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Formulation of Complementary Baby Foods Based on Some Grains and Legumes

Saad A. Maghoub[1], Mahmoud T. El-Mougi[2]

Authors Affiliation
[1] Crops Technology Research Department, Food Technology Research Institute, Agriculture Research Center, Giza, Egypt

[2] Department of Pediatrics, Faculty of Medicine, El Azhar University, Egypt

Correspondence to: Maghoub SA
saadk125@yahoo.com

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Abstract

Nursing mothers in developing countries cannot afford nutritious weaning foods and rely on low-nutritive-value weaning foods, which may result in poor nutritional status for their children. This study aimed to develop nutritious complementary formulas for infants. Three formulations based on cereals and legumes were developed. The first formula (WFF) contained 30 g of germinated wheat flour and 30 g of germinated faba bean flour; the second formula (RCF) contained 30 g of raw rice flour and 30 g of germinated chickpea flour; and the third formula (BLF) contained 30 g of germinated barley flour and 30 g of cooked lentil flour (30 g). All formulas contained the same amounts of maltodextrin (15 g), peanut (10 g), date powder (5 g), skimmed milk powder (5 g), carrot powder (2.5 g), and corn starch (2.5 g). The chemical composition, minerals, beta-carotene, vitamin A, in-vitro protein digestibility, anti-nutritional elements, and amino acids were determined. The three formulas were also evaluated for microbiology, physical properties, color, rheological properties, and sensory evaluation. The three formulas' moisture, fat, and fiber content showed no discernible difference. The BLF has the most carbs, while the WFF has the fewest. The caloric values for the three formulas ranged from 360.4 to 355.6 kcal/100g. The protein digestibility (%) for the WFF and RCF was 84.51% and 76.42%, respectively, while the BLF was 71.63%. In conclusion, combining substances produced nutritional formulae with high acceptability, with the WFF formula being the best and possibly comparable to a commercial supplement.

Keywords: Faba Bean, Chickpea, Lentil, Rice, Wheat, Barley, Infants

1. Introduction:

FOR MAXIMUM health, growth, and development, exclusive breastfeeding from birth through the first six months with breastmilk is essential [1]. After the initial six months of a baby's life, as newborns develop and become more active, breast milk alone is insufficient to provide for their nutritional needs; this nutritional gap widens as infants and young children age. Supplementary nutrition is crucial for bridging these gaps [1,2].

FAO [3] stated that over 2.0 billion people worldwide suffer from malnutrition, evidenced by kwashiorkor, marasmus, and other malnutrition-related disorders. Around 1,2 billion of this population resides in developing nations in Asia, Africa, and Latin America. After weaning, protein-energy malnutrition is the primary cause of infant death. Protein–energy malnutrition remains a major global public health concern among children [4].

According to WHO [1] complementary feeding is "a process that begins when breast milk alone is no longer sufficient to meet the nutritional needs of infants, and other foods and liquids, in addition to breast milk, are required." Infants should be given complementary foods to supplement their nutrition [5].

When most infants have reached a stage of general and neurological development that allows them to be fed other foods instead of breast milk. The recommended age range for complementary feeding is 6 to 23 months (when breastfeeding is continued) [1,6]. Complementary foods can be specifically designed transitional foods (to satisfy infants' nutritional and physiological needs) or general family foods. They are expected to bridge the gap between infants and young children's daily energy and nutrient needs and what they get from breastfeeding [7].

In many impoverished countries, the average family cannot afford marketed weaning foods. Hence nursing moms frequently rely on conventional weaning foods with minimal nutritious value [8]. In addition, they are low in protein, low in energy, and have an excessive volume density. Cereals are the principal component of most traditional African weaning diets [9].

Vicia faba (Fabaceae) is one of the most ancient cultivated plants. It is native to the Near East and the Mediterranean but is now widely planted worldwide for its edible seeds, which can be eaten fresh, dry, green, or canned [10].

This bean provides protein, carbohydrates, fiber, choline, lecithin, vitamins, and minerals [11,12]. Faba bean protein levels range from 20 to 41 percent, depending on the cultivar. The carbohydrates in the seeds range from 51% to 68%, with starch accounting for the majority (41% to 53%) [13].

Phosphorus, potassium, calcium, sulfur, and iron are all abundant in faba beans. Calcium concentration varies between 120 and 260 mg/100 g dry mass [13]. However, including anti-nutritional elements, such as trypsin inhibitors, hemagglutinins, tannins, and favism-inducing substances, reduces the biological value of faba beans. To increase the nutritional value of the bean, traditional methods like soaking, boiling, germinating, and fermenting have been used [14]. Chickpeas can be used as an infant weaning diet or as a follow-up formula with minimal mineral and vitamin fortification. Because of its high nutritional value and economic value, the chickpea was examined for this purpose. It is heavy in protein, carbohydrates, vitamins (thiamine and niacin), and minerals (calcium, phosphorus, iron, magnesium, and potassium), and its oil is high in linoleic acid [15].

Carrot is a root plant containing carotenoids, flavonoids, vitamins, and minerals, providing various nutritional and health benefits. Carrots have been used as anti-diarrhea, anti-infection, anti-fungal, and anti-bacterial [16,17].

This study aimed to formulate a nutritious cereal- and legume-based complementary food for 6- to 24-month-old Egyptian infants. Moreover, the prepared complimentary food was compared to Cerelac's commercial formula regarding its sensory properties.

2. Materials and Methods

2.1 Materials

Wheat, rice, and barley grains were purchased from local markets in Giza-Egypt, as were faba bean, chickpea, lentil seeds, peanut butter, date powder, skimmed milk powder, and carrot. Egyptian Starch and Glucose Manufacturing Co., The 10-Ramadan City, Egypt, supplied maltodextrin and corn starch. All additional chemicals were obtained from the Algomhorya Company in Giza, Egypt.

2.2 Methods

2.2.1 Preparation of raw materials:

Wheat, and barley grains, also faba bean, and chickpea seeds were germinated. The grains and seeds were cleaned, washed, and disinfected for 15 minutes at room temperature with 0.07% sodium hypochlorite before being thoroughly rinsed with running tap water. The seeds were then steeped for 12 hours at room temperature in 4-5 volumes of water. The water was drained at the end of this period, and under a moist cheesecloth, bean samples germinated for 24, 48, and 72 hours. Soaked and germinated seeds were dried in an oven at 40 degrees Celsius before being pulverized in a mill. Samples were stored at four °C until analysis. Lentil seeds were cleaned, washed, and cooked in boiling water for 15 min. Cooked seeds were dried in an oven at 40°C then ground using a grinder. Samples were stored at four °C until analysis. The carrot was cleaned and washed with tap water, peeled, and sliced. The slice materials were soaked in boiling water for 5 minutes, cooled with tap water, then dried at 40°C for 24 hrs in an air oven dryer. The samples were ground in a laboratory mill and sieved through a 40-mesh screen to create a fine powder.

Table (1). The food ingredients of suggested formulas (g/100 gram).

Ingredients	(g/100gm)		
	Formula 1	Formula 2	Formula 3
Germinated wheat flour	30	00	00
Raw rice flour	00	30	00
Germinated barley flour	00	00	30
Germinated faba bean flour	30	00	00
Germinated chickpea flour	00	30	00
Cooked lentil flour	00	00	30
Maltodextrin	15	15	15
Peanut baste	10	10	10
Date powder	5	5	5
Skimmed milk powder	5	5	5
Carrot powder	2.5	2.5	2.5
Corn starch	2.5	2.5	2.5

2.2.2 Chemical composition of the formulas.

Moisture, protein, fat, crude fiber, and ash were determined for formulas using AOAC [18] techniques. The amount of carbohydrates was determined by differential.

2.2.3 Minerals of the formulas.

AOAC procedures were used to determine the phosphorus (p), potassium (K), calcium (Ca), irons (Fe), magnesium (mg), Zinc (Zn), selenium (Se), copper (Cu), and manganese (Mn) concentrations of basic formulas [19].

2.2.4 The formulas' beta-carotene and vitamin A value calculations.

HPLC was used to examine the formulas for ß-carotene using the method of Pupin et al. [20]. HPLC Agilent 1200 Series with a quaternary pump, Autosampler, column compartments at 35oC, and wavelength detector set at 330 mm 280 nm for detection of beta-carotene degasser column used for fractionation (Hyprsil ODS 250X4mm 5mm), and the mobile phase flow rate was 1 ml/min during the run.

The vitamin A activity of the beta-carotenes and the conversion factor provided by Russell et al. [21] were used to compute vitamin A values. Retinol activity equivalents (RAE) were used to represent vitamin A activity as retinol, with 12 g of dietary beta-carotene required to make 1 g of retinol, giving dietary beta-carotene an RAE ratio of 12:1.

2.2.5 Total calories of the formulas.

The following equation calculated the total calories for formulas:

Calories = (Grams of protein + carbs)*4) + (grams of fat*9).

2.2.6 The in vitro protein digestibility (%) of the formulas.

The In-vitro protein digestibility of the dry vegetarian soup combinations was determined using the Akeson and Stahmann technique after enzymatic digestion of samples with pepsin (37 C/3h at pH 2) and pancreatic (37 C/24h at pH 8) [22]. According to AOAC [18], the supernatant's total nitrogen (N) was calculated using the Kjeldahl method. The percentage of N digestibility was determined by calculating the ratio of nitrogen (N) in the supernatant to nitrogen (N) in the sample as follow:

$$\text{In vitro protein digestibility (\%)} = \frac{\text{N in supernatant - N in Blank}}{\text{N in sample}} \times 100$$

2.2.7 The anti-nutritional factor of the formulas.

According to the modified procedure described by Mohamed et al. [23], phytate was extracted. Elfalleh et al. [24] provide the Folin-Ciocalteu method for quantifying total phenols. Tannins were determined in the prepared formulas by using the vanillin Hydrochloric Acid Method as described by Price et al. [25]

2.2.8 Microbiological assay of the formulas.

Plate count agar media was used to determine the total bacterial count, and Lactose-broth media was used to detect the coliform group [26]. According to Galloway and Burgess, potato dextrose agar was used to determine yeasts and molds [27].

2.2.9 Physical properties of the formulas.

2.2.9.1 Water Activity (WA)

According to Cadden [28], the water activity (WA) was measured with a Rotronic Hygrolab 3CH-8303, Switzerland. According to Silvia et al. [29], the water absorption index (WAI) and water solubility index (WSI) were obtained.

2.2.9.2 Color measurement of the formulas.

According to the approach described by McGuire [30], the exterior color of formulations was measured. The formula's color was measured three times with a colorimeter (CR-400, Konica Minolta Sensing Inc., Japan). The hue values were documented as:

L∗ = lightness (0=black, 100=white), a∗ (−a∗=greenness, + a∗=redness), and b∗(−b∗ = blueness, + b∗=yellowness.

2.2.10 Rheological properties of the formulas.

2.2.10.1 Viscosity

The powdered formula was placed in a water bath at 40 °C (the viscosity measurement temperature). The formula viscosity (in centipoise, cps) was measured using Brookfield DV- III ultra with a spindle at a shear rate of 50 rpm in 30 seconds. According to Tizazu et al. [31], all formulas were measured using a Brookfield Viscometer.

2.2.10.2 Rehydration Ratio (RR)

The RR was calculated following Huang et al. [32]. Two grams of dried formula were rehydrated in 20 milliliters of distilled water at a consistent temperature and speed in a water bath. After 10 minutes, the samples were extracted from the bath and weighed. The rehydration ratio was defined as the ratio of rehydrated samples' weight to dry samples' weight.

$$\text{RR ratio} = \frac{2\text{-}W1}{W1}$$

The rehydration ratio was computed using the initial and final sample weights: W1 and W2 are the initial and final porridge sample weights, respectively.

2.2.11 Amino acids of the formulas.

The amino acid content was measured using high-performance liquid chromatography (HPLC) according to Alajaji and Elaawy's [33] method. The essential amino acid score [34] was calculated using the Food and Agricultural Organization/World Health Organization/United Nations University (FAO/WHO/UNU) reference amino acid pattern for children aged 6 to 36 months.

2.2.12 Sensory evaluation of the formulas

Ten food technology specialists examined the sensory characteristics of the three formulations. The panelists sat in separate booths in a 25°C temperature-controlled room lit by daylight fluorescent lights. Using a nine-point hedonic scale ranging from 1 (very dislike) to 9 (extremely like) for appearance, color, aroma, taste, mouth feel, and overall acceptability, participants were asked to score the complementing foods [35].

Twenty-five grams of formulae and the complementing commercial meals were individually mixed with 80 mL of hot water cooled to 70 C. At room temperature (25 °C), the suspension was agitated for 2 minutes with a stainless steel rod. After 1 minute of submerging the cup in cold or icy water, the slurry was ready to be used. Dishes with lids and arbitrary three-digit numbers were used to hold the freebies.

2.2.13 Statistical analysis

The collected data from the analyses were subjected to ANOVA, an analysis of variance. Duncan's multiple range tests were employed to compare means at the ($P<0.05$) level.

3. Results and Discussion

The formulas were analyzed for chemical composition; the data are presented in table (2). The data revealed that formula (1) has the highest ($P<0.05$) contents of moisture, protein, fats, ash, and crude fiber than other formulas (2 & 3). In contrast, formula (2 & 3) has the highest ($P \leq 0.05$) content of carbohydrates. Also, data revealed that formula (2) has the lowest ($P< 0.05$) moister, ash, and crude fiber contents than other formulas (1 & 2). Legumes and cereals are excellent protein, carbohydrate, and fiber sources, they deliver numerous necessary vitamins and minerals. Their high nutritional value has been linked to a variety of health-promoting characteristics. Moreover, as a cheap and concentrated protein source, legumes are combined with cereals in food preparations [36].

Data concerning the mineral contents of formulas are shown in table (2). The results differed significantly (P<0.05), showing that all minerals occurred with a sufficient amount in different formulas. Phosphorus, potassium, calcium, iron, magnesium, zinc, manganese, copper, and selenium were the highest content in formulas 3 and 2. While formula 2 recorded the highest amount of iron (4.149 mg/100gm), magnesium recorded the highest amount in formula 1 (336.2 mg/100gm).

Zinc reduces the duration of fever and severity of illness among children with pneumonia and other serious lower respiratory infections [42]. The mineral has already been shown to prevent such infections, a leading cause of childhood death. Clinical manifestations of borderline zinc insufficiency include impaired immunity, poor taste and smell, and the beginning of severe blindness. [43]. Manganese recorded the highest content in formula (2); copper recorded the highest amount in formula (3). Selenium occurred in the highest amount in formula (2) flowed by formula (1) (1.30 and 1.24 mg/100gm, respectively).

Micronutrients are critical for young children's growth, development, and disease prevention [7]. Iron, zinc, and calcium are essential nutrients for infants' and young children's health, growth, and development [37]. Cereals and legumes are high in iron, zinc, and calcium for newborns and children in rural areas [38]. According to Roy et al. [36], chickpeas are rich in minerals such as calcium, phosphorus, iron, and magnesium. In addition, according to Della et al. [40], lentils are a great source of micronutrients, including iron.

Even after accounting for bioavailability, numerous additional micronutrients are relatively scarce in breast milk. 30% to 97% of the total daily requirement for micronutrients must be met by consuming supplementary meals. At 9-11 months, complementary foods are predicated to provide 97% iron, 86% zinc, 81% phosphorus, 76% magnesium, 73% salt, and 72% calcium. Hence, newborns have a limited stomach capacity to digest substantial food, so their diets need a very high nutrient density [41].

Table (2) data indicated that caloric values ranged between 360.4 and 355.6 kcal/100 g. Formula (2) recorded the highest, having 360.4 kcal/100 g. The number of meals per day is determined by the energy requirements of the child's age, his or her stomach capacity, and the calorie density of each meal (kcal per gram). In order to calculate the appropriate number of meals for a specific age range and degree of breast milk intake, it is necessary to know the calorie density of the foods. Older children require more daily meals to be partitioned into many servings than their younger counterparts [7].

The estimated total calorie requirements for breastfed infants aged 6–8 months, 9–11 months, and 12–23 months are 615 kcal/day, 686 kcal/day, and 894 kcal/day, respectively. For newborns in developing nations with "average" breast milk intake, the energy requirement for supplemental foods rises from 200 kcal/day at 6-8 months to 300 kcal/day at 9-11 months and 500 kcal/day at 12-23 months. This equates to 29, 55, and 71% of total daily calorie requirements, respectively, corresponding to the fall in human milk intake with age [2].

Results show that the amount of beta-carotene in the different formulas ranged from 95.30 to 142.3 req/100g. The suggested formulas contain the lowest (P<0.05) beta-carotene content; this may be due to the amount added of carrots which represented 2.5%. Results also show that formula (2) and formula (3) contained higher ($P<0.05$) amounts of beta-carotene; this may be due to chickpeas and lentils.

The results in table (2) showed that the *in vitro* protein digestibility (%) (PDI) of the formulas under study recorded a value for formula (1) 84.51%, formula (2) 76.42%, and formula (3) 71.63%. From the obtained data, significant differences were found between prepared formulas. It has been demonstrated, however, that cooking legumes boosts their digestibility and improves their aroma, sensory aspects, and nutritional properties [45].

Antinutritional chemicals affecting protein digestibility are responsible for the proteolytic resistance of dry seeds [42]. Mineral content and availability can be altered with relatively low-cost and easy treatments by reducing or eliminating antinutritional factors. Various methods, including soaking, heating, germination, and fermentation, have been employed to enhance the nutritional value of the bean [43].Protein digestibility is important when assessing a food product's protein quality and nutritional value [44].

Antinutritional factors of prepared formulas are given in table (2). The results showed that there is a significant difference ($P<0.05$) in phytic acid between formula (1), formula (2), and formula (3), represented (0.212±0.03, 0.145±0.01, and 0.184±0.02 mg/100g respectively). It is observed from the result that there are no significant differences ($P<0.05$) in the total phenol compound in the tested formula. However, formula (1) recorded the highest content ($P<0.05$) of total phenol, while formula (2) recorded the lowest content ($P<0.05$) of the total phenol compound. It could be noticed that soaking and germination reduced the total phenolic compound, as demonstrated by Alonso et al. [46]. The same table illustrated that tannins content ranged from 0.41 mg/100g to 0.53 mg/100g in formula (1) and formula (3), respectively.

Formula (2) had the highest ($P<0.05$) total bacterial count (TBC), 372 CFU/gm. On the contrary, formula (1) had the lowest ($P<0.05$) CFU/gm and recorded (336); yeast, molds, and coliform groups were not detected. Microorganisms are important and impact our lives; they are fundamental for obtaining food products like yogurt, cheese, etc. However, they are also the main cause of food and cultivar deterioration [47]. The suggested formulations have a high humidity rate. This makes it an excellent growth medium for bacteria, but commercialization requires protection against microbial contamination and microbiological controls.

These results agreed with the results recorded by EOS [48] in the hygienic practice of food for infants and children up to three years. It was reported that the total bacterial count should stay the same at 1000 organisms/g for baby foods that could be prepared without boiling. The total count of molds and yeasts could not be more than 100 cell/g formulas.

Table (3) data represents the moisture (%) of dietary formulas; as shown, formula (1) recorded the maximal water content, while formula (2) has the lowest value ($P<0.05$). Water influences the stability, palatability, and overall food quality. Powder or powder-based goods can have their physical qualities, such as hardening or clotting, altered by moisture. As a plasticizer, water further impacts the shelf life of low- and medium-moisture foods [49].

Protein type, concentration, number of exposed polar groups, pH, salt(s), and temperature affect the amount of water and degree of binding [50]. Woodroof [51] found that when the moisture content of dehydrated food is less than 8%, germs cannot grow. Certain germs may proliferate gradually when the relative humidity exceeds 18 percent.

Table (2). Chemical analysis, antinutritional factors, and microbiology assay of dietary formulas.

Properties	Formula 1	Formula 2	Formula 3
Moisture	7.532±1.12a	6.634±1.03b	7.132±1.34a
Protein	17.52±0.41a	14.21±0.32b	13.36±0.42c
Fats	2.954±0.13a	2.832±0.12a	2.614±0.14b
Ash	3.042±0.05a	2.836±0.07b	2.975±0.06b
Crude fiber	4.216±0.52a	3.964±0.42c	4.167±0.41b
Total carbohydrate	64.74±3.42b	69.52±2.43a	69.75±3.02a
Phosphorus (p)	197.3±3.12c	216.2±3.45b	256.5±3.86a
Potassium (K)	786.5±8.45c	985.2±9.32a	965.8±8.67b
Calcium (Ca),	213.6±4.26a	173.1±1.46b	172.6±1.42b
Irons (Fe)	3.387±0.12b	4.149±0.42a	3.681±0.23b
Magnesium (Mg),	336.2±3.21a	293.4±2.89b	273.8±2.87c
Zinc (Zn),	2.839±0.15b	3.029±0.24a	2.815±0.14b
Manganese (Mn)	0.715±0.04b	1.157±0.08a	0.741±0.01b
Cupper (Cu)	0.525±0.02c	0.544±0.03b	0.856±0.03a
Selenium (Se)	1.240±0.01b	1.303±0.03a	1.227±0.04b
Caloric Value Kcal./100g	355.6±5.13	360.4±4.35	355.9±4.62
Beta-carotene µg/100g	63.28	142.3	115.7
Vitamin A**	5.273	11.86	9.642
In vitro protein digestibility (%)	84.51±1.64a	76.42±1.41b	71.63±1.62c
Phytic acid (g/100g)	0.212±0.03a	0.145±0.01c	0.184±0.02b
Total phenol compound (mg/100g)	2.751±0.21a	2.5542±0.13c	2.651±0.12b
Tannins (mg/100g)	0.534±0.06a	0.415±0.02c	0.482±0.03b
T.B.C. 1000 cell/g	336±5.12c	372±4.86a	356±4.23b
Yeast and molds	ND	ND	ND
Coliform group	ND	ND	ND

***Retinol Activity Equivalent (RAE). 1 RAE = 1 µg retinol, 12 µg β-carotene, whereas the RAE For preformed vitamin A is the same as Retinol Equivalent (RE),*
T.B.C: Total bacterial count, ND: Not detected
Data are displayed as mean±SD, and means in the same row subscribed by different letters are significant at P< 0.05.

The physicochemical state of water is linked to its activity, which measures the amount of water available for the growth of various microorganisms. All the water activity values in the table were tested at temperatures ranging from 32.60 to 33.30 degrees Celsius. The data demonstrated that adding legumes considerably (P0.05) altered the water activity values of the dietary formulae. Formula (1) yielded the highest (P0.05) value for water activity (0.42), but formula (2) yielded the lowest (P0.05) value. Water activity is a significant element affecting the chemical stability of dry food products and has been established as an intrinsic factor controlling shelf life [52].

Lowering water activity impacts microbial development, the main microbial culture, and enhances shelf life by reducing the water available for microbial growth [53]. Virtually all microbial activity is inhibited below water activity = 0.6; the majority of fungi below 0.7; the majority of yeasts below 0.8; and the majority of bacteria below 0.9 [54]. Very low water activity values are associated with high-fat oxidation rates. In contrast, lipids are thought to be most stable between water activity values of 0.2 and 0.4, and oxidation rates rise with increasing water activity [55]. Given the information mentioned above, it is possible to predict the chemical stability, safety, and quality of nutritional formulations (the lower the moisture content of a foodstuff, the longer the shelf life). The dietary formulas exhibited the highest (P<0.05) extended shelf-life and stability in formula (2) compared to formula (1) and formula (3).

Color is one of vegetable products' most important quality attributes [56]. The color parameter values of differently prepared formulas samples were presented in table (3); lightness (L), redness (a), and yellowness (b) were significantly different (P<0.05) among the prepared sample. The table shows formulas (2) were slightly higher in lightness (L) than other treatments. However, formula (3) has the lowest value of (L) and recorded (81.51). Formula (3) recorded a moderate value (L) between formula (2) and formula (1), respectively. It can be concluded that the formula's color was primarily affected by the flour used for its production [57].

In the same table, the value of (a) ranged from 0.97 up to 2.33 in formula (2) and formula (1), respectively. The highest (P<0.05) value may be due to its germinated wheat flour and faba bean flour content. Yellowness (b), owing to its content of cooked lentil flour in formula (3), recorded the highest (P<0.05) value of (b). Formula (1) recorded the second order (26.40), but formula (2) recorded the lowest (P<0.05) value (25.05).

For quality control and process control, the rheological behavior of foods during processing is helpful. Additionally, viscosity is an important characteristic of liquid foods in many food preparation areas. This classification makes processing, quality control, sensory evaluation, and structural analysis easier [55].

The data in Table (3) demonstrated that the dietary formulas' apparent viscosity (CP) was reduced. (1) yielded the greatest (P0.05) value (5120), whereas (3) yielded the lowest (P0.05) value (4220). Procedures such as germination and soaking may contribute to the reduction in the perceived viscosity of formulations. The reduction in viscosity may be attributable to germination, soaking, and an increase in moisture and amylose; starch viscosity would be low at a high moisture content. The viscosity of composite flour prepared from germinated and soaked cereals is considerably reduced [58]. Variations in amylose content may account for variances in viscosity, where viscosity is inversely connected with amylose, and low amylose content of starch is associated with increased viscosity [59].

The rehydration properties, rate, and capacity are crucial aspects of numerous consumables concerning their final preparation [60]. The rehydration capacity of the dried product was utilized as a quality indicator [61]. When reconstituted, dried foods must exhibit acceptable textural, visual, and sensory qualities while minimizing rehydration time [62].

In the same table, addition of legumes affected the RR considerably (P0.05). Where faba bean supplementation (1) is 3.72, chickpea supplementation (2) is 3086, and lentil supplementation (3) is 3.79. Due to the drop in water quantity and water activity, rehydration has the greatest (P0.05) value of formula (2), 3.86, compared to formula (1) and formula (3). According to Rhim et al. [63], it may be due to the low initial moisture content. According to Joki et al. [60], items with a high rehydration capability are tastier and preserve their fresh appearance.

Amino acids are essential biological components for the human body's biosynthesis, neurotransmission, and other metabolic processes. Due to their rapid growth and undeveloped gastrointestinal function, infants have significant dietary requirements. Babies require the following amino acids: threonine, valine, leucine, isoleucine, lysine, tryptophan, phenylalanine, methionine, and histidine. Arginine and cystine are also required for babies with low birth weight [64].

Table (3). Physical and rheological properties of dietary formulas.

Properties	Formula 1	Formula 2	Formula 3
Physical tests			
Moisture Contents (%)	7.532±0.14a	6.634±0.13c	7.132±0.16b
Water Activity (aw)	0.42±0.01a	0.39±0.01b	0.41±0.01c
Water absorption index (%)	381.6±4.15a	346.3±5.12b	332.4±4.15c
Water soluble index (%)	40.32±0.84a	35.91±0.95b	32.14±0.74c
Color measurement			
L*	82.64±1.23b	83.60±2.01a	81.51±2.42c
a**	0.33±0.18c	0.97±0.13b	1.65±0.16a
b***	26.40±2.61b	25.05±3.01c	27.10±2.21a
Rheological tests			
Viscosity (CP)	5120±5.12a	4830±4.95b	4220±3.61c
Rehydration Ratio (RR)	3.72±0.12c	3.86±0.14a	3.79±0.11b

Data are displayed as mean±SD, and means in the same row subscribed by different letters are significant at P< 0.05.
L (lightness with L = 100 for lightness, and L = zero for darkness), a** [(chromaticity on a green (−) to red (+)], b***[(chromaticity on a blue (−) to yellow*

The composition of amino acids within the recipes is detailed in Table 4. All amino acids, both essential and non-essential, were found. As demonstrated, the essential amino acid composition of the formulae exceeded the amino acid profile of the FAO/WHO/UNU reference protein for infants aged 0.5 to 1 and 1 to 2 years [38].

Identified amino acids of dietary formulas are given in table (4) concerning the amino acid patterns of formulas; the analysis indicated that formula (3) was the highest content in leucine, aromatic amino acids (phenylalanine + tyrosine) g/100gm respectively. However, formula (3) had the lowest content in valine.

The results indicated that aspartic acid, glutamic acid, and arginine were the most abundant non-essential amino acids in the proteins of formula (1), formula (2), and formula (3), respectively (3).

The data in the same table showed that formula (2) has the highest valine, threonine, and histidine content. Formula (1) recorded the highest lysine, isoleucine, and total amino acid content.

These results agree that "the high protein content of legumes increases the protein content of cereal-based complementary foods and supplements the deficient amino acids" [65].

The findings of the sensory evaluation of dietary formulae and supplemental commercial foods are displayed in Table 5. The sensory evaluation of supplemental baby food formulations was regarded as one of the most influential tests on their acceptability [66]. Appearance, color, scent, flavor, mouthfeel, and overall acceptance differed significantly between the commercial and complementary products. Customers may be accustomed to consuming commercial products [39].

The tested samples were prepared in semisolid by adding a suitable amount of warm water. The sensory evaluation of prepared formulas was performed for appearance, color, aroma, taste, mouth feel, and over-acceptability out of (9). Results showed that appearance ranged from 7.64 up to 6.54 in formula (1) and formula (3), respectively, while the control (commercial product recorded (8.20). The nearest degree of taste was found in formula (1) compared to commercial products. The commercial product had the highest value of overall acceptability, followed by formula (1).

Table (4) Amino acids (g/100g) of the formulas

Properties EAA	Formula (1) A.A of g/100g	Formula (2) A.A of g/ 100g	Formula (3) A.A of g/ 100g	FAO/WHO/UNU reference protein [a]	
				(0.5–1 yr.)	(1–2 yr.)
Leucine	4.30	7.10	7.40	6.6	6.3
Valine	4.89	5.44	3.92	4.3	4.2
Lysine	9.54[b]	5.56[b]	5.73[b]	5.7	5.2
Isoleucine	7.46	3.92	4.15	3.2	3.1
AAA	2.63+4.80	4.91+3.91	5.0+4.08	5.2	4.6
SAA	4.30+1.37	1.89+1.35	1.60+2.61	2.8	2.6
Threonine	3.26	3.37	3.23	3.1	2.7
Histidine	5.14	5.66	2.40	2	1.8
Tryptophan	ND	ND	ND	0.85	0.74
Total E.A.A	47.69	43.11	40.12		
L.A.A	Lysine	Lysine	Lysine		
N.E.A.A					
Aspartic	10.08	9.85	9.56		
Serine	4.40	4.84	4.70		
Glutamic	20.20	18.0	20.90		
Glycine	4.70	4.11	4.25		
Alanine	4.65	4.96	5.18		
Arginine	5.90	9.30	7.34		
Proline	2.03	5.44	5.90		
T.N.E.A.A	54.71	59.82	50.29		

a. FAO/WHO/UNU reference protein for children 0.5 to 1 and 1 to 2 years of age [38].
b. First Limiting Amino Acid.
E.A.A.: Essential Amino Acids
N.E.A. A: Non-Essential Amino Acids
T.N.E.A. A: Total Non-Essential Amino Acids
A.A.A.: Aromatic Amino Acids (Phenylalanine +Tyrosine)
S.A.A.: sulfur Amino Acids (Methionine + Cystine)
L.A.A: Limiting Amino acids

Table (5). Sensory evaluation of the formula's complementary food and the complementary commercial food.

Properties	Formula 1	Formula 2	Formula 3	Commercial complementary food
Appearance (9)	7.642±0.43 a	7.201±0.53 b	6.542±0.21 b	8.241±0.54 a
Color (9)	6.723±0.51 b	6.351±0.42 c	5.863±0.38 c	8.324±0.72 a
Aroma (9)	6.624±0.53 b	6.621±0.51 b	5.734±0.46 c	8.262±0.63 a
Taste (9)	7.642±0.82 a	6.652±0.63 b	6.623±0.51 b	8.623±0.42 a
Mouth feel (9)	7.846±0.61 a	6.642±0.54 b	5.534±0.42 c	8.434±0.46 a
*OA (9)	7.412±0.37 b	6.531±0.46 b	5.723±0.61 c	8.612±0.51 a

**OA: Overall Acceptability*
Data are displayed as mean±SD and means in the same row subscribed by different letters are significant at P< 0.05.

4. Conclusion:

Formulating complementary food formulas includes using different materials, such as wheat, rice, barley, faba bean, chickpea, lentil, maltodextrin, pea nut, date powder, skimmed milk powder, carrot powder, and corn starch. Formula products have been fortified to enhance their nutritional properties via supplementing grains, legumes, fruits, vegetables, and sweeteners. According to the above results, it is clear that formula (1) is good quality compared to complementary commercial food.

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Conflict of interest

The author of this article has indicated that he has no conflicts of interest to disclose.

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