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# Development and Optimization of a Quinoa–Barley-Based Complementary Food Using Natural Fruit Powders: Physicochemical and Sensory Evaluation

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**Abstract**
The present study aimed to develop a nutritionally enriched complementary (weaning) food using quinoa, barley, skimmed milk powder, date powder, and fruit powders as an alternative to conventional cereal-based infant foods. Multiple formulations were prepared by subjecting quinoa and barley flours to different pre-treatments, including roasting, roasting followed by drying, and cooking, to improve sensory quality and reduce bitterness. A total of forty-one formulations were developed with varying ingredient proportions and evaluated using a 9-point hedonic scale based on color and appearance, aroma, taste, texture, and overall acceptability. The optimized formulation (Sample 41), containing 16% cooked quinoa flour, 30% cooked barley flour, 26% skimmed milk powder, 8% date powder, and 10% each of apple and banana powders, exhibited the highest overall sensory acceptability. Proximate analysis of the optimized product revealed a moisture content of 0.10%, ash content of 2.50%, fat content of 5.50%, and protein content of 20.01 µg/mL. The particle size ranged from 75 to 200 µm, making the product suitable for infant consumption. The incorporation of quinoa, barley, fruit powders, and date powder significantly enhanced the nutritional and sensory characteristics of the complementary food. The developed formulation demonstrates potential as an affordable, nutrient-rich, and acceptable weaning food with scope for further evaluation through microbiological, shelf-life, and clinical studies before commercialization.

**Keywords:** Complementary food, Weaning food, Quinoa, Barley, Infant nutrition, Sensory evaluation, Proximate analysis, Functional foods.

## 1. INTRODUCTION

Weaning food allows children to start adapting to solid food as soon as they start chewing after six months. Milk cereal-based complementary food is easy to digest and provides nutrients lacking in breast milk. It gives infants a well-rounded diet with ingredients ranging from cereals to vegetables. It is recommended to serve infants weaning food from 6 months to 24 months of age (Kabeer, 2023).
Balanced nutrition is essential during infancy. Negligence can stunt physical growth, hamper brain development, and lead to underdeveloped immune systems. Feeding infants weaning food can help combat

malnutrition and other various ailments. Using fortified weaning food can protect infants from further health issues like anemia. (Glinz et al., 2017)

Sorghum is a major food crop primarily used as fodder. It is rich in protein, fiber, vitamin B1, B2, folic acid, calcium, phosphorus, iron, zinc, and sodium. Quinoa is rich in fiber, protein, nutrients, and antioxidant properties (Jillian et al., 2023). Another cereal widely used in the food industry is barley. It is a good source of protein, carbohydrates, phosphorus, and many other minerals. Since it doesn't have a lot of gluten, it is used in making semi-solid food like porridge (The Editors of Encyclopaedia Britannica, 2024). Date powder is a healthy alternative to sugar. It provides instant energy, improves brain health, and helps bones grow stronger (Admin, 2022). Additional fruit powders improve the overall color and taste of the composition.

## 2. REVIEW OF LITERATURE

### 2.1 Complimentary Feeding and Infant Nutrition

The period between **6 and 24 months of age** represents a critical phase in infant growth and development, during which breast milk alone is insufficient to meet the increasing nutritional requirements. Complementary feeding, commonly referred to as weaning, involves the gradual introduction of semi-solid and solid foods while continuing breastfeeding. Appropriate complementary feeding practices are essential for ensuring optimal physical growth, cognitive development, immune competence, and prevention of malnutrition. Inadequate complementary feeding during this period is strongly associated with protein-energy malnutrition, micronutrient deficiencies, stunting, wasting, impaired cognitive development, and increased susceptibility to infectious diseases.

The World Health Organization (WHO) and the Food Safety and Standards Authority of India (FSSAI) recommend introducing nutritionally balanced complementary foods after six months of age. Such foods should possess adequate energy density, high-quality protein, essential fatty acids, vitamins, minerals, and acceptable sensory characteristics while remaining safe, hygienic, affordable, and easy to digest. In addition to nutritional adequacy, complementary foods should exhibit desirable physicochemical and sensory properties to encourage regular consumption by infants and improve caregiver acceptance.

Several investigations have highlighted the importance of developing complementary foods using locally available cereals, legumes, pseudocereals, fruits, and dairy ingredients to improve nutritional security while reducing production costs. The incorporation of nutrient-rich indigenous ingredients can significantly improve dietary diversity and contribute towards combating childhood malnutrition, particularly in developing countries.

Kim (2019) emphasized that caregivers consider nutritional value, hygiene, affordability, convenience, and product safety as major determinants when selecting complementary foods. Similarly, Koo et al. (2018) reported that commercial infant foods often vary considerably in nutritional quality and recommended stricter nutritional profiling and product labeling to enable informed consumer choices. These observations underscore the need for scientifically developed complementary foods possessing balanced nutritional composition and superior sensory quality.

Micronutrient fortification has emerged as one of the most effective interventions to reduce nutritional deficiencies during infancy. A systematic review and meta-analysis by Csölle et al. (2022) demonstrated that fortified complementary foods significantly improve micronutrient status, reduce anemia prevalence, and enhance overall growth outcomes among infants aged 6–23 months. These findings indicate that

properly formulated complementary foods can substantially contribute toward improving childhood nutrition.
Despite the availability of numerous commercial weaning foods, affordability remains a major challenge in many developing countries. Consequently, researchers have increasingly focused on utilizing locally available cereal grains and pseudocereals to formulate nutritionally superior complementary foods with reduced production costs.

**2.2 Cereals and Pseudo cereals as Functional Ingredients in Complimentary Foods**

Cereals remain the primary source of carbohydrates in complementary foods because of their digestibility, availability, and cost-effectiveness. However, traditional cereal-based formulations often lack adequate protein quality and essential micronutrients. Consequently, researchers have explored the incorporation of pseudo cereals and other functional ingredients to improve nutritional quality.
Among pseudo cereals, **quinoa (*Chenopodium quinoa* Willd.)** has attracted considerable attention because of its exceptional nutritional composition. Unlike conventional cereals, quinoa contains high-quality protein with a balanced amino acid profile comparable to casein. It is particularly rich in lysine, methionine, and cysteine, amino acids that are generally limiting in cereal proteins. Quinoa also provides dietary fiber, unsaturated fatty acids, vitamins, minerals, and numerous bioactive compounds exhibiting antioxidant activity.
El-Sohaimy et al. (2018) reported that quinoa possesses excellent functional properties, including high water absorption capacity, emulsifying ability, and nutritional density, making it an attractive ingredient for infant complementary foods. Furthermore, quinoa is naturally gluten-free, allowing its incorporation into specialized foods intended for infants with gluten intolerance or celiac disease. Nevertheless, quinoa contains naturally occurring saponins that impart bitterness, necessitating appropriate processing techniques before incorporation into food products.
Sorghum has also been extensively investigated for complementary food development because of its nutritional value and climate resilience. Sorghum provides substantial amounts of carbohydrates, protein, dietary fibre, minerals, and antioxidant phytochemicals. Akin et al. (2022) highlighted that sorghum contains various phenolic compounds capable of exerting antioxidant activity while contributing to improved nutritional quality. However, sorghum also contains tannins and other phenolic compounds that may adversely affect flavour and reduce protein digestibility if not adequately processed.
Barley has recently gained attention owing to its unique composition, particularly its high concentration of β-glucan soluble fibre. Zhang et al. (2022) demonstrated that barley consumption contributes to improved gastrointestinal health, glycemic regulation, cholesterol reduction, and cardiovascular protection. In complementary foods, barley enhances porridge consistency, improves mouthfeel, and contributes valuable minerals and dietary fibre. The relatively mild flavour profile of barley further improves its suitability for infant foods compared with certain bitter cereal grains.
Several researchers have explored cereal combinations to improve protein quality and nutritional density. Gindy (2018) reported that complementary foods formulated from quinoa, pearl millet, and sweet potato exhibited enhanced nutritional composition, improved antioxidant capacity, and satisfactory storage stability. Likewise, Abiose et al. (2015) demonstrated that fortification of maize-based complementary foods with soybean flour substantially improved protein quality, mineral content, and growth-promoting potential.
Similarly, Nwakalor (2014) developed sorghum-based complementary food fortified with soybean and unripe plantain flour and reported significant improvements in sensory acceptability, protein quality,

mineral composition, and iron availability. These studies collectively demonstrate that blending multiple cereal and non-cereal ingredients offers considerable opportunities for improving nutritional quality while maintaining acceptable sensory characteristics.

Research Gap: Although previous investigations have successfully demonstrated the nutritional advantages of quinoa, barley, sorghum, and fruit-based fortification individually, very limited research has systematically evaluated the combined influence of **processing techniques (roasting, drying, and cooking)** together with **fruit powder incorporation** on the sensory and physicochemical quality of quinoa–barley-based complementary foods. Furthermore, most published studies have focused primarily on nutritional enhancement, with comparatively fewer investigations optimizing flavour, aroma, texture, and overall consumer acceptability.

Therefore, the present study aimed to develop and optimize a complementary food using quinoa, barley, skimmed milk powder, date powder, and natural fruit powders through sequential processing interventions, followed by comprehensive sensory evaluation and physicochemical characterization to identify a formulation suitable for infant nutrition.

## 3. MATERIALS AND METHODOLOGY

### 3.1 Methodology

The mix was formulated using quinoa flour by varying the sorghum and barley flour.

#### 3.1.1 Unroasted sorghum and quinoa flour

The mix was prepared using unroasted sorghum and quinoa flour. Sorghum flour (SF), quinoa flour (QF), milk powder (MP), and date powder (DP) were used. Table 3.1 shows the ratio of different ingredients used for the formulation.

**Table 3.1. Formulation with unroasted sorghum and quinoa flour**

| (Per 100 g) | B1 (g) | B2 (g) | B3 (g) | B4 (g) | B5 (g) | B6 (g) | B7 (g) | B8 (g) |
|---|---|---|---|---|---|---|---|---|
| **SF** | 40 | 50 | 40 | 50 | 35 | 40 | 60 | 45 |
| **QF** | 40 | 30 | 40 | 30 | 35 | 30 | 30 | 30 |
| **MP** | 10 | 10 | 15 | 15 | 15 | 15 | 5 | 10 |
| **DP** | 10 | 10 | 5 | 5 | 15 | 5 | 5 | 15 |

**B: batch**

#### 3.1.2 Roasted sorghum and quinoa flour

Eight trials were made using roasted sorghum and quinoa flour. Sorghum and quinoa flour were roasted for 3 minutes on a low flame (over the stove on a skillet). The timing was based on the flour's change in color and aroma upon roasting (Maillard's reaction). Roasted sorghum flour (RS), Roasted quinoa flour (RQ), Milk powder (MP), and date powder (DP) were used. A sensory analysis was also conducted. Table 3.2 shows the ratio of different ingredients used for the formulation.

**Table 3.2. Formulation with roasted sorghum and quinoa flour**

| (Per 50 g) | B9 (g) | B10 (g) | B11 (g) | B12 (g) | B13 (g) | B14 (g) | B15 (g) | B16 (g) |
|---|---|---|---|---|---|---|---|---|
| **RS** | 20 | 25 | 20 | 25 | 17.5 | 20 | 30 | 22.5 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **RQ** | 20 | 15 | 20 | 15 | 17.5 | 15 | 15 | 15 |
| **MP** | 5 | 5 | 7.5 | 7.5 | 7.5 | 7.5 | 2.5 | 5 |
| **DP** | 5 | 5 | 2.5 | 2.5 | 7.5 | 7.5 | 2.5 | 7.5 |

**B: batch**

### 3.1.3 Roasted quinoa flour and barley flour

Since the bitterness remained, sorghum was removed and replaced by barley. For the next set of trials, Roasted quinoa flour (RQ), barley flour (BF), Milk powder (MP), and Date powder (DP) were used. Quinoa flour was roasted for 7 minutes on a low flame until the color and aroma changed. Table 3.3 shows the ratio of different ingredients used for the formulation.

**Table 3.3. Formulation with roasted quinoa and barley flour**

| (Per 50 g) | B17 (g) | B18 (g) |
|---|---|---|
| **MP** | 20 | 20 |
| **RQ** | 7.5 | 15 |
| **DP** | 2.5 | 5 |
| **BF** | 20 | 10 |

**B : batch**

### 3.1.4 Roasted quinoa flour, barley flour, and fruit powders

Fruit powders were added to improve the flavor. Apple (A) and banana (B) powders were used. The flavors were apple, banana, and a combo of apple & banana for B19, B20, and B21, respectively. Table 3.4 shows the ratio of different ingredients used for the formulation.

**Table 3.4. Formulation with roasted quinoa flour, barley flour, and fruit powders**

| (Per 100 g) | B19 (g) (A) | B20 (g) (B) | B21 (g) (A+B) |
|---|---|---|---|
| **MP** | 40 | 40 | 40 |
| **RQ** | 30 | 30 | 30 |
| **DP** | 7 | 7 | 7 |
| **FP** | 7 | 7 | 3.5+3.5 |
| **BF** | 16 | 16 | 16 |

**B : batch**

### 3.1.5 Roasted quinoa flour, roasted barley flour, and fruit powders

To further improve the flavor and remove the bitterness, roasted barley flour (RB) was used. Barley flour was roasted for 7 minutes on a low flame until the aroma and color changed). The fruit powders (FP) used were apple (A) and banana (B). The flavors were apple, banana, and a combo of apple & banana for B22, B23, and B24, respectively. Table 3.5 shows the ratio of different ingredients used for the formulation.

**Table 3.5. Formulation with roasted quinoa flour, roasted barley flour, and fruit powders**

| (Per 100 g) | B22 (g) (A) | B23 (g) (B) | B24 (g) (A+B) |
|---|---|---|---|
| **MP** | 40 | 40 | 40 |

| | | | |
|---|---|---|---|
| **RQ** | 20 | 20 | 20 |
| **DP** | 8 | 8 | 8 |
| **FP** | 12 | 12 | 6+6 |
| **RB** | 20 | 20 | 20 |

**B : batch**

According to the sensory analysis, the mix of apple and banana tasted better. For samples 17-24, the sensory evaluation was performed by the student and guide.

**3.1.6 Roasted quinoa flour, roasted barley flour, and fruit powders (with limits)**

Ten more variations were made, with limits set for the ingredients. A sensory evaluation was conducted for the new set of variations. The set limits for the variations are roasted quinoa flour: 15-20 %, milk powder: 25-35 %, date powder: 8 %, roasted barley flour: 25-35 %, and fruit powder (apple and banana): 10-15 %. Table 3.6 shows the ratio of different ingredients used for the formulation.

**Table 3.6. Formulation with roasted quinoa flour, roasted barley powder, and fruit powders (with limits)**

| (Per 100 g) | B25 (g) | B26 (g) | B27 (g) | B28 (g) | B29 (g) | B30 (g) | B31 (g) | B32 (g) | B33 (g) | B34 (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| **RQ** | 15 | 17 | 20 | 18 | 16 | 19 | 20 | 16 | 16 | 20 |
| **MP** | 32 | 35 | 30 | 30 | 28 | 30 | 25 | 31 | 33 | 26 |
| **RB** | 30 | 25 | 27 | 33 | 34 | 30 | 35 | 35 | 33 | 32 |
| **Apple** | 7.5 | 7.5 | 7.5 | 5.5 | 7 | 6.5 | 6 | 5 | 5 | 7 |
| **Banana** | 7.5 | 7.5 | 7.5 | 5.5 | 7 | 6.5 | 6 | 5 | 5 | 7 |
| **DP** | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |

**B : batch**

Samples 26, 27, 29, 30, 31, 32, and 33 were acceptable.

**3.1.7 Roasted and dried quinoa and barley flour with fruit powders (with limits)**

Further processes were done to remove the bitterness of the samples. Quinoa flour and barley flour were roasted until the aroma and color changed. Quinoa flour (RQ) was roasted for 7 minutes on a low flame, whereas barley flour (RB) was roasted for 8 minutes on a low flame. The roasted flours were then made into dough balls, which dried in the cross-flow tray dryer (for about 3 hours at 60-62 $^{o}$ C) and ground into powder. Apple (A) & banana (B) fruit powders, skimmed milk powder (MP), and date powder (DP) were also used. A sensory analysis was conducted. Table 3.7 shows the ratio of different ingredients used for the formulation.

**Table 3.7. Formulation with roasted and dried quinoa flour, roasted and dried barley flour, and fruit powders (with limits)**

| (Per 50 g) | B35 (in g) | B36 (in g) | B37 (in g) | B38 (in g) | B39 (in g) |
|---|---|---|---|---|---|
| **RQ** | 10 | 8 | 8 | 8 | 10 |
| **MP** | 15 | 14 | 15.5 | 16.5 | 13 |
| **RB** | 13.5 | 17 | 17.5 | 16.5 | 16 |
| **A** | 3.75 | 3.5 | 2.5 | 2.5 | 3.5 |
| **B** | 3.75 | 3.5 | 2.5 | 2.5 | 3.5 |

| | | | | | |
|---|---|---|---|---|---|
| **DP** | 4 | 4 | 4 | 4 | 4 |

**B : batch**

**3.1.8 Cooked quinoa and barley flour with fruit powders (with limits)**

Since roasting the flour didn't remove the bitterness, further cooking of quinoa flour (QF) and barley flour (BF) was done. 100 g of flour and 500 ml of water were made into a slurry. The slurry was cooked for 5-7 mins on a low flame until a sticky mass was formed. The mass was then placed on a tray and kept in a dryer at 60 º C for about 14 hours (until completely dry). The dried, cooked mass of quinoa and barley was ground into powder using the hammer mill. Apple (A) and banana (B) fruit powders, skimmed milk powder (MP), and date powder (DP) were also used. Table 3.8 shows the ratio of different ingredients used for the formulation.

**Table 3.8. Formulation with cooked quinoa flour, cooked barley flour, and fruit powders (with limits)**

| (Per 50 g) | B40 (g) | B41 (g) |
|---|---|---|
| **QF** | 8 | 8 |
| **MP** | 16.5 | 13 |
| **BF** | 16.5 | 15 |
| **A** | 2.5 | 5 |
| **B** | 2.5 | 5 |
| **DP** | 4 | 4 |

**B : batch**

A sensory evaluation was performed between samples 35, 36, 38, 40, and 41 (the samples were chosen based on their score through the 9-point hedonic scale).
Sample 41 was chosen as the optimized sample (score based on the 9-point hedonic scale).

### 3.2 Sensory evaluation

Sensory evaluation was conducted to determine the acceptability of the developed complementary food formulations and to identify the optimized product based on consumer preference. A 9-point hedonic scale was employed to evaluate the sensory characteristics of each formulation. The attributes assessed included colour and appearance, aroma, taste and flavour, texture, and overall acceptability, where a score of 9 represented "Like Extremely" and 1 represented "Dislike Extremely."
Initially, formulations containing unroasted sorghum and quinoa flour (B1–B8) were evaluated. Based on the sensory scores, modifications were made by roasting the flours to improve flavour development through the Maillard reaction and reduce the raw cereal flavour. Subsequently, sorghum was replaced with barley because the roasted sorghum formulations continued to exhibit a noticeable bitter aftertaste.
Further optimization involved incorporating natural fruit powders (apple and banana) and date powder to improve sweetness, aroma, flavour, and colour while enhancing nutritional quality. Different processing techniques, including roasting, roasting followed by drying, and cooking of quinoa and barley flour, were evaluated to determine their effect on sensory quality.
The final comparison was performed among the most acceptable formulations (B35, B36, B38, B40, and B41), and the optimized formulation was selected based on the highest overall acceptability score.

Commercial based food was served as the control product for comparison throughout the sensory evaluation.

The optimized formulation (Sample 41) consisted of 16% cooked quinoa flour, 30% cooked barley flour, 26% skimmed milk powder, 8% date powder, 10% apple powder, and 10% banana powder, which achieved the highest sensory scores across all evaluated attributes.

### 3.3 Proximate Analysis

Proximate analysis was performed to determine the nutritional composition of the sample. The sample's moisture, ash, fat, and protein content were measured.

#### 3.3.1 Determination of Moisture Content (AOAC official method 925.09)

A dry, clean Petri plate was taken and weighed. Then, 10 g of the sample was placed onto the Petri plate, and the total weight was recorded. The Petri plate was placed into a hot air oven set at 105˚C for 2 hours until a constant weight was achieved.

The moisture content was calculated using the formula:

$$\text{Moisture content } (\%) = \frac{W_1 - W_2}{W_1 - W} \times 100$$

Where:

$W_1$ = weight in g of the dish with the materials before drying

$W_2$ = weight in g of the dish with the materials after drying

W = weight in g of the empty dish

#### 3.3.2 Determination of Ash Content (AOAC official method 923.03)

Two grams of the sample from the moisture analysis was weighed into a crucible. A muffle furnace was used for incinerating the sample at 550˚C - 600 ˚C for 2 hours until it completely oxidized. After cooling, the crucible and residue were weighed.

The initial and final weight values were put into the formula to determine the ash content.

$$\text{Total ash (\% by weight dry basis)} = \frac{W_2 - W}{W_1 - W} \times 100$$

Where:

W = Mass in g of empty dish

$W_1$ = Mass in g of the dish with the dried material (moisture-free) taken for the test

$W_2$ = Mass in g of the dish with the ash

#### 3.3.3 Determination of Fat Content (Soxhlet method)

Five grams of sample was taken, placed on tissue paper, and folded. The tissue paper was placed in a thimble and inserted into the Soxhlet apparatus. The weight of a 150 mL round-bottomed flask was taken. Hexane/petroleum ether was added into the flask and attached to the extractor. The condenser was attached, and the water bath was turned on. The extraction lasted 6-8 hours, at a rate of 8-10 cycles per hour. The round-bottomed flask was removed, and the remaining solvent was evaporated in a rotavapor. After solvent evaporation, the remaining mass was weighed.

Fat content was determined using the following formula:

$$\text{Fat content } (\%) = \frac{W_2 - W_1}{W_s} \times 100$$

Where:

$W_S$ = weight of the sample (in g)

$W_1$ = weight of the flask (in g)
$W_2$ = weight of the flask with fat (in g)

**3.4 Determination of Protein by Lowry's method (Lowry et al., 1951)**
*Reagent preparation:*
*Reagent A:* 2% sodium carbonate in 0.1 N sodium hydroxide.
*Reagent B:* 0.5% copper sulphate (CuSO4.5H2O) in 1% potassium sodium tartrate. Prepare fresh by mixing stock solutions.
*Alkaline copper solution (Reagent C):* Mix 50 mL of reagent A and 1 mL of reagent B before use.
*Diluted Folin's reagent (Reagent D):* Dilute Folin-Ciocalteau reagent with an equal volume of 0.1 N NaOH
*Standard:* Dissolve 50mg BSA in 50 mL of distilled water in a volumetric flask. Take 10 mL of this stock standard and dilute to 50 mL in another flask for a working standard solution.
Procedure:
A standard working solution of 0.2, 0.4, 0.6, 0.8, and 1 ml was pipetted into the labelled test tubes. 1 mL of the sample was pipetted out in another test tube. The volume was made up to 1 mL in all the test tubes. A tube with 1 mL of distilled water served as the blank. Now, 5 mL of reagent C was added to all the test tubes, including those labelled 'blank' and 'unknown.' The contents of the tubes were mixed by vortexing / shaking the tubes and allowed to stand for 10 min. Then 0.5 mL of reagent D was added rapidly with immediate mixing and incubated at room temperature in the dark for 30 min. The absorbance at 660 nm against blank was recorded. Then, the standard curve was plotted by taking the protein concentration along the X-axis and absorbance at 660 nm along the Y-axis. Then, from this standard curve, the concentration of protein in the given sample was calculated.

## 4. RESULTS AND DISCUSSION

The product was optimized based on the sensory attributes. Trial 41 has a composition of quinoa (16%), barley (30%), skimmed milk powder (26%), date powder (8%), apple powder (10%), and banana powder (10%) was thus chosen as the optimized sample.

**4.1 Proximate Analysis of the optimized weaning food**

The particle size was analyzed using the sieve. It ranged from 75 – 200 µm. The proximate analysis result is shown in Table 4.1. The protein content was estimated using Lowry's method. Figure 4.1 shows the standard BSA curve.

**Table 4.1 Proximate analysis of the optimized product**

| Sn | Parameters | Result |
|---|---|---|
| 1 | Moisture content (%) | 0.1 |
| 2 | Ash content (%) | 2.5 |
| 3 | Total fat (%) | 5.5 |
| 4 | Protein content (ug/ml) | 20.01 |

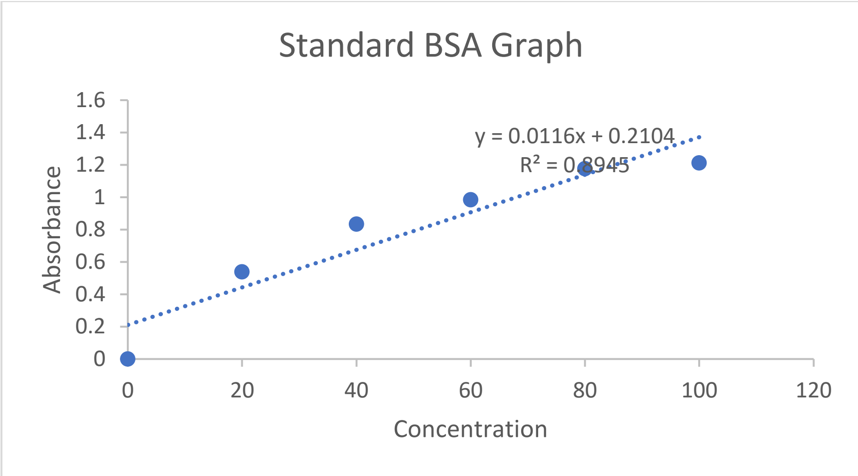


**Figure 4.1 Standard BSA graph**

### 4.2 Sensory analysis

Upon analyzing the scores received for each sample, number 41 was deemed the optimized sample.

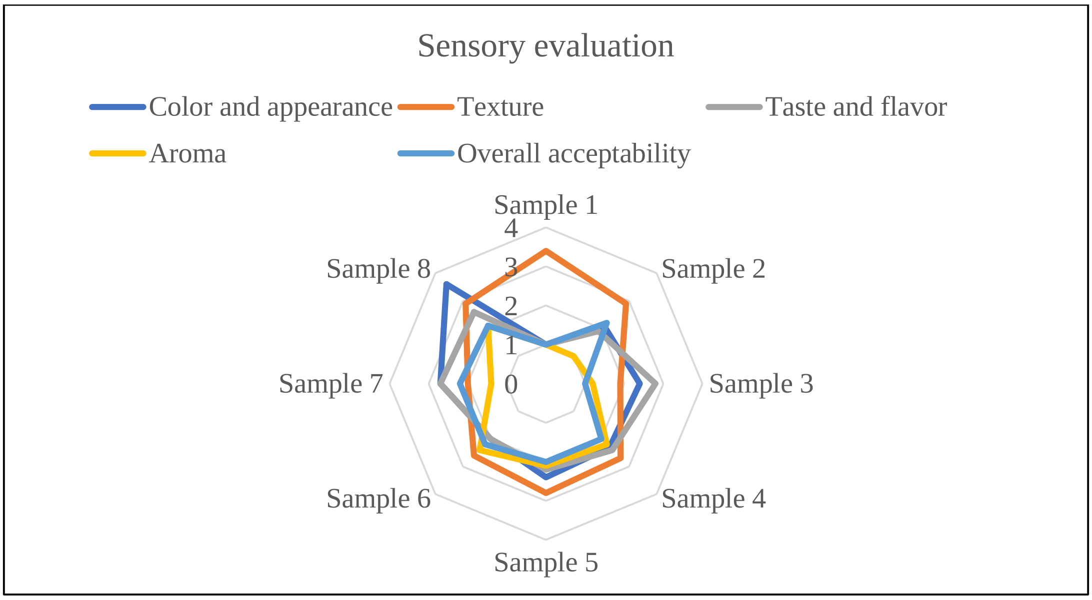


**Figure 4.2 Sensory evaluation for formulation with unroasted sorghum and quinoa flour**

Sample 1 had a higher rating for texture. Coming to taste and flavor, sample 3 had a higher rating. Sample 6 had a higher rating for aroma. For color and appearance, sample 8 had a higher rating. Overall, in terms of aroma, appearance, taste, and texture sample 8 was deemed more acceptable.

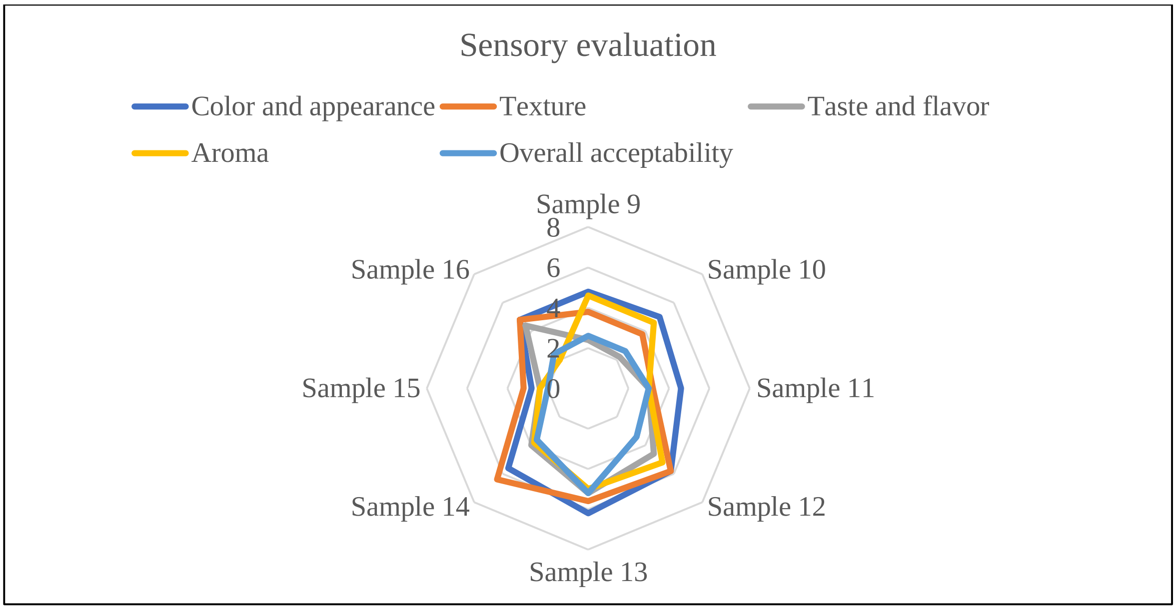


**Figure 4.3 Sensory evaluation for formulation with roasted sorghum and quinoa flour**

Sample 14 had a higher rating for texture. Coming to taste and flavor, sample 13 had a higher rating. Sample 12 had a higher rating for aroma. For color and appearance, sample 13 had a higher rating. Overall, in terms of aroma, appearance, taste, and texture sample 13 was deemed more acceptable.

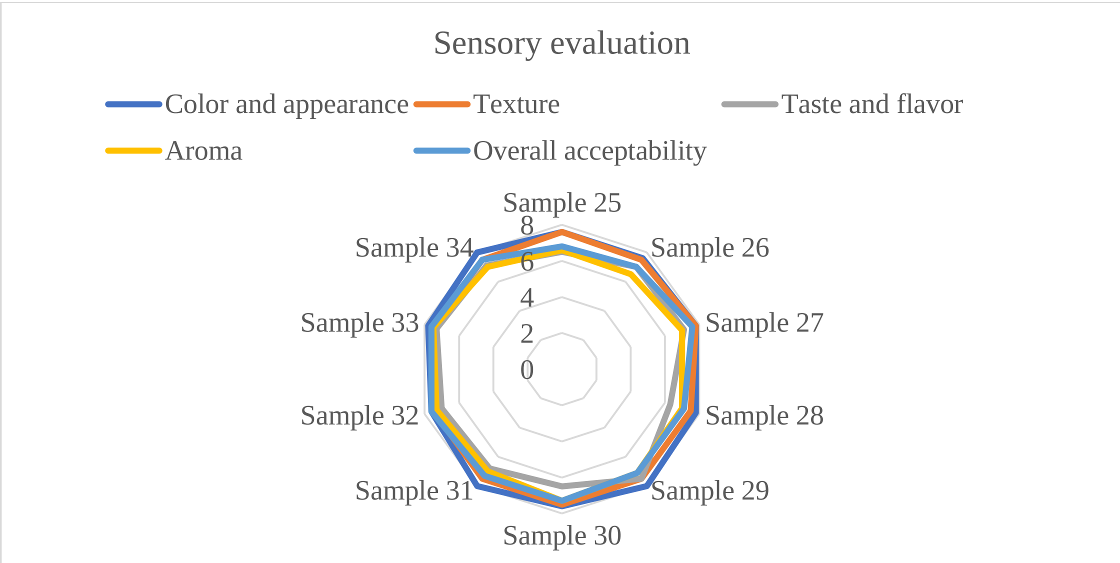


**Figure 4.4 Sensory evaluation for formulation with roasted quinoa flour, roasted barley powder, and fruit powders (with limits)**

Sample 27 had a higher rating for texture. Coming to taste and flavor, sample 29 had a higher rating. Sample 33 had a higher rating for aroma. For color and appearance, sample 29, 31, and 34 had the same rating. Overall, in terms of aroma, appearance, taste, and texture sample 33 was deemed more acceptable.

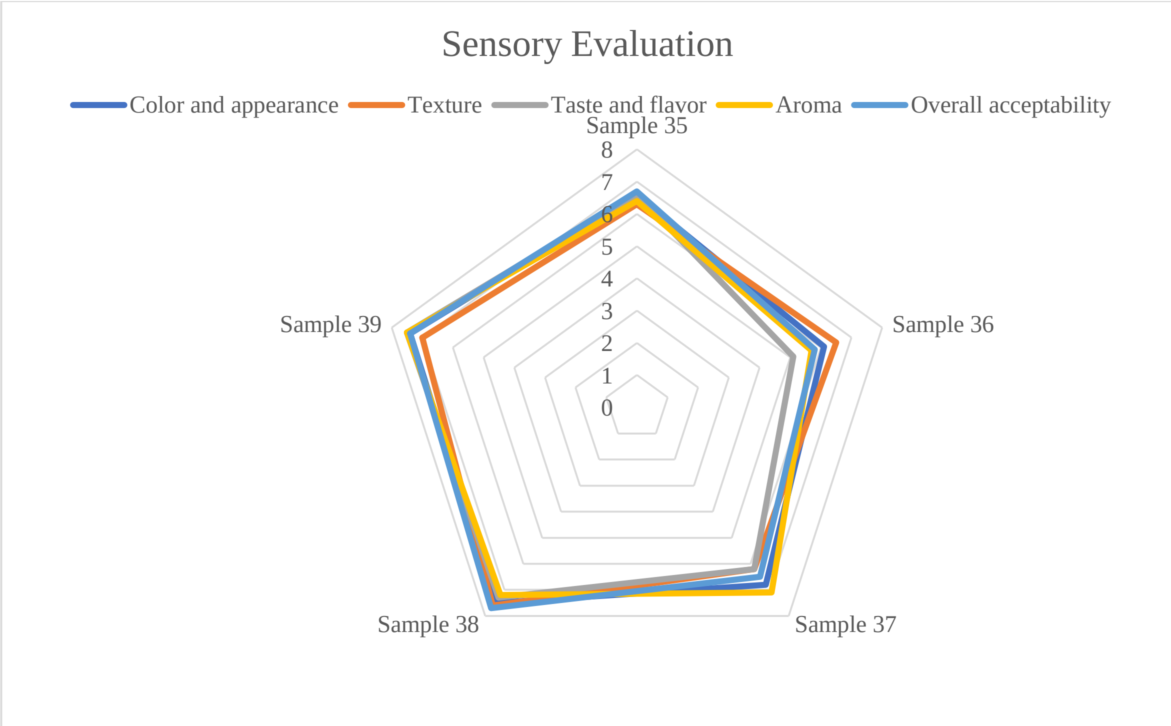


**Figure 4.5 Sensory evaluation for formulation with roasted and dried quinoa flour, roasted and dried barley flour, and fruit powders (with limits)**

Sample 38 had a higher rating for texture, color and appearance. Coming to taste, flavor and aroma, sample 39 had a higher rating. Overall, in terms of aroma, appearance, taste, and texture sample 38 was deemed more acceptable.

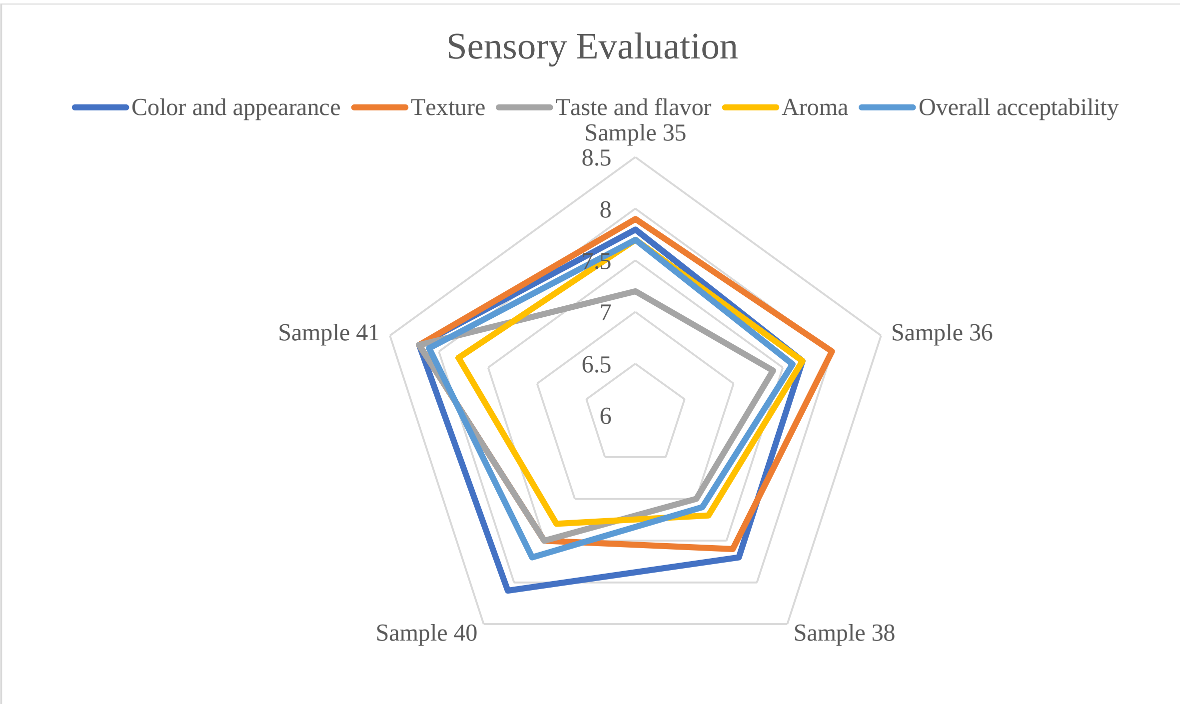


**Figure 4.6 Sensory evaluation for samples 35, 36, 38, 40, and 41**

Sample 41 was selected as the optimized sample regarding aroma, appearance, taste, texture, and overall acceptance.

**Justification:**

- **Formulations B1-B8 (Unroasted Sorghum and Quinoa Flour)**

The formulations prepared using unroasted sorghum and quinoa flour received comparatively lower sensory scores, particularly for flavor and aroma. Although Sample B8 showed relatively better overall acceptability among this group, the presence of raw cereal flavor and characteristic bitterness of quinoa reduced consumer preference.

The lower sensory acceptability may be attributed to the presence of naturally occurring saponins in quinoa, which impart a bitter taste. Additionally, the absence of heat treatment resulted in a raw cereal aroma and limited the development of desirable flavour compounds. The use of untreated quinoa flour also contributed to a coarse mouthfeel, further reducing the overall acceptability of the product.

- **Formulations B9-B16 (Roasted Sorghum and Quinoa Flour)**

Roasting significantly improved colour, aroma, and flavour by promoting Maillard browning reactions**,** which generate desirable volatile flavour compounds.

The highest overall acceptability of Sample B13 can be attributed to the roasting process, which significantly enhanced its sensory quality. Roasting imparted a pleasant roasted aroma, improved the colour, developed a richer and more complex flavour, and produced a smoother texture. These improvements collectively increased the overall appeal and acceptability of the product among the sensory panelists.

However, sensory evaluation indicated that the bitterness associated with sorghum–quinoa combinations was still perceptible, suggesting that roasting alone was insufficient to completely eliminate undesirable flavors.

**Conclusion:**

The present study successfully developed and optimized a nutritionally balanced, cereal-based complementary food for infants aged six months and above using quinoa, barley, skimmed milk powder, date powder, apple powder, and banana powder. Various processing techniques, including roasting, roasting followed by drying, and cooking, were employed to reduce the inherent bitterness of quinoa and barley and enhance the sensory quality of the product. A total of forty-one formulations were developed and evaluated using a 9-point hedonic scale based on color and appearance, aroma, taste, texture, and overall acceptability. Progressive optimization of ingredient proportions and processing conditions significantly improved the sensory characteristics, with the cooked flour formulation (Sample 41) achieving the highest overall acceptability. The optimized formulation comprised 16% cooked quinoa flour, 30% cooked barley flour, 26% skimmed milk powder, 8% date powder, and 20% fruit powders (10% apple and 10% banana). Proximate analysis revealed low moisture content (0.10%), ash content (2.50%), fat content (5.50%), and satisfactory protein content, indicating good nutritional quality and enhanced storage stability. The incorporation of natural fruit powders and date powder improved the product's nutritional value and palatability without the addition of refined sugar. Overall, the findings demonstrate that quinoa and barley can be effectively utilized as functional ingredients to develop an affordable, nutritious, and sensory acceptable complementary food with potential to support infant growth and reduce nutritional deficiencies. Further studies on microbiological safety, vitamin and mineral composition, antinutritional factors, shelf-life stability, digestibility, and clinical acceptability are recommended before large-scale production and commercialization.

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