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DEVELOPMENT AND NUTRITIONAL EVALUATION OF ECONOMICAL WEANING FOODS BASED ON RICE, GERMINATED QUINOA, AND PUMPKIN

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ABSTRACT

When developing weaning food formulas, it is important to consider both economic cost and nutritional value. The current study aimed to develop weaning foods for infants using rice, germinated quinoa, and pumpkin flours; the physical-chemical and sensory properties, total caloric, minerals, and amino acid contents, as well as the protein quality, amino acid score, and protein efficiency ratio, were estimated for each ingredients and final products. Rice flour (RF) had higher levels of carbohydrates, energy content, calcium, and magnesium; germinated quinoa flour (GQF) had higher levels of protein, sodium, and potassium; and pumpkin flour (PF) had the highest levels of fat, iron, and zinc. The weaning food formula consisting of 40% RF, 50% GQF, and 10% PF (FW5) had a higher content of protein, fat, ash, and crude fiber compared to the control. The sensory qualities were unaffected by the 30% addition of GQF. The WF0 samples showed the higher bulk density, water absorption capacity, and swelling capacity, while, the FW5 was the lowest. Regarding the Recommended Daily Allowance (RDA) for infants, the WF3 formula (60% RF, 30% GQF, and 10% PF) can supply 75% protein, 49.30% fiber, 40.2% Ca, 52.1% MG, 29% Fe, 48.1% Zn, and 40% arginine. To prepare weaning food, this study recommended adding GQF up to 30% with 10% PF and 60% RF.

Keywords: Weaning foods, RDA, Amino acids, Protein biological value, Germinated quinoa

INTRODUCTION

According to the World Health Organization, breastfeeding should be the mainstay during the first six months of a child's life, with the possibility of gradually adding weaning foods until approximately two years of age **(WHO, 2019).** Weaning is defined as the process of gradually introducing foods other than breast milk into the baby's diet to provide essential nutrients and help in the gradual transition to an adult diet. In general, breast milk is often insufficient for rapid growth after the first six months of a baby's life, so appropriate weaning foods are introduced as a complementary and supportive factor for the baby's growth **(Sajilata *et al.*, 2002; Özogul and Hamed, 2018)**. Weaning is a critical period in an infant's life while many children may begin to suffer from malnutrition diseases, contributing to the increased prevalence of malnutrition in children less than five years of age **(WHO, 2018)**. Weaning foods should be puréed or semi-solid, precooked or well-processed and low in indigestible fiber so that babies can swallow and digest they easily, free from anti nutritional factors, rich in calories, proteins, fats, minerals (such as calcium, manganese, phosphorus, zinc, copper, and iron) and vitamins (such as riboflavin and thiamine) **(Abeshu *et al.*, 2016; Koletzko *et al.*, 2019; Oladiran and Emmambux, 2020)**. In contrast, inadequate nutritional quality or quantity of weaning foods has negative consequences for growth and mental development and increases morbidity and mortality rates among infants **(Nwosu *et al.*, 2014; Chuwa *et al.*, 2020)**. In most developing countries, weaning foods are based on root crops or staple grains, because high-quality commercial foods are expensive, inconsistent with the low incomes of households, and not always available. Therefore, there is an urgent need to find an alternative to commercial weaning foods with improved formulas using low-cost and locally available staple foods that allow families to feed their children **(Mkapa *et al.*, 2022)**.Therefore, the development of low-cost plant-based weaning foods is an adequate strategy, considering the availability and nutritional value of each crop **(Chuwa *et al.*, 2022)**. Rice (*Oryza sativa* L.) is the second-most main cereal crop in the world and the main source of nutrition for half of the world's population. Additionally to energy, rice is a rich source of minerals (such as phosphorus, magnesium, and calcium, as well as traces of iron, zinc copper, and manganese) **(Tamás *et al.*, 2009; Badawy *et al.*, 2022)**. Although rice is a relatively low-allergenic food, gluten-free, rice proteins are nutritionally insufficient for human nutrition due to the deficiency of some essential amino acids, which must be supplemented from other sources. Therefore, alternative protein-rich crops (such as quinoa) are needed as a supplement to rice flour in infant formulas (**Tzifi *et al.*, 2014; Venlet *et al.*, 2021**). The Food and Agriculture Organization (FAO) has listed quinoa (*Chenopodium Quinoa* Willd) as one of the most promising crops for humanity, due to its being a suitable solution to malnutrition problems such as protein insufficiency, in addition to its many distinct health benefits **(FAO, 2011)**. Quinoa is naturally gluten-free and is a useful source of hypoallergenic proteins, making it a suitable component for Infant formula **(EFSA Panel on Dietetic Products Nutrition and Allergies, 2014; Alvarez-Jubete *et al.*, 2010)**. In addition, quinoa contains considerable levels of thiamine, riboflavin, B6, niacin, magnesium, zinc, copper, potassium, and manganese **(Bhaduri, 2013)**. Also, quinoa exerts useful impacts on high-risk status consumers, such as lactose intolerance in children and the old, and patients with celiac disease, dyslipidemia, diabetes, anemia, and obesity **(Hernández-Ledesma, 2019)**. These beneficial health effects are due to quinoa's content of fatty acids, protein, vitamins, fiber, minerals, and various phytochemicals **(Navruz-Varli and Sanlier, 2016)**. As demonstrated by **Paśko *et al.* (2009)**, germinated seeds are among the best examples of functional foods that can be used to improve human health by lowering risk factors for many diseases. Particularly vitamins, amino acids, minerals, and phenolic compounds rise during the germination process, while some anti-nutritional elements like phytic acid, cyanogenic glycosides, oligosaccharides, and trypsin inhibitors fall in concentration **(Nkhata *et al.*, 2018; Demir and Bilgiçli, 2020)**. Pumpkin (*Cucurbita* sp.) belongs to the family of Cucurbitaceae and is widely grown through-out the world **(Dhiman *et al.*, 2009)**. Pumpkins are sweet when fully mature with yellow or orange flesh rich in carotene, vitamins, minerals and dietary fiber **(Sirohi *et al.*, 1991)**. Besides, as the amount of organic acids and cellular tissues are low in infants, they can be consumed to cure stomach and intestinal disorders **(Dhiman *et al.*, 2009; Chuwa and Dhiman, 2023)**. As a result of the nutritional properties and health impacts of pumpkin, it was used as a food additive in varied food products such as jam, weaning mix, crackers, candy, and bread, etc. **(Kaur *et al.*, 2020; Chuwa and Dhiman, 2023)**. This study aimed to prepare and evaluate a new economically weaning food containing rice flour, germinated quinoa flour, and pumpkin flour, and suitable for infants aged 6 to 24 months.

MATERIAL AND METHODS

Materials

Quinoa was obtained from The Crop Research Institute, Agricultural Research Center, Giza, Egypt. Rice and pumpkin were purchased from the local market of Alexandria, Egypt. All chemicals and reagents utilized in this study were of analytical grade.

Methods

Preparation of rice flour (RF)

Rice flour was prepared according to the method of **Bazaz *et al.* (2016)**. Rice was sorted to remove defective seeds, lumps of dirt, and small stones, washed using tap water, and soaked in water (1:3) for 3 hours at room temperature. After that, dried at 50˚C for 4 hours in a hot air oven dryer. Dried rice was milled using a mill (Moulinex AR1044, Frence), and sieved through a 40-mesh sieve, then kept at 4˚C in polyethylene bags until used.

Preparation of germinated quinoa flour (GQF)

Water was poured over the quinoa seeds at room temperature to wash away any dust, debris, or foreign objects. This process continued until the saponin bubble vanished and clean washing water was achieved. After soaking for 3 hours, the seeds were placed on wire grids covered with sterile cotton and gauze, and they were left to germinate in a controlled cabinet at 20±2°C and 80–90% relative humidity. The seeds were irrigated every 12 hours with sterile distilled water to keep the moisture content constant and prevent microbial contamination. After two days, the germinating stage was complete. Germinated seeds were dried for six hours at 45 °C in a hot air oven. The seeds were ground into whole grain flour with a 100% extraction ratio using an electric grinder (Moulinex AR1044, France), achieving a particle size of 40 mesh sieve. For additional analysis, germinated quinoa flour (GQF) was kept in glass containers at 4 °C using, with some modifications, the techniques outlined by **Demir and Bilgiçli (2020)**.

Preparation of pumpkin flour (PF)

After removing the rind, fibrous material, and seeds, the flesh was cut into slices (1-inch cubes) using a stainless steel knife, then, the pumpkin pieces cut into slices that were 1 mm thick. After that, they were dipped in 0.5% citric acid solution for 30 minutes, drained once more, and dried for 24 hours at 60 °C in a hot air oven dryer. After being dried and ground in an electric grinder (Moulinex AR1044, France), the pumpkin slices were sieved using a regular sieve with a mesh size of 40. An airtight container was used to store the flour **(Usha *et al.*, 2010)**.

Standardization of recipe for preparation of formulation weaning foods using rice, germinated quinoa and pumpkin flours

The main ingredient of the basic recipe was rice flour (RF). The amounts of germinated quinoa flour (GQF) varied, while pumpkin flour (PF) remained constant. Table 1 shows the six formulations that were developed for the weaning foods.

Table 1 Ingredients of weaning food formulations

Weaning food	RF	GQF	PF
WF0	100	-	-
WF1	80	10	10
WF2	70	20	10
WF3	60	30	10
WF4	50	40	10
WF5	40	50	10

RF: Rice flour; GQR: germinated quinoa flour; PF: Pumpkin flour

Preparation of weaning food formulations

Weaning foods were prepared using the method of **Opara *et al.* (2012)**. Fifty grams of weaning food blends were prepared by dissolving them in water (100 mL). After that, about 150 mL of boiling water was added to the suspension and heated for three to five minutes before being cooled.

Gross chemical composition and total caloric values

The AOAC procedures were used to determine the chemical composition (moisture, protein, fat, ash, and crude fiber) of weaning food ingredients and final products. Carbohydrate (NFE) content was calculated using the difference **(AOAC, 2023)**.

Total caloric values (K.Cal) of ingredients and the final weaning food products were calculated based on the method of AOAC **(AOAC, 2023)** using the following equation

Energy content (K.cal) = 4 × [protein (g) + carbohydrate (g)] + [9 × fat (g)]

The energy values contributed by protein, carbohydrate, fat, and the utilizable of energy due to protein (UEDP) were estimated as expressed by **Adeyeye (2013)** and **Sudik (2016)** as follow:

Percentage of energy attributed to protein [%] = %protein x 4 x 100/energy

Percentage of energy attributed to fat [%] = %fat x 9 x 100/energy

Percentage of The AOAC procedures energy attributed to protein carbohydrate [%] = %carbohydrate x 4 x 100/energy

Utilizable energy attributed to protein = %protein x 0.60

Determination of minerals

The minerals content of ingredients and final formulations (calcium (Ca), iron (Fe), potassium (K), sodium (Na), zinc (Zn), and magnesium (Mg)) was estimated in ash solution utilizing ICP-OES Agilent 5100 VDV (Santa Clara, USA) based on the AOAC protocol **(AOAC, 2023).**

Amino acid content and protein quality evaluation

The amino acid content of the ingredients and final weaning food formulations was estimated using the High Performance Amino Acid Analyzer **(AOAC, 2012).**

Amino acid score

The amino acid score (AAS) was estimated using the standard method recommended by the FAO **(FAO, 2013)** based on the following formula:

$$\text{AAS} = \frac{\text{mg of amino acid in g test protein}}{\text{mg of amino acid in the requirement pattern}}$$

Calculation of A/E ratio

Using the FAO procedure (FAO, 1965), the ratio between the individual essential amino acid content (A) and the total essential amino acid content (E) in food protein was calculated as follows:

$$\text{A/E ratio} = \frac{\text{mg essential amino acid in the food protein (A)}}{\text{g of total essential amino acid (E)}}$$

Protein efficiency ratio (PER)

To calculate the protein efficiency ratio, the formula given by **Alsmeyer *et al.* (1974)** was used:

PER= -0.684+ 0.456 x (Leucine) - 0.047 x (Proline) (g/100g protein)

Biological value (BV)

The biological value of protein was calculated using the equation given by **Oser (1959)**

BV= 49.09+10.53 x (PER).

Physical properties of weaning food formulations

Bulk density

Into a 10 mL measuring cylinder, A measured amount of weaning food formula was poured, and the volume was recorded to estimate the bulk density (weight per unit volume) using the procedure outlined by **Jangam and Thorat (2010).**

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{Mass of powder}}{\text{Initial volume of powder}}$$

Water absorption capacity (WAC)

The water absorption capacity (WAC) of the weaning food formulations was assessed utilizing the method of **Theresa *et al.* (2020).**

$$\text{WAC (g/g)} = \frac{\text{(Initial} - \text{Final solution volume) x Water density}}{\text{Original sample weight (g)}} x100$$

Swelling capacity

The following formula was used to evaluate the swelling capacities of weaning food formulations based on the **Theresa *et al.* (2020)** method:

$$\text{Swelling Capacity (\%)} = \frac{\text{Volume occupied by sample before swelling}}{\text{Volume occupied by sample after swelling}} x100$$

Color measurement of weaning food formulations

Using a Hunter Lab Ultra Scan (VIS model calorimeter, USA), color values such as the L* (lightness), a* (red intensity), and b* (yellow intensity) of weaning food formulations (WF0, WF1, WF2, WF3, WF4, and WF5) were measured. The mean of five measurements for each Hunter scale color index (L*, a*, and b*) was recorded by **Santipanichwing and Suphantharika (2007)**. Every sample measurement was conducted with a standardized instrument (L* = 94.1, a* = 1.12, b* = 1.26).

Sensory evaluation of weaning food formulations

The sensory properties (color, taste, odor, texture, mouth feel and overall acceptability) of weaning food formulations (WF0, WF1, WF2, WF3, WF4, and WF5) were evaluated according to the method of **Banach *et al.* (2014)** using twenty female and five male, staff members at the Food Technology Research Institute, Alexandria, Egypt., ranging in age from thirty to fifty-fives, based on the standard 9 point-hedonic scale (9= like extremely, and 1= dislike extremely).

Statistical Analysis

Using SAS statistical analysis software 2004, the one-way analysis of variance (ANOVA) was used for the statistical analysis of the current data. Duncan's test was used to compare means at a significance level of $P < 0.05$ (SAS, 2004).

RESULTS AND DISCUSSION

Gross chemical composition and energy content of raw ingredients

Table 2 compares the chemical composition and energy content of rice flour (RF), germinated quinoa flour (GQF), and pumpkin flour (PF). The results showed that the GQF had the highest protein content (19.5%), followed by the PF (14.81%), and the RF had the lowest protein content (6.9%). Conversely, the fat and moisture contents of PF were the highest (1.74% and 6.68%, respectively), while RF had the lowest (0.63% and 5.88%, respectively). On the other hand, Carbohydrate content was higher in the RF (85.71%) than in the PF (70.10%), and lowest in the GQF (66.54%). Between GQF and PF, there were no appreciable variations in ash (%) or crude fiber (%) (P>0.05). With RF, the higher energy content (376.14 Kcal/100 g) was achieved, and there were no discernible differences (P>0.05) between GQF and PF. Also, RF was the higher in Ca and Mg contents, while GQF was the highest in Na and K content. On the other hand, PF had the higher content in Fe and Zn followed by GQF, whereas, RF was the lowest. Conversely, RF had the lowest content of Fe and Zn, while PF had the highest content, followed by GQF. These findings are consistent with **Ibrahim (2022)** finding that carbohydrate accounts for approximately 82% of the dry matter in rice flour, with proteins making up 8.50%, lipids for 0.64%, and fibers for less than 0.5%. Because it has no allergic reactions and improves muscle thickness and strength, rice protein is a good substitute for whey protein **(Babault *et al.*, 2015; Health Canada, 2018)**.Quinoa is regarded as an alternative food because of its high nutritional content and variety of uses in food products, making it perfect for use by the food industry **(Vega-Gálvez *et al.*, 2010)**. Quinoa seed (pseudocereal) is a significant source of dietary fiber, minerals, vitamins, polyphenols, and hypoallergenic protein **(López-Alarcón *et al.*, 2019)**. Because it is naturally gluten-free, the **EFSA Panel on Dietetic Products Nutrition and Allergies (2014)** states that it is a suitable ingredient for infant formula (IF) and follow-on formula (FOF). Since starch makes up between 58.1 and 64.2% of the dry matter in quinoa seeds, it is a relatively high-calorie food **(Ribo-Carrasco *et al.*, 2003)**, and because of the high viscosity of quinoa starch, it can be used in certain industrial applications. The exceptional freeze-thaw stability of quinoa makes starch a perfect thickening agent for frozen foods and other applications where resistance to retrogradation is required **(Tang *et al.*, 2002)**. On the other hand, germination process significantly increased the ash content of quinoa flour. It's possible that the loss of dry matter (carbohydrate) during germination is the cause of this increase in ash content **(Demir and Bilgiçli 2020)**. According to **Abdellatif (2018)**, quinoa flour contained a balanced amount of magnesium, potassium, manganese, copper, iron, phosphorus, zinc, sodium, and calcium. The mineral content of GQF in this study is near to the USDA's report on the mineral content of quinoa **(USDA 2018)**. Thus, quinoa grain contains large quantities of minerals, mainly potassium (0.01-1200 g/100 g edible matter), phosphorus (140-530 g/100 g edible portion), magnesium (26.0-502.0 g/100 g), and calcium (27.5-148.7 g/100 g). Other minerals present in quinoa are iron (1.4-6.8 g/100 g), zinc (2.8-4.8 g/100 g), and copper (0.2-5.1 g/100 g) **(Vega-Gálvez *et al.*, 2010; USDA, 2018; Repo-Carrasco-Valencia *et al.*, 2010)**, these results are consistent with the results of the current study. Because of their greatest nutritional profile, ripe pumpkin fruit, pulp, and powder are excellent choices for promoting health. Along with carotenoids, ascorbic acid, vitamins, minerals, dietary fibers, zeaxanthin, and vitamin E, it also contains bioactive substances like linoleic acid, peptides, sterols, para-aminobenzoic acids, and polysaccharides which functions as an antioxidant in human nutrition. In addition to a healthy diet, these substances also prevent chronic diseases beyond basic nutrition **(Rodríguez *et al.*, 2018; Hussain *et al.*, 2022; Chuwa and Dhiman, 2023)**. A variety of nutrients are present in pumpkin power, according to **Chuwa et al. (2022)** moisture content (6.12%), total soluble solids (52.80%), total sugars (40.32%), reducing sugars (16.40%), crude protein (5.04%), crude fat (2.72%), crude fiber content (4.91%), total carbohydrate content (81.54%), ascorbic acid (10.26 mg/100 g), β-carotene values (10.77 mg/100 g), ash content (4.58%), and total energy of 351.16 Kcal/100 g, These results differ slightly from the results of this study which may be due to differences in cultivar, climatic factors, and fertilization. The pulp contain low amount of fat (2.3%), carbohydrates (66%), protein (3 %) and the carotenoid content about (171.9 mg/g) on dry weight basis **(Martha and Gutierrez, 2016)**.

Table 2 Chemical composition and energy content of rice, germinated quinoa, and pumpkin flours

Component	Rice flour (RF)	Germinated quinoa flour (GQF)	Pumpkin flour (PF)
Moisture (%)	5.88 ± 0.08^{c}	6.23 ± 0.21^{b}	6.68 ± 0.90^{a}
Protein (%)	6.90 ± 0.28^{c}	19.50 ± 0.17^{a}	14.81 ± 019^{b}
Fat (%)	0.63 ± 0.08^{c}	1.20 ± 0.02^{b}	1.74 ± 0.08^{a}
Ash (%)	0.51 ± 0.04^{b}	3.20 ± 0.09^{a}	3.29 ± 0.10^{a}
Crude fiber (%)	0.37 ± 0.10^{b}	3.24 ± 0.05^{a}	3.38 ± 0.06^{a}
Total carbohydrate (%)	85.71 ± 0.47^{a}	66.54 ± 0.16^{c}	70.10 ± 0.24^{b}
Energy content (Kcal/100 g)	376.14 ± 0.22^{a}	355.29 ± 0.94^{b}	355.31 ± 0.65^{b}
Minerals (mg/100g)			
Ca	235.83 ± 1.04^{a}	74.67 ± 0.57^{c}	180.33 ± 0.57^{b}
K	104.05 ± 1.88^{c}	570.33 ± 0.57^{a}	260.67 ± 0.57^{b}
Mg	240.33 ± 0.58^{a}	108.67 ± 0.58^{b}	60.33 ± 0.57^{c}
Na	50.33 ± 0.57^{c}	108.67 ± 0.57^{a}	60.33 ± 0.57^{b}
Fe	1.14 ± 0.16^{c}	5.73 ± 0.17^{b}	13.17 ± 0.16^{a}
Zn	0.96 ± 0.06c	2.41 ± 0.02^{b}	2.72 ± 0.20^{a}

Results are reported as mean ±SD of triplicate analysis. Means in the same row with different letters are significantly different (p<0.05).

Amino acid content

One of the most significant markers of a food's nutritional value is its amino acid content **(Raza *et al.*, 2019)**. Table 3a shows the amino acid content of rice flour (RF), germinated quinoa flour (GQF) and pumpkin flour. The results demonstrated that GQF contained a higher concentration of essential and nonessential amino acids. In the meantime, it was discovered that, aside from lysine, all essential and nonessential amino acids were higher in RF than PF. Also, the highest leucine: isoleucine ratio was found with RF (1.89:1) followed by GQF (1.64:1) while PF was the lowest (1.52:1). Table 3b presents the results of the amino acid score analysis for RF, GQF, and PF. It indicates that lysine was the first limit amino acid in RF, whereas methionine and phenylalanine were the first limit amino acids in GQF and PF, respectively. As opposed to this, the second limit amino acid in RF and PF was methionine, and the second limit amino acid in GQF was lysine. According to the data in Table 3C, the RF had the highest B.V. and PER (2.53 g, 75.54%), followed by the GQF (1.929 g, 70.08%), and the PF (0.459 g, 54.66%). The amounts of essential amino acids in protein define its nutritional quality. The current results are consistent with Ibrahim (2022) who found that the total amount of essential amino acids in rice is 2.08%, and the ratio of leucine to isoleucine was 1.92:1. Furthermore, non-essential amino acids were (2.41%). Additionally, rice contained 0.63 and 0.11% of total sulfur amino acids (TSAA) and total aromatic amino acids (TAAA), respectively. Also, **Ibrahim (2022)** demonstrated that lysine was the first and threonine was the second limiting amino acid in rice. It was discovered that rice had a lower content of methionine and histidine. FAO has acknowledged the potential use of quinoa in infant formula (IF) and follow-on milk (FOF) due to its excellent protein composition and amino acid balance, given the limited amino acids found in other protein sources, such as rice and soybean **(FAO, 2019; Dakhili *et al.*, 2019)**. Quinoa contains these in close enough proportions to meet the FAO's recommended ideal protein balance and is comparable to milk protein **(Balakrishnan *et al.*, 2022)**. Quinoa protein can provide more than 180 %

of the daily required intake of essential amino acids for adult nutrition, as per FAO/WHO recommendations (WHO, 2007). According to **López-Alarcón *et al.* (2019)**, and **Tirkey and Paul (2023)**, Quinoa protein is rich in lysine, threonine, and methionine—nutrients lacking in some cereals which differ from the results of the current study. However, **Abdellatif (2018)** reported that the total essential amino acids (TEAA) of Quinoa flour were 34.72, phenylalanine + tyrosine 6.09, leucine 5.95, and lysine 5.42g/100g protein. On the other hand, the total non-essential amino acids (TNEAA) were 39.66, glutamic 12.19, glycine 8.22, and aspartic 6.55g/100g protein. Also, it was found that the process of germination in cereals and legumes enhances their composition of amino acids and lysine, while also making them more easily absorbed by babies **(Nkhata *et al.*, 2018)**. **Takahashi *et al.* (2011)** reported that the sufficient quantity of both essential and non-essential amino acids, which are necessary for both bodily and mental functions, can be found in pumpkin fruit, and the current study is partially consistent with his results. The most abundant amino acid among the essentials is lysine, while glutamic acid is found in the case of the non-essentials **(Kim *et al.*, 2012)**. In partial agreement with the present results, **Tirkey and Paul (2023)** noted that the protein quality is assessed by measuring its biological value (BV), which links nitrogen uptake and nitrogen excretion to serve as an indicator of protein consumption for both human and animal sustenance. **Ibrahim (2022)** reports that rice flour has the lowest PER (1.74 g) and B.V. of protein (67.37%). In contrast, quinoa protein flour protein had 87.73% B.V. and 2.99 PER **(Abdellatif, 2018)**. According to Valencia-Chamorro (2003), 78%–93% PER of casein is present in raw, debittered quinoa, these percentages rise to 102%–105% of casein when the quinoa is cooked.

Table 3a Amino acids content of rice, germinated quinoa and pumpkin flours

Amino Acids (mg/g protein)	Rice flour (RF)	Germinated quinoa flour (GQF)	Pumpkin flour (PF)
Essential amino acids			
Threonine (THR)	2.2	6.1	2.1
Valine (VAL)	3.7	9.2	3.0
Isoleucine (ILE)	2.7	7.2	2.5
Leucine (LEU)	5.1	11.8	3.8
Phenylalanine (PHE)	3.0	7.8	1.7
Lysine (LYS)	2.4	9.9	2.5
Methionine (MET)	1.3	2.8	1.0
Histidine (HIS)	1.8	5.6	1.4
Total essential amino acids	22.2	60.4	18.0
Non-essential amino acids			
Aspartic (ASP)	6.0	15.2	6.8
Serine (SER)	2.7	5.6	2.6
Glutamic (GLU)	11.1	27.6	12.6
Glycine (GLY)	3.0	10.2	3.8
Alanine (ALA)	3.5	8.1	3.3
Tyrosine (TYR)	0.2	6.4	0.4
Arginine (ARG)	4.8	16.3	3.0
Proline (PRO)	2.3	6.6	1.1
Cystine (CYS)	1.7	4.6	1.2
Total non-essential amino acids	35.3	100.6	34.8
TAAA	3.2	14.2	2.1
TSAA	1.3	2.8	1.0
Leucine: Isoleucine ratio	1.89:1	1.64:1	1.52:1

Total Aromatic Amino Acids (TAAA) = Tyrosine + Phenylalanine, Total Sulfur-containing Amino Acid (TSAA) = Cystein + Methionine

Table 3b Amino Acid Score (AAS) of rice, germinated quinoa and pumpkin flours compared with FAO/WHO

Amino Acids	Amino Acid Score (AAS)			FAO/WHO pattern (2013)
	Rice flour (RF)	Germinated quinoa flour (GQF)	Pumpkin flour (PF)	
Threonine (THR)	118.09	115.86	52.55	27
Valine (VAL)	130.79	115.07	49.44	41
Isoleucine (ILE)	126.23	119.11	54.49	31
Leucine (LEU)	117.32	96.05	40.76	63
Phenylalanine (PHE)	94.52	86.96	24.97	46
Lysine (LYS)	66.89	97.63	32.48	52
Methionine (MET)	75.36	57.44	27.03	25
Histidine (HIS)	144.93	159.54	52.55	18
TAAA	100.82	158.31	30.84	46
TSAA	173.91	151.79	56.77	25
Limiting amino acids				
First	Lysine	Methionine	Phenylalanine	-
Second	Methionine	Lysine	Methionine	-

Total Aromatic Amino Acids (TAAA) = Tyrosine + Phenylalanine, Total Sulfur-containing Amino Acid (TSAA) = Cystein + Methionine

Table 3c The values of A/E, PER and B.V. of rice, germinated quinoa and pumpkin flours

Essential amino acids	**Rice flour (RF)**	**Germinated quinoa flour (GQF)**	**Pumpkin flour (PF)**
		A/E ratio	
Therionine (THR)	99.10	100.99	116.67
Valine (VAL)	166.67	152.32	166.66
Isoleucine (ISO)	121.62	119.21	138.89
Leucine (LEU)	229.73	195.36	211.11
Phenylalanine (PHE)	135.14	129.14	94.44
Lysine (LYS)	108.11	163.91	138.89
Methionine (MET)	58.56	46.36	55.56
Histidine (HIS)	81.08	92.72	77.78
PER (g)	2.53	1.92	0.45
B.V. (%)	76.54	70.08	54.66

A/E ratio: essential amino acid in the food protein (A)/total essential amino acids content (E) ratio, PER: protein efficiency ratio and B.V.: biological value.

Chemical composition of weaning food formulations

Table 4 lists the weaning food formulations' chemical composition and energy content. In comparison to all other formulations, it was discovered that the WF5 formula (40% RF, 50% GQP, and 10% PF) had the highest content of protein, fat, ash, crude fiber, and moisture, while the control formula (100 % RF) had the lowest. On the other hand, the control formula had the highest energy content (376.72 Kcal/100 g) and carbohydrate content (85.93%) of any formula. In contrast, as the amount of GQF in the formulations increased, the energy and carbohydrate contents significantly decreased ($P<0.05$). This is because, as Table 2 illustrates, RF had higher carbohydrate content, GQF had higher protein content, and PF had the highest levels of fat, ash, and crude fiber. In terms of the proportion of energy due to protein, fat and carbohydrates (Table 4), the results observed that the of the proportion of energy due to protein and fat in WF5 (15.25 % and 2.37%, respectively) was higher than the control (WF0) and this percentages increased with the increase of GQF in the formulations. On the other side, the WF0 was the higher in the proportion of energy due to carbohydrates, while WF5 was the lowest. Table 4 also showed that utilizable energy due to protein in WF5 (8.34) was higher than WF0 (4.11), and this value increased with the GQF increase in the formulations. The current results are consistent with the **Egyptian standard No. 3284 (2005)** which recommends that infant formula should have no more than 7% moisture content. Also, **El Gindy (2018)** discovered that the moisture content of PMQ weaning food which includes 60 % pre-cooked quinoa, 30% germinated pearl millet, and 10% orange-fleshed sweet potato flour was 7.45% compared to commercial weaning food (6.4%). Additionally, the present results agree with all of **Rim *et al.* (2021)**, results except for the ash content. He found that the moisture content of the weaning food formulation made with germinated cereals, pulses, and ground nuts ranged from 1.49 to 3.89, while the crude protein and fat ranged from 15.09 to 16.79, and 11.11-12.80, respectively, total ash from 2.06 to 2.21, and the carbohydrate content ranged from 65.9740 to 68.2641. The energy value was found to range from 431.68 to 449.18. The crude protein content (%) of the weaning food formula (WF5) in this study was close to the minimum protein requirement (14%) of the WHO/UN **(Rim *et al.,* 2021)**, and higher than the weaning formulations of maize-soybean (7.68 to 8.56) which reported by **Amankwah *et al.* (2009)**. Therefore, it can be concluded that, WF5 formula meet the minimum recommended daily allowances (RDA) for protein according to FAO/WHO recommendations **(FAO/WHO, 2010)**. **Jadhavar *et al.* (2022)** prepared a weaning food formulation using 37.5: 25:3 7.5 of finger millet, soaked rice, and germinated and roasted green gram flours, respectively, and found that The final formula's contents of carbohydrates, protein, fiber, fat, and energy were 65.20, 16.05, 3.0, 1.42, and 337.78, respectively, and these results contradict the results of the current study. **Demir and Bilgiçli (2020)** reported that the addition of quinoa flour by ration of 30 % increased the content of ash, fat, and protein in the pasta formulation from 0.81%, 0.49%, and 12.56% to 1.35%, 1.39%, and 16.65%, respectively. While, **Cannas *et al.* (2020)**, found that the substituting 25%, 50%, 75%, and 100% of rice flour (RF) with quinoa flour (QF) on the chemical-physical, nutritional, and sensory properties of ladyfinger biscuits. The nutritional profile of the biscuits was greatly enhanced by the substitution of QF for RF because of the rise in protein, lipid, ash, total soluble and insoluble polyphenol (IP), flavonoid, and antioxidant activity levels, all of which increased linearly with the rate of substitution. According to the results shown in Table 4, WF0 samples had the highest Ca and Mg values (234.74 and 239.85 mg/100 g, respectively), while WF5 samples had the lowest (149.33 and 155.99 mg/100 g, respectively). On the other hand, WF0 samples had the lowest K, Na, Fe, and Zn content, while WF5 samples had the highest (352.70, 80.28, 4.05, and 1.85 mg/100 g, respectively). These findings are in line with Table 2, which shows that RF had the highest Ca and Mg content, GQF the highest K and Na content, and PF the highest Fe and Zn content. For newborns and early children to have the best possible health, growth, and development, they must consume enough micronutrients like zinc, iron, and calcium **(Huffman *et al.,* 1994)**. The developed weaning food's calcium content is essential for the growth of teeth and bones, while the magnesium content is crucial for the preservation of nerve and muscle cells **(Eboagu *et al.,* 2020)**. According to the **WHO (2013)**, weaning food should contain 400–500 mg of calcium daily. Potassium aids in maintaining cell membranes, while iron is necessary to form hemoglobin, the pigment in red blood cells that carries oxygen throughout the body. Children who are iron deficient experience anemia **(Eboagu *et al.,* 2020)**. In contradict with the current study, **Jadhavar *et al.* (2022)** discovered that the weaning food, which is composed of soaked rice, germinated and roasted green gram and finger millet flours in a 25:37.5:37.5 ratio, has a concentration of 207, 9.36, 990, 126.28, 293, and 38.5 mg/100 g of Ca, Fe, K, Mg, P, and Na.

Table 4 Chemical composition and energy content of weaning food (WF) formulations

Component	**WF0**	**WF1**	**WF2**	**WF3**	**WF4**	**WF5**
Moisture (%)	5.78±0.03^{d}	5.86±0.08^{cd}	5.93±0.07^{bc}	6.00±0.02^{ab}	6.02±0.02^{ab}	6.04±0.05^{a}
Protein (%)	6.85±0.03^{f}	8.89±0.21^{e}	10.17±0.11^{d}	11.39±0.09^{c}	12.64±0.08^{b}	13.90±0.05^{a}
Fat (%)	0.62±0.04^{d}	0.79±0.01^{c}	0.82±0.01^{c}	0.89±0.01^{b}	0.93±0.05^{ab}	0.96±0.06^{a}
Ash (%)	0.49±0.07^{f}	1.00±0.01^{e}	1.27±0.05^{d}	1.48±0.05^{c}	1.79±0.01^{b}	2.01±0.02^{a}
Crude fiber (%)	0.33±0.06^{f}	0.90±0.02^{e}	1.16±0.06^{d}	1.49±0.05^{c}	1.80±0.07^{b}	2.02±0.06^{a}
Carbohydrate (%)	85.93±0.06^{a}	82.55±0.27^{b}	80.64±0.12^{c}	78.74±0.13^{d}	76.82±0.05^{e}	75.06±0.01^{f}
Energy content (Kcal/100 g)	376.72±0.26^{a}	372.89±0.20^{b}	370.67±0.56^{c}	368.55±0.05^{d}	366.24±0.07^{e}	364.52±0.71^{f}
Proportion of energy due to						
Protein [%]	7.27	9.54	10.98	12.36	13.81	15.25
Fat [%]	1.48	1.91	1.99	2.17	2.26	2.37
Carbohydrate [%]	91.24	88.55	87.02	85.46	83.90	82.37
Utilizable energy due to protein	4.11	5.33	6.10	6.83	7.58	8.34

Minerals (mg/100g)						
Ca	234.74±0.07^{a}	212.43±2.12^{b}	196.99±0.11^{c}	181.22±0.57^{d}	165.40±0.38^{e}	149.33±0.29^{f}
K	104.72±26^{f}	165.03±0.92^{e}	210.81±0.89^{d}	258.80±0.89^{c}	305.68±0.30^{b}	352.70±0.34^{a}
Mg	239.85±1.00^{a}	208.90±0.10^{b}	194.59±0.52^{c}	182.40±0.30^{d}	169.27±0.31^{e}	155.99±0.11^{f}
Na	50.22±0.22^{f}	55.67±0.98^{e}	62.79±0.17^{d}	68.40±0.40^{c}	74.09±0.10^{b}	80.28±0.22^{a}
Fe	1.09±0.11^{f}	2.64±0.05^{e}	3.00±0.03^{d}	3.33±0.04^{c}	3.72±0.06^{b}	4.05±0.02^{a}
Zn	0.93±0.06^{f}	1.23±0.04^{e}	1.36±0.06^{d}	1.54±0.02^{c}	1.71±0.01^{b}	1.85±0.01^{a}

WF0 (100% rice flour), WF1 (80% rice flour+10% germinated quinoa flour + 10% Pumpkin flour), WF2 (70% rice flour+20% germinated quinoa flour + 10% Pumpkin flour), WF3 (60% rice flour+30% germinated quinoa flour + 10% Pumpkin flour), WF4 (50% rice flour+40% germinated quinoa flour + 10% Pumpkin flour) and WF5 (40% rice flour+50% germinated quinoa flour + 10% Pumpkin flour)

Functional properties of weaning food formulations

The bulk density, water absorption capacity, and swelling capacity of weaning food formulations were presented in Figure (1). It was found that the sample containing 100% RF (WF0) was the higher in bulk density (0.618 g/cm3), water absorption capacity (1.42 g/g), and swelling capacity (1.64 mL /g), meanwhile, the FW5 was the lowest in these properties values. The results also showed that, following the addition of GQF, an increase in protein content was linked to a decrease in functional properties. The weight of a substance is measured by its bulk density; a lower bulk density improves the product's digestibility and is therefore nutritionally advantageous. Dietary energy content is increased when there is a decrease in bulk density because more flour particles can bind together. Food samples with lower bulk density readings allow for the best possible energy and nutrient content when prepared with less water **(Dilrukshi and Senarath, 2021)**. Furthermore, bulk density is influenced by a variety of characteristics such as solid material density, surface qualities, and particle shape and size. Cereal flour typically has a bulk density of 0.76–0.84 g/cm³. Both bulk and tapped densities influence inter-particulate interactions, which may restrict powder movement. By reducing the quantity of air trapped inside the powder, increasing its bulk density reduces the danger of oxidation and improves the powder's stability during storage **(Barba *et al.*, 2020)**. the current study in line with **Sadawarte *et al.* (2020)** who reported that the bulk density of weaning food sampled prepared with (60% rice flour, 5% carrot powder, 20% Horse gram Malt, 10% sugar, and 5% milk powder) ranged from 0.45 and 0.54 g/cm3, and disagreement with **Noman *et al.* (2021)**, who discovered that the developed weaning foods had bulk densities ranging from 0.57 to 0.75 g/cm^3 The amount of water that food or powder absorbs to give the finished product the appropriate texture and quality is measured by its water absorption capacity (WAC). It illustrates the ideal water content for dough before it gets overly sticky. Food quality can be negatively impacted by both excessive and insufficient WAC **(Godswill, 2019)**; moreover, the weight of the food or flour is used to express the amount of water absorbed. For example, 60% WAC means that 100 pounds of flour must be rehydrated using 60 pounds of water. Proteins and other hydrophilic ingredients in food draw water molecules to them. Differences in protein amounts, properties, and interactions with water can be linked to variations in WAC between various foods or flours **(Budnimath *et al.*, 2023)**. The low ability of the weaning food to bind and absorb water means the formation of a thinner porridge with a high-calorie density/unit volume **(Elkahalifa *et al.*, 2005)**. According to **Noman *et al.* (2021)**, formulas containing rice flour, soy flour, and wheat flour or soy flour, wheat flour, and malt extract had higher water absorption capacities than the weaning food formula containing malted soya flour, lentils, wheat flour, carrot powder, and peanuts. In agreement with **Naeem *et al.* (2020)**, the capacity of weaning food to absorb water was reduced when its protein content increased. Furthermore, less availability of polar amino acids in formulated products is linked to lower WAC. The milliliters of water that a single gram of food material can absorb during its expansion under particular circumstances is known as its swelling capacity. This depends on whether the food material is chopped, crushed, or whole and whether water or a suitable swelling agent is added **(Budnimath *et al.*, 2023)**. The strength of the associative forces inside starch granules is revealed by the water absorption and expansion capacities of starch as determined by swelling capacity. The ability of flours to swell is affected by variables like species variety, particle size, and processing techniques. **Budnimath *et al.* (2023)** found that the intricate structure of starch polysaccharides causes water to enter the material slowly, resulting in increased water retention and swelling. According to **WHO (2003)**, an appropriate weaning diet should yield a gruel that is neither too thin for the infant to consume nor too thick, as this will make it difficult for the infant to ingest and digest due to limited stomach capacity.

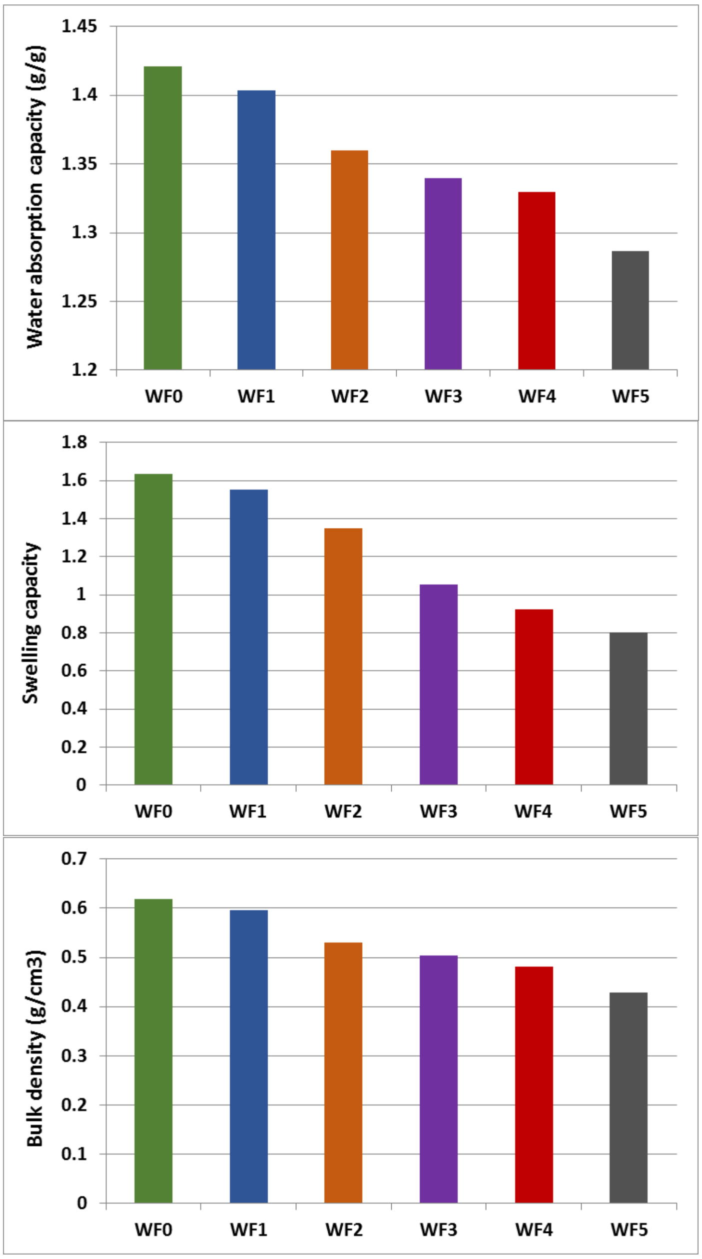

Figure 1 Functional properties of prepared weaning food formulations; WF0 (100% rice flour), WF1 (80% rice flour+10% germinated quinoa flour + 10% Pumpkin flour), WF2 (70% rice flour+20% germinated quinoa flour + 10% Pumpkin flour), WF3 (60% rice flour+30% germinated quinoa flour + 10% Pumpkin flour), WF4 (50% rice flour+40% germinated quinoa flour + 10% Pumpkin flour) and WF5 (40% rice flour+50% germinated quinoa flour + 10% Pumpkin flour).

Color measurements of weaning food formulations

The results in Table 5 showed that the weaning food formula with a higher GQF content (WF5) had lower redness and lightness values (67.17 and 0.52, respectively) than the WF0 (90.28 and 1.54, respectively). Conversely, the yellowness values increased significantly (P<0.05) as more GQF was added to the formulas; the WF5 formula showed the highest yellowness (31.42), compared to

10.18 in the control (WF0). The color of the final product can be influenced by the color of the raw material Unlike the findings of WF5 samples, **Demir and Bilgiçli (2020)** found that quinoa germination increased the amount of total phenolic content (TPC), which resulted in a brightness that may have an impact on the color of the final product, and the L* and b* values were lowered by adding more quinoa flour to the pasta recipe. This could be because quinoa flour has more protein and lysine than wheat semolina, which might result in an increase in the Maillard reaction during pasta drying and a drop in the product's L* value **(Prinyawiwatkul *et al.*, 1993)**. **Cannas et al. (2020)** found that partial or complete replacement of rice flour with quinoa flour in biscuits resulted in lower lightness and higher redness values. These outcomes are a result of quinoa flour increased protein content, which promotes non-enzymatic browning through the Maillard reaction, as well as its higher concentration of polyphenols and ashes, which have a direct effect on color.

Table 5 Color measurement of weaning food formulations

Weaning food formulation	Lightness (L*)	Redness (a*)	Yellowness (b*)
WF0	90.28±0.25^{a}	1.54±0.04^{a}	10.18±0.14^{f}
WF1	85.89±0.12^{b}	1.32±0.02^{b}	9.32±0.02^{e}
WF2	80.39±1.40^{c}	1.23±0.04^{c}	20.18±0.18^{d}
WF3	71.17±1.26^{d}	1.07±0.06^{d}	28.86±0.12^{c}
WF4	67.17±1.04^{e}	0.82±0.03^{e}	30.09±0.08^{b}
WF5	67.17±0.76^{e}	0.52±0.03^{f}	31.42±0.09^{a}

WF0 (100% rice flour), WF1 (80% rice flour+10% germinated quinoa flour + 10% Pumpkin flour), WF2 (70% rice flour+20% germinated quinoa flour + 10% Pumpkin flour), WF3 (60% rice flour+30% germinated quinoa flour + 10% Pumpkin flour), WF4 (50% rice flour+40% germinated quinoa flour + 10% Pumpkin flour) and WF5 (40% rice flour+50% germinated quinoa flour + 10% Pumpkin flour)

Sensory evaluation of weaning food formulations

Evaluating the sensory properties of a product in terms of colour, taste, smell, texture and appearance is very important to determine its consumer acceptability **(El-Sayed *et al.*, 2024)**. Even though the product has a high energy density and is appealing, it is unlikely to be accepted if it lacks good taste **(Mkapa *et al.*, 2022)**. Figure (2) shows the sensory characteristics (color, taste, texture, aroma, mouthfeel, and overall acceptability) of the weaning food formulations. The sensory characteristics of the weaning food formulations decreased significantly (P<0.05) as the amount of added GQF increased. In contrast, the best sensory properties were obtained with the WF0 formula followed by WF1, WF2 and WF3. These findings concur with those of **Cannas *et al.* (2020)**, who discovered that the replacing rice flour (RF) in lady biscuits with a high proportion of quinoa flour led to poor acceptability because of the presence of grassy and bitter tastes. **Jadhavar *et al.* (2022)** found that the weaning food is made of germinated and roasted green gram, soaked rice, and finger millet flours in a ratio of 37.5: 25: 37.5 received scores of 9, 8, 9, 8, 7, 8, and 9 for color, flavor, taste, aroma, texture (mouth feel), sweetness, and overall acceptability compared to the control. So, according to the sensory evaluation results the WF1, WF2, and WF3 formulas were selected to estimate the content of amino acids, compute the RDA (%), and determine nutrition facts with comparing them to the control (WF0) formula.

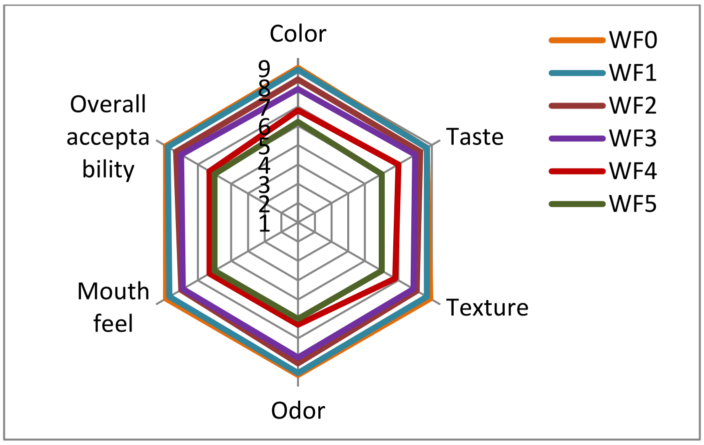

Figure 2 Sensory evaluation of weaning food formulations; WF0 (100% rice flour), WF1 (80% rice flour+10% germinated quinoa flour + 10% Pumpkin flour), WF2 (70% rice flour+20% germinated quinoa flour + 10% Pumpkin flour), WF3 (60% rice flour+30% germinated quinoa flour + 10% Pumpkin flour), WF4 (50% rice flour+40% germinated quinoa flour + 10% Pumpkin flour) and WF5 (40% rice flour+50% germinated quinoa flour + 10% Pumpkin flour).

Amino acids content of weaning food formulations

Table 6a, b, c. shows the amino acids content in some weaning food formulations (WF0, WF1, WF2, and WF3). The proportion of essential and non-essential amino acids increased significantly (P<0.05) with increasing amount of GQF added to weaning food formulas. The results discovered that WF3 was the highest in the content of essential and non-essential amino acids compared to the control (WF0) and all other formulations (FW1 and FW2). The nutritional value of a protein or protein mixture depends on the amount and proportion of essential amino acids provided by these proteins. The amounts of essential amino acids vary among proteins. **Reeds and Garlick (2003)** suggested that the issue of meeting protein requirements may be solved by providing essential amino acids in adequate proportions rather than increasing total protein intake. **El Gindy (2018)** states that nine amino acids (threonine, valine, leucine, isoleucine, lysine, tryptophan, phenylalanine, methionine, and histidine) have been determined to be vital for infants. Also, children's diets must contain arginine **(Rachwarosiak *et al.*, 2015)**. Additionally necessary for low birth weight babies are arginine and cysteine **(Behrma and Vaughan, 1983)**. Furthermore, according to **Perez-Conesa *et al.* (2002)**, Protein Efficiency Ratio (PER) is used to estimate the quality of protein by combining the essential amino acid score with digestibility during processing. **El Gindy (2018)** found that the PER of the PMQ formula 60:30:10 (pre-cooked quinoa, germinated Pearl millet, and orange-fleshed sweet potato flour) product and the commercial product were 2.80 and 2.42, respectively. Also, **Wadud *et al.* (2004)** reported that that the range of PER of some weaning food mixture was from 2.3 to 3.1.

Table 6a Amino acids content of weaning foods formulations

Amino Acids (mg/g protein)	WF0	WF1	WF2	WF3
Essential amino acids				
Threonine (THR)	2.1	2.4	2.8	3.2
Valine (VAL)	3.6	3.9	4.2	5.0
Isoleucine (ILE)	2.7	3.2	3.8	4.0
Leucine (LEU)	4.2	6.4	7.0	7.0
Phenylalanine (PHE)	2.9	3.6	4.1	4.2
Lysine (LYS)	2.3	3.7	4.2	4.5
Methionine (MET)	1.2	1.4	1.5	1.7
Histidine (HIS)	1.7	2.6	2.9	2.9
Arginine (ARG)	4.8	5.5	7.7	8.0
Total essential amino acids	25.5	32.7	38.2	40.5
Non-essential amino acids				
Aspartic (ASP)	5.9	7.0	7.8	8.4
Serine (SER)	2.7	3.2	3.3	3.5
Glutamic (GLU)	11.0	13.9	15.7	16.0
Glycine (GLY)	3.0	4.2	5.0	5.1
Alanine (ALA)	3.5	4.1	4.2	4.7
Tyrosine (TYR)	0.2	1.3	1.9	2.0
Proline (PRO)	2.3	2.9	3.1	3.3
Cystine (CYS)	1.7	2.1	2.4	2.5
Total non-essential amino acids	30.3	38.7	43.4	45.5
TAAA	3.1	4.9	6.0	6.2
TSAA	1.2	1.4	1.5	1.7

WF0 (100% rice flour), WF1 (80% rice flour+10% germinated quinoa flour + 10% Pumpkin flour), WF2 (70% rice flour+20% germinated quinoa flour + 10% Pumpkin flour) and WF3 (60% rice flour+30% germinated quinoa flour + 10% Pumpkin flour). Total Aromatic Amino Acids (TAAA) = Tyrosine + Phenylalanine, Total Sulfur-containing Amino Acid (TSAA) = Cystein + Methionine

Table 6b Amino Acid Score (AAS) of weaning food formulations compared with FAO/WHO

Amino Acids	**Amino Acid Score (AAS)**				**FAO/WHO pattern (2013)**
	WF0	**WF1**	**WF2**	WF3	
Threonine (THR)	113.54	99.99	101.97	104.06	27
Valine (VAL)	128.18	107.00	100.73	107.07	41
Isoleucine (ILE)	127.15	116.12	120.53	113.29	31
Leucine (LEU)	97.32	114.27	109.25	97.55	63
Phenylalanine (PHE)	92.03	88.03	87.64	80.16	46
Lysine (LYS)	64.57	80.04	79.42	76.00	52
Methionine (MET)	70.07	62.99	59.00	59.70	25
Histidine (HIS)	137.88	162.48	158.42	141.45	18
TAAA	98.38	119.82	128.25	118.33	46
TSAA	70.07	62.99	59.00	59.70	25

WF0 (100% rice flour), WF1 (80% rice flour+10% germinated quinoa flour + 10% Pumpkin flour), WF2 (70% rice flour+20% germinated quinoa flour + 10% Pumpkin flour) and WF3 (60% rice flour+30% germinated quinoa flour + 10% Pumpkin flour). Total Aromatic Amino Acids (TAAA) = Tyrosine + Phenylalanine, Total Sulfur-containing Amino Acid (TSAA) = Cystein + Methionine.

Table 6c The values of A/E, PER and B.V. of weaning food formulations

Essential amino acids	**WF0**	**WF1**	**WF2**	**WF3**
A/E ratio				
Therionine (THR)	101.45	88.24	91.80	98.46
Valine (VAL)	173.91	143.38	137.71	153.85
Isoleucine (ISO)	130.44	117.65	124.59	123.08
Leucine (LEU)	202.90	235.29	229.51	215.39
Phenylalanine (PHE)	140.10	132.35	134.43	129.23
Lysine (LYS)	111.11	136.03	137.71	138.46
Methionine (MET)	57.97	51.47	49.18	52.31
Histidine (HIS)	82.13	95.59	95.08	89.23
PER (g)	1.95	2.45	2.31	1.98
B.V. (%)	69.67	74.84	73.43	69.96

WF0 (100% rice flour), WF1 (80% rice flour+10% germinated quinoa flour + 10% Pumpkin flour), WF2 (70% rice flour+20% germinated quinoa flour + 10% Pumpkin flour) and WF3 (60% rice flour+30% germinated quinoa flour + 10% Pumpkin flour). A/E ratio: essential amino acid in the food protein (A)/total essential amino acids content (E) ratio, PER: Computed protein efficiency ratio and B.V.: Computed biological value.

Recommended daily allowance (RDA) of weaning food formulations

The information in Table 7 shows the recommended daily intake (%RDA) for WF0, WF1, WF2, and WF3 formulations and contrasts it with the RDA provided by the FAO and WHO. The main building element of body tissues is protein. The weaning food's formulation conforms to **Egyptian Standard No. 3284 (2005)** as well as the **Food and Nutrition Board (1989)** allowed levels of protein (15%).The RDA% of every amino acid increased significantly ($P<0.05$) with the addition of more GQF. When compared to the control and the other treatments (WF1 and WF2), it was found that WF3 performed the best across all amino acids. Furthermore, the WF3 samples' contents of arginine and histidine contribute 40% and 15.3% of RDA, respectively, while methionine contributes 7.7%. In terms of energy content, the **IOM (2004)** states that an infant's recommended daily allowance (RDA) for energy is 880 kcal. Weaning food fiber contents should be lowered to a maximum of 5 g/100 g **(Noman *et al.,* 2021)**. According to the Egyptian Organization for Standardization **(Egyptian Standard No. 3284, 2005)**, the ash content of vegetarian baby food fortified with milk should not exceed 3%.The **FAO/WHO (1994)** states that the amount of calcium in weaning foods must be at least 435.51 (mg/100g). Also, the **WHO (2013)** stated that 400–500 mg of calcium per day should be included in weaning food. Meanwhile, the recommendation of potassium intake for children is 750 mg/day **(Bresson *et al.,* 2016)**. According to the **IOM (2004)**, an infant's RDA for Fe is 11 mg/100g. Thus, the baby's daily Fe needs can be satisfied by the high iron content of formulated baby food. The WHO recommends 10–12.5 mg of iron per day for children between the ages of 6 and 23 months **(WHO, 2016)**. Conversely, a number of studies have documented the negative consequences of consuming large amounts of iron, such as stunted growth, interactions with copper and zinc, gut microflora transformation to pathogenic bacteria, and impaired cognitive development **(Alexeev *et al.,* 2017)**. Children who are iron deficient may experience anemia **(Dickinson and Schweizer, 2004)**. The FDA and the WHO have recommended 3.0 mg/100g of zinc as the recommended dietary allowance (RDA) for infants' food **(FAO/WHO 1998)**.

Table 7 Recommended daily allowance (RDA) of chemical composition met per 100g of prepared weaning food formulations

Nutrient	**RDA (g/100gm)**	**% of RDA**			
		WF0	**WF1**	**WF2**	**WF3**
Protein	≥15	45.7	59.3	67.8	75.9
Fat	10-25	2.3	2.9	3.0	3.2
Fiber	≤ 5	16.3	33.3	42.3	49.3
Ash	≤ 3	6.6	18.0	23.2	29.8
Carbohydrate	60–75	127.3	122.3	119.5	116.7
Energy (kcal)	880	42.8	42.4	42.1	41.9
Minerals (mg/1oo g)					
Ca	500	52.2	47.2	43.8	40.2
K	750	14.0	22.0	28.1	34.5
Mg	350	68.5	59.5	55.6	52.1
Na	400	12.6	13.9	15.7	17.1
Fe	10-12.5	9.7	23.5	26.7	29.6
Zn	3.20	29.1	38.4	42.5	48.1
Amino Acids (mg/g protein)					

Threonine	3.40	6.2	7.1	8.2	9.4
Valine	3.50	10.3	11.1	12	14.3
Isoleucine	2.80	9.6	11.4	13.6	14.3
Leucine	6.60	6.4	9.7	10.6	10.6
Phenylalanine	2.80	10.4	12.9	14.6	15.0
Lysine	5.80	4.0	6.4	7.2	7.8
Methionine	2.20	5.5	6.4	6.8	7.7
Histidine	1.90	9.0	13.7	15.3	15.3
Arginine	2.0	24.0	27.5	38.5	40.0

WF0 (100% rice flour), WF1 (80% rice flour+10% germinated quinoa flour + 10% Pumpkin flour), WF2 (70% rice flour+20% germinated quinoa flour + 10% Pumpkin flour) and WF3 (60% rice flour+30% germinated quinoa flour + 10% Pumpkin flour)

Nutrition facts of weaning food formulations

The nutrition facts of weaning food formulations (WF0, WF1, WF2, and WF3) shown in Table 8. The findings showed that, in comparison to all other formulations, the WF3 provided the highest daily value requirement (%) from protein, fat, fiber, minerals, and amino acids, while the control provided the lowest. WF3 (25 g) was found to supply 75.9% protein, 123% carbohydrate, 89.4% energy, 50.2% K, 48.1% Zn, 36.2% Ca and 20.8% Fe, meeting the daily value requirement (%).

Table 8 Nutrition facts of weaning food formulations

Nutrition Facts	WF0		WF1		WF2		WF3	
	Amount Per Serving*	% Daily Value	Amount Per Serving*	% Daily Value	Amount Per Serving*	% Daily Value	Amount Per Serving*	% Daily Value
Protein(g)	1.71	45.7	2.22	59.3	2.54	67.8	2.85	75.9
Fat (g)	0.155	3.5	0.20	4.5	0.205	4.7	0.223	5.1
Ash (g)	0.123	16.3	0.25	33.3	0.318	42.3	0.370	49.3
Fiber (g)	0.083	6.6	0.23	18.0	0.290	23.3	0.373	29.8
Carbohydrate(g)	21.48	134.3	20.64	129.0	20.16	126.0	19.69	123.0
Energy (Kcal)	94.18	91.3	93.22	90.4	92.67	89.9	92.14	89.4
Ca (mg)	58.69	47.0	53.11	42.5	49.25	39.4	45.31	36.2
K (mg)	26.18	20.3	41.26	32.0	52.70	40.9	64.70	50.2
Mg (mg)	59.96	315.6	52.02	273.8	48.65	256.0	45.60	240.0
Na (mg)	12.56	17.0	13.92	18.8	15.70	21.2	17.10	23.1
Fe (mg)	0.273	6.8	0.66	16.5	0.750	18.8	0.833	20.8
Zn (mg)	0.233	29.1	0.31	38.44	0.340	42.5	0.385	48.1
Threonine (mg)	0.525	1.5	0.600	1.8	0.700	2.1	0.8	2.4
Valine (mg)	0.900	2.6	0.975	2.8	1.05	3.0	1.25	3.6
Isoleucine (mg)	0.675	2.4	0.800	2.9	0.950	3.4	1.0	3.6
Leucine (mg)	1.05	1.6	1.60	2.4	1.75	2.7	1.75	2.7
Phenylalanine (mg)	0.725	2.6	0.900	3.2	1.03	3.7	1.05	3.8
Lysine (mg)	0.575	1.0	0.925	1.6	1.05	1.8	1.13	1.9
Methionine (mg)	0.300	1.4	0.350	1.6	0.375	1.7	0.425	1.9
Histidine (mg)	0.425	2.2	0.650	3.4	0.725	3.8	0.725	3.8
Arginine (mg)	1.20	6.0	1.38	6.9	1.93	9.6	2.0	10

WF0 (100% rice flour), WF1 (80% rice flour+10% germinated quinoa flour + 10% Pumpkin flour), WF2 (70% rice flour+20% germinated quinoa flour + 10% Pumpkin flour) and WF3 (60% rice flour+30% germinated quinoa flour + 10% Pumpkin flour). Serving Size 25g.

CONCLUSION

The weaning food formulations in the present study were based on locally available low-cost food materials commonly consumed in Egypt. The fact that these recipes are inexpensive, locally available and nutritious makes them potentially effective in solving some of the nutrition problems facing infants. The present study was conducted to develop cereal-vegetable-based weaning foods for infants and evaluate the nutritional quality of such types of foods. The results show that the three main components in the weaning food (RF, GQF, and PF) had a complementary relationship in terms of their contribution to the nutritional content of the final products. The results showed that the WF3 formula was the best in terms of covering the RDA of infants, while the control treatment was the best in terms of physical properties. Furthermore, it was discovered that the sensory qualities of weaning food formulations were unaffected by the addition of GQF up to a 30%. The study suggested adding GQF up to 30% with 10% PF and 60%RF when preparing weaning food.

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