7 (13.5)	78	14 (11.9)	169.7
Rice with fish soup	1 (1.7)	97	3 (5.8)	71.67	17 (14.4)	119.3
Fruits	3 (5)	143.3	2 (3.8)	41.5	2 (1.7)	53.5
Infant formula	1 (1.7)	40	1 (1.9)	180	*	*
Banana with meat	*	*	*	*	2 (1.7)	134.5

*n=Number of children who consumed the food, %= proportion of children who consumed the food, g = Median portion size consumed based on the child's age, * = none of the children in that age group consumed the food*

Recipe formulation by linear programming method

Selected list of potential ingredients for

information (nutrient content) of each food item was obtained from Tanzania Food Composition Tables (Lukmanji *et al.,* 2008). The price of

each food item (in Tanzanian shillings) is shown in Table 3.

Using Linear Programming Model of Nutri-Survey, seven recipes (banana puree

Table 3: Key food list, price and their nutrient contents

Food	Price (Tshs/ kg)	Mentioned in 24-hour recall	Available in the market	Produced at home	Targeted nutrient
Bananas	900	Frequently	Yes	Yes	Energy, Potassium
Meat (beef)	6500	Frequently	Butchers	Yes	Protein, iron, zinc
Fish	6000	Frequently	Market/ butchers	No	Protein
Milk	2000	Frequently	Yes	Yes	Protein and calcium
Maize	1400	Frequently	Yes	Yes	Carbohydrates
Groundnuts	2000	Frequently	Yes	Yes (Rarely)	Protein
Rice	1800	Frequently	Yes/shops	No	Carbohydrates
Beans (varieties)	2000	Frequently	Yes	Yes	Protein
Pumpkins	1000	Rarely	Yes (Seasonal)	Yes	Carbohydrates and vitamin A
Wheat	1800	Rarely	Yes/shops	No	Carbohydrates
Carrots	1000	Frequently	Yes	Yes	
Tree tomato	1000	No	Yes (Rarely)	Yes	Vitamin A and C
Cherry tomato	500	No	Yes (Rarely)	Yes	Vitamin A and C
Baobab	3000	No	Yes	No	
Bell peppers	2000	No	Yes	Yes (Rarely)	Vitamin A and C
Onions	1500	Frequently	Yes	Yes	Vitamin C
Sunflower seed	1000	No	Yes	Yes	Energy
Amaranth seed	4000	No	Yes	Yes	Energy
Sesame seeds	4000	No	Yes	Yes (Rarely)	Energy
Cassava	1000	No	Yes	Yes	Carbohydrates
Potatoes	1200	Rarely	Yes	Yes	Carbohydrates
Cooking oil	3000	Frequently	Yes/shops	Yes	Fat
Coconut	2000	No	Yes	No	Fat
Citrus fruits	1000	Rarely	Yes	Yes	Vitamin C
Eggs	1600	No	Yes/shops	Yes	Proteins
Pork	5500	No	Butchers	Yes	Zinc
Chicken	8000	No	Yes	Yes	Protein

with minced-beef, fish, pumpkins or milk, rice porridge as well as maize and composite flour porridges) were formulated taking into account the price of the ingredients and nutrition composition (Table 4). Upper and lower acceptable limit of each of the food items were based on the local preparation methods of the frequently used complementary foods as well as estimated portion size (g) from 24-hour recall. Breast milk intake was set between 540 and 550 ml (WHO, 2002) and the price of 100 g for each food was entered. Based on Tanzania food composition tables (Lukmanji *et al.,* 2008), foods with high energy and nutrient content were selected to be added or substituted from the local recipes. Examples of selected ingredients were bananas, beef, fish, sunflower oil, sunflower seeds, sesame seeds, amaranth seeds, pumpkin seeds, carrots, green pepper, onions, tomatoes, baobab flour, pumpkin flesh, soya beans, yellow maize and milk. Built-in linear programming function of Nutri-Survey software (2004), optimized the nutrients while minimizing cost.

Despite the addition of high energy ingredients (such as pumpkin, sunflower, amaranth and sesame seeds) to banana-based complementary foods, it was still difficult to fill the energy gap (the difference between what is recommended by World Health Organization and the actual nutrient content of the recipes) because the portion size was a limiting factor. All maize-based recipes contained adequate energy (894 kcal), whereas banana porridge with milk had the lowest energy content (651.6 kcal (Gap=242.7)). The limiting micronutrients were vitamin A (in banana puree with fish (gap=47µg), maize porridge (gap=4.1 µg) and composite flour porridge (gap=107.4 µg), iron (in banana puree with beef (gap=2.5 mg), banana porridge with fish) (gap=2.9 mg), banana porridge with milk (gap=2.1 mg), banana puree with pumpkin (gap=3.5 mg) and rice porridge with milk (gap=4.6 mg), calcium (banana puree with beef (gap=131.7 mg), maize porridge (gap=126.3 mg), composite flour porridge (gap=103.3 mg), banana puree with pumpkin (gap=205.2 mg) and rice porridge with milk

Table 4: Nutrient content of seven formulations optimized through linear programming for children aged 12-23 months (Breast milk was included to meet RDA)

Formulation	RDA	F1	F2	F3	F4	F5	F6	F7
Amount (g)	-	165.4	148	192	140.79	143	155.5	140
Cost (OR)		458.22	182.5	481.08	140.79	319.2	301.53	237.91
Cost (NR)	-	426.4	169	468	125.3	229	131.8	220
Energy(Kcal)	894	756.5	687.2	893.8	651.6	894.1	706.7	727
Protein (g)	10.9	22.5	35	30.5	17.2	31.1	12.9	13.5
Fat (g)	29.8	49.3	36.4	36.2	40.5	34.3	50	39.5
Carbohydrate (g)		63.4	62.4	120.3	64.4	125.7	60.9	84.1
Vitamin A (µg)	400	401.2	353	395.9	511.3	292.6	521	445.3
Vitamin C (mg)	30	51.4	39	33.5	35.2	29.4	43.3	31.9
Iron (mg)	6	3.5	3.1	8.6	3.9	11.1	2.5	1.4
Zinc (mg)	4.1	4.3	4.8	4.3	4.2	4.7	3.3	2.5
Calcium (mg)	400	268.3	867.1	273.7	397.5	296.7	194.8	232.9

Cost (OR) = Cost of the old recipe (frequently used complementary foods in Rombo)
Cost (NR) = Cost of the new recipe (formulated recipes)

(gap=167.1) and zinc (in banana puree with pumpkin (gap=0.8 mg) and rice porridge with milk (gap=1.6 mg)) (Table 4).

Sensory evaluation of the formulated recipes

Sensory evaluation had both semi-trained (Food Science students (n=49)) and untrained panellists (mothers/caregivers (n=53). Most of them (students and mothers/caregivers) were aged between 20-35 years by the time of data collection. All formulated complementary food recipes were evaluated for acceptance testing by a total of 102 panellists (Table 5). The mean scores for the attributes evaluated ranged from 5.78-7.73, 5.29-7.51, 5.53-7.57, 5.80-7.69, 5.73-7.57 and 5.65-7.51 in terms of appearance, taste, aroma, colour, texture and general acceptability, respectively. Five-point Likert scale was used for untrained panellists and the range of scores were; appearance (4.32 to 4.94), taste (4.17 to 4.89), aroma (4.28 to 4.96), colour (4.62 to 4.98), texture (4.53-4.83) and general acceptability (4.45 to 4.98). The choice of likert scale to use depended on the level of understanding among the panel members.

Appearance

In terms of appearance, the highest mean score was given for maize porridge (F3) (7.73) and banana puree with beef (F1) (4.94) by semi-trained and untrained panellists respectively and the lowest mean score was given for rice puree with milk (F7) by both groups (5.78 and 4.32, respectively). There was no significant difference between banana puree with beef (F1) and banana puree with pumpkins (F6) in terms of appearance for both groups. Formulation F7 (rice puree with milk) was rated significantly lower than the rest of the formulations ($p<0.05$) by both semi-trained and untrained panellists (5.78 and 4.32, respectively) (Table 5).

Taste

This study also revealed moderate likeness of the formulated recipes regarding taste ranging from 5.29 to 7.51 and 4.17 to 4.89 for semi-trained and untrained panellists, respectively (Table 5 and 6). Banana puree with beef (F1) had the highest rating (7.51), closely followed by banana puree with pumpkins (F6) (7.27) while milk-based formulations (F4 and F7) had the least ratings for taste.

The rating for formulations F3 (Maize porridge), F5 (Composite flour porridge) and F7 (Rice porridge with milk) were not significantly different at $P>0.05$ for trained panellists. All the formulations rated by untrained panellists were not significantly different in terms of taste with the exception of F4 (Banana puree with milk) and F7 (Rice porridge with milk) at $p>0.05$. Most of the panellists suggested that, salt or lemon should be added to rice porridge with milk (F7) in order to improve flavour.

Aroma

Aroma is an important attribute in sensory evaluation because it influences the choice of foods to eat. Ratings for all the formulations in terms of smell/aroma were within acceptable range of 5-9 and 3-5 for nine and five point Likert scales, respectively (Tables 5 and 6). Banana puree with beef (F1) and banana puree with pumpkins (F6) had flavour ratings significantly higher than the rest of the formulated diets at $p<0.05$, while the least rated were milk-based formulations (F4 and F7). For trained panellists, banana porridge with fish (F2) and rice porridge with milk (F7) as well as maize porridge (F3) and composite flour porridge (F5) were not significantly different at $p>0.05$. For untrained panellists, formulations F1 (banana puree with beef), F3 maize porridge), F5 (composite flour porridge) and F6 (banana puree with pumpkins) were not significantly different at $p>0.05$.

Colour

The mean score of colour for all the formulated complementary food recipes ranged from 5.8 to 7.69 and 4.62 to 4.98 for semi-trained and untrained panellists, respectively (Tables 5 and 6). Banana-based foods (F1 and F6) were not significantly different at $p>0.05$ for trained panellists. For untrained panellists, formulations F2 (banana puree with fish), F3 (maize porridge), F5 (composite flour porridge) and F6 (banana puree with pumpkins) were not significantly different from each other but were different from other formulations in terms of colour at $p>0.05$.

Texture

The texture of complementary foods is an important attribute that drives child's acceptance depending on his/her developmental stage and therefore, it was important for it to be included in sensory evaluation. Based on the present study, both panellist groups showed significantly higher preference ($p<0.05$) for formulation F1 (banana puree with beef) followed closely by F3 (maize porridge) in terms of texture (Table 5). Rice porridge with milk (F7) was the least preferred formulation although it was not significantly different from banana porridge with milk (F4) for both groups at $p>0.05$. Generally, all the formulations scored within the acceptable range for both groups.

General acceptability

In general, banana puree with beef (F1) was highly acceptable for both groups (Tables 5 and 6). However, the general acceptability score was not significantly different from F2 (banana puree with fish), F3 (maize porridge), F5 (Composite flour porridge) and F6 (banana puree with pumpkins) for both panellist groups at $p>0.05$. For trained panellists, banana puree with milk (F4) had the least score in terms of general acceptability but it was not significantly different ($p>0.05$) with rice porridge with milk (F7). Untrained panellists rated rice porridge with milk (F7) as the least generally acceptable formulation as compared to the rest of other formulated complementary foods although it

Table 5: Mean scores of sensory evaluation of the formulated complementary food recipes as tested by semi- trained panellists

	Appearance	Taste	Aroma	Colour	Texture	General acceptability
F1	7.27 ± 1.30^{ab}	7.51 ± 1.43^{a}	7.57 ± 1.38^{a}	7.12 ± 1.69^{ab}	7.57 ± 1.21^{a}	7.51 ± 1.45^{a}
F2	6.88 ± 1.63^{ab}	6.69 ± 2.11^{ab}	6.86 ± 1.61^{ab}	6.80 ± 1.66^{abc}	7.14 ± 1.14^{ab}	6.92 ± 1.69^{ab}
F3	7.73 ± 0.97^{a}	6.22 ± 1.52^{bc}	6.29 ± 1.15^{bc}	7.69 ± 1.39^{a}	7.51 ± 1.32^{a}	7.20 ± 1.29^{a}
F4	5.94 ± 1.81^{cd}	5.29 ± 2.18^{c}	5.53 ± 2.08^{c}	5.80 ± 2.08^{c}	6.00 ± 2.13^{c}	5.65 ± 2.06^{c}
F5	6.69 ± 1.57^{bc}	6.27 ± 1.83^{bc}	6.12 ± 1.54^{bc}	6.57 ± 1.51^{bc}	6.47 ± 1.57^{bc}	6.80 ± 1.61^{ab}
F6	7.12 ± 1.25^{ab}	7.27 ± 1.79^{ab}	7.33 ± 1.52^{a}	7.24 ± 1.46^{ab}	7.16 ± 1.59^{ab}	7.37 ± 1.67^{a}
F7	5.78 ± 1.95^{d}	6.22 ± 1.87^{bc}	6.78 ± 1.77^{ab}	6.59 ± 1.94^{bc}	5.73 ± 1.99^{c}	6.12 ± 2.02^{bc}

Means bearing different superscripts on the same column are significantly different ($p<0.05$). F1 to F7 are the complementary foods formulation names as detailed in Table 2.

Table 6: Mean scores of sensory evaluation of the formulated complementary food recipes as tested by un-trained panellists

	Appearance	Taste	Aroma	Colour	Texture	General acceptability
F1	4.94 ± 0.23^{a}	4.87 ± 0.39^{a}	4.96 ± 0.19^{a}	4.98 ± 0.14^{a}	4.98 ± 0.14^{a}	4.98 ± 0.14^{a}
F2	4.74 ± 0.49^{bc}	4.72 ± 0.53^{a}	4.64 ± 0.71^{ab}	4.72 ± 0.69^{ab}	4.74 ± 0.59^{abc}	4.85 ± 0.50^{a}
F3	4.85 ± 0.36^{a}	4.89 ± 0.32^{a}	4.85 ± 0.46^{a}	4.85 ± 0.41^{ab}	4.87 ± 0.52^{ab}	4.92 ± 0.33^{a}
F4	4.42 ± 0.93^{bc}	4.34 ± 0.85^{b}	4.36 ± 0.88^{bc}	4.62 ± 0.69^{b}	4.60 ± 0.66^{bc}	4.72 ± 0.60^{ab}
F5	4.91 ± 0.30^{a}	4.87 ± 0.42^{a}	4.91 ± 0.35^{a}	4.87 ± 0.48^{ab}	4.91 ± 0.35^{ab}	4.85 ± 0.53^{a}
F6	4.85 ± 0.41^{a}	4.75 ± 0.68^{a}	4.87 ± 0.32^{a}	4.83 ± 0.51^{ab}	4.83 ± 0.43^{abc}	4.81 ± 0.48^{a}
F7	4.32 ± 0.92^{c}	4.17 ± 1.01^{b}	4.28 ± 0.93^{c}	4.62 ± 0.66^{b}	4.53 ± 0.95^{c}	4.45 ± 0.91^{b}

Means bearing different superscripts on the same column are significantly different ($p<0.05$). F1 to F7 are the complementary foods formulation names as detailed in Table 2.

was not significantly different ($p>0.05$) from banana puree with milk (F4).

Discussion

This study aimed at formulating low-cost complementary foods using locally available ingredients by linear programming module of nutri-survey. The findings from this study have revealed banana-based foods as the frequently used complementary foods in Rombo district followed closely by cereal based foods. This is due to the fact that, the main staple food in Kilimanjaro region is banana and about 15,950 hectares are used for banana production in Rombo district alone with estimated yields of 10 tonnes per hector (Rombo DC profile, 2013). However, Tanzania Food Composition Tables (Lukmanji *et al.,* 2008) shows low energy and nutrient contents of banana-based foods relative to cereal-based foods. This means that, there is a need to alternate the two food types in order to improve nutrient intake for children by encouraging mothers to diversify foods for their children. Most of the studies (Mamiro *et al.,* 2004; Nyaruhucha *et al.,* 2006; Kimanya *et al.,* 2009: 2010; Muhimbula *et al.,* 2010; Kulwa *et al.,* 2015) have continuously reported cereal-based foods as the frequently used complementary foods in Tanzania which is contrary to the current study.

The present study shows that low cost, nutritious, age appropriate and culturally acceptable complementary food recipes which are consistent with the local preparation methods and feeding practices can be developed using linear programming method. Slightly improving nutrient content of the existing complementary foods without much interference to their normal cooking methods may likely enhance their acceptability and long-term sustainability. This was best achieved by including locally available foods (frequently used and underused) that contain high levels of macro and micro nutrients as suggested by Ferguson *et al.* (2004), Kuyper *et al.* (2013) and Parlesak *et al.*(2016). Another study conducted by Raymond *et al.* (2017) in Dodoma, Tanzania showed that it is even possible to optimise the use of locally available nutrient-dense foods to improve recommended dietary intakes (RDIs) for nutrients like iron, zinc and calcium that are frequently reported as limiting nutrients among rural infants and young children in developing countries.

Animal products which offered highest overall amount of micronutrients such as meat were also the most expensive. Conversely, addition of nutritious seeds, fruits and vegetables may have helped to lower the cost while increasing the nutrients. This is supported by Slavin and Lloyd (2012)who recommended additional of fruits and vegetables into the diet to improve nutritional quality. It was possible to achieve optimal complementary foods that meet energy needs in cereal-based complementary foods. However, reformulation of banana-based complementary foods was unable to meet recommended energy needs despite the addition of high energy seeds such as pumpkins, sunflower and sesame seeds. Addition of vitamin C sources such as tamarind, baobab flour or lemon juice have been able to meet the recommended amounts. In this study, the nutrients that were likely to remain low in most formulations were energy, vitamin A, iron, calcium and zinc. This is similar to what have been reported in other studies where it was also difficult to meet iron, niacin, zinc, and calcium levels using locally available foods (Santika *et al.,* 2009; Suri *et al.,* 2014; Stuart *et al.,* 2015). However, Raymond *et al.* (2017) suggested additional of enhancers for absorption of various micronutrients such iron and zinc as well as increased consumption of animal food sources that will increase bioavailability of the limiting micronutrients.

Sensory analysis is an important tool in food science and is becoming accepted as a necessary part of food quality experiments. It is easy in its principle but its implementation in the field is often complicated because of low literacy among untrained panellists (Muhimbula *et al.,* 2010). Likert scale, a psychometric response scale is primarily used to obtain consumer's preferences or degree of agreement of a product during sensory analysis process (Bertram, 2010). Based on the level of understanding among the two panellist groups, this study used both nine-point and five-point Likert scales. The findings from this study showed that, different attributes of most of the formulations were equally

accepted by both panellist groups (semi-trained and untrained). Muhimbula *et al.* (2010) also found no difference between semi-trained and untrained panellists. The overall acceptability of milk contained formulations (banana and rice porridges with milk) was relatively lower than the rest of the formulations. For semi-trained panellists, the score for banana puree with milk ranged from 'neither like nor dislike, like slightly' and 'like moderately to like extremely' for untrained panellists. This could probably be due to the fact that, banana puree with milk (mixture of cooked bananas, milk and cooking oil only) is one of the traditional foods that defines local people and in the study area and it is not widely consumed by people from other areas and therefore, it was totally new to most of the semi-trained panellists and they suggested that salt should be added to improve flavour.

The roasted seeds (pumpkins, sunflower, sesame, amaranth and soybeans) had an important impact in flavour improvement for most of the formulations (Singh-Ackbarali and Maharaj, 2014). Addition of lemon, baobab flour or roasted seeds' flour to maize based formulations (F3 and F5) contributed not only to the improved flavour, appearance, aroma, texture, colour and general acceptability of the foods but also to increased energy and nutrient density of the foods (Stodolak *et al.,* 2009). Also, the introduction of roasted bean flavour (soya beans) to maize based formulations (F3 and F5) did not affect the flavour of the products instead the consumers liked it even more. This supports what has been reported by Maseta *et al.* (2016) who suggested the use of extrusion technology to improve the organoleptic quality of the recipes

General acceptability of all banana-based formulations (with the exception of banana puree with milk) in all attributes was high. This is because banana based puree with meat (Known as mtori in Swahili) is widely consumed in Tanzania and therefore, it was not new even to semi-trained panellists. The addition of salt increased general acceptability of salted formulations as compared to non-salted ones (Milk versus non-milk based formulations). The finding is supported by Mugula and Lyimo (2000) who used various processing technologies to improve sensory attributes of their products such as frying and addition of condiments. Therefore, this study has shown that addition of potentially more nutrient dense ingredients of low cost to the frequently used complementary foods doesn't affect the sensory quality of those foods.

Conclusion and recommendations

Conclusion

This study revealed that low cost, nutritious, locally available and culturally acceptable complementary food recipes can be developed by linear programming method. Sensory evaluation done on all the recipes revealed that addition of vitamin C rich ingredients such as lemon and baobab flour to the recipes significantly improved organoleptic quality of the recipes and contributed to their high acceptance. Also addition of seeds such as pumpkin, sunflower, amaranth seeds increased energy and nutrient content of the recipes. This study provides a benchmark for educating mothers and caregivers on the importance of including nutrient-dense ingredients and proper preparation methods for complementary foods as well as adequate portion sizes based on child's age.

Recommendations

This study recommends public health nutritionists and food technologists in Tanzania to use linear programming methods to design dietary guidelines that are more cost-effective in preventing energy and micronutrient deficiencies which will capture even the poorest segment of the population. If the method is adopted, it may save a lot of foreign exchange used on supplements and contribute in the efforts to combat malnutrition in Tanzania

Study limitations

This study was conducted in October and November, which was the time for land preparation and planting. This may have affected what was available in the market and therefore, another study is recommended in the harvest season to see if there is a variation in the range of foods available in the market and if the cost of the complementary foods can be

minimized even further.

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