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Formulation and Assessment of Nutritious Complementary Food Blended with Germinated (Maize, Millet and Soybean), Carrot, and Coconut Flour

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Abstract

In developing nations, malnutrition related to protein and energy in young children is possibly the most widespread health issue. Complementary foods are essential for the growth and development of children as they address both the nutritional and developmental requirements of infants when breastfeeding alone is insufficient. The purpose of this study was to evaluate effects of blending ratio and processing technique on physicochemical composition, and sensory acceptability of quality germinated maize, millet, and soybean, along with carrot and coconut flour based complementary food. The different staples were processed into flours and were combined in ratios of (70:10:10: 5:5), (60:15:15:5:5), (50:20:20:5:5), and (40:25:25:5:5) of maize flour, millet flour, soybean flour, carrot and coconut flour and the samples were denoted as A, B, C, and D. The result revealed that composite the moisture levels varied from 6.55% to 7.15%, with sample C containing 50% maize flour exhibiting the highest moisture content, while sample D with 40% maize flour showed the lowest moisture content. The protein content values of all samples exceeded the 15%. The fat content of the complementary food samples varied between 6.44% and 8.58%, showing highest in sample highest in sample A and lowest in sample E. The range of crude fiber content varied from 1.89% to 4.73%, with sample D showing the highest level and sample E the lowest. The ash content of the formulated complementary food samples increased with the rising addition of maize, soybean, and millet flour. From the sensory analysis sample C recorded the highest score.

Keywords: Malnutrition; Complementary Food; Millet; Maize; Proximate Analysis.

INTRODUCTION

One of the most significant issues today, affecting both developed and developing nations, is malnutrition. Despite the varying socio-economic conditions, generally, less affluent countries are at a higher risk of malnutrition. The World Health Organization (WHO) reports that malnutrition is responsible for 45 percent of deaths among children under the age of five worldwide (Obasi et al., 2018). Malnutrition in the early stages of life leads to lasting stunted growth (Onis and Blossner, 2009), and deficiencies in micronutrients can result in irreversible effects that impede brain development and other functional outcomes (Martorell et al., 2005). During the initial two years of life, malnutrition significantly impacts a child's development, particularly during the early stage of complementary feeding (6 – 12 months), when low-nutrient foods start to replace breast milk and the prevalence of diarrhea caused by food contamination peaks (Oyegoke et al., 2021). Once breast milk no longer meets the nutritional needs of the infant, it is important to incorporate complementary foods into the baby's diet (WHO, 2001). Complementary foods refer to the items consumed by infants from the period when their diet consists solely of breast milk to the stage when their meals primarily consist of family foods (Oyegoke et al., 2021). Complementary foods are essential for the growth and development of children as they address both the nutritional and developmental requirements of infants when breastfeeding alone is insufficient (Temesgen, 2013). These foods mainly come from diverse origins, including grains like wheat, maize, and rice, along with roots, tubers, and legumes such as soybeans and cowpeas. Creating complementary foods frequently entails the use of either single or a mix of plant-based ingredients, like combining cereals with legumes (Adepeju et al., 2024).

Millets are tiny-seeded cereal plants that are part of the Poaceae family and are recognized as the sixth most important cereal crop based on production, after rice, wheat, corn, sorghum, and barley (Thapa et al., 2025). Finger millet provides a variety of vitamins, minerals, and fiber, especially calcium (Thagunna et al., 2022). The soybean (*Glycine max*), a leguminous plant indigenous to East Asia, is widely grown for its adaptable edible beans (Adepeju et al., 2024). Soybeans stand out for their comparatively low levels of carbohydrates and high levels of protein, along with numerous health-enhancing compounds (Onaolapo, 2024). Maize (*Zea mays*), commonly known as corn, comprises three main parts: the outer layer (bran), the embryo (germ), and the endosperm, which are rich in fiber, oil, and starch, respectively. Whole maize typically contains approximately 11% protein, 4% fat, 3% fiber, 65% starch, along with other carbohydrates, and 1.5% minerals (Okafor and Usman, 2014). Carrot (*Daucus carota*) is recognized as the most important crop in the Apiaceae family and is cultivated globally as a root vegetable (Onaolapo, 2024). Originally used for medicinal purposes, carrots eventually became a key component of the diet (Aduke et al., 2024). The flesh of carrots can be found in a variety of colors including white, yellow, orange, red, purple, and very dark purple (Pc et al., 2022). Carrots are well-known for being rich in antioxidant compounds, earning them the distinction of being the top vegetable source of pro-vitamin A carotene (Obinna-Echem et al., 2018). Coconut (*Cocos nucifera*) belongs to the palm family Arecaceae. Coconut flour, known for its distinctive flavor and scent, is a fine flour derived from coconut pulp as a by-product of coconut milk production. This flour is a rich source of vitamins, minerals, healthy fats, and dietary fiber, which could have potential uses in baking and human nutrition (Ramaswamy, 2014). Cereals are deficient in key essential amino acids like lysine and tryptophan, whereas legumes are abundant in these nutrients (Ademulegun et al., 2021). Improving the nutritional value of locally-sourced complementary foods with the addition of soybeans and carrots is both cost-effective and efficient. Even small amounts of soybean and carrot can enhance the protein, vitamin, and mineral content of locally-produced complementary foods (Ademulegun et al., 2021). This research aims to formulate and assess the nutritional composition and sensory attributes of complementary foods made from sprouted maize, sprouted millet, sprouted soybean and carrot, along with coconut flour.

MATERIALS AND METHOD

Preparation of sprouted millet, maize, soybean, carrot flour and coconut flour. All the raw materials were purchased from the local market of Pokhara Valley, Nepal. One kilogram each of maize, millet, and soybean was sorted, cleaned, and soaked in water for 24 hours. Following this period, the water was drained, and the seeds were washed once more. The seeds were then spread out on jute bags, with water sprayed on them every three hours for three days (72 hours) to allow for sprouting at room temperature. After sprouting, the soybean was washed and dried in an oven at 105°C. Once dried, the sprouts were removed and processed using a hammer mill. The flour was then sifted and stored in a properly labeled plastic container for nutrient analysis (Onaolapo, 2024).

Fresh carrots were cleaned, and their tops, leaves, and ends were trimmed. The outer layers were peeled off, then chopped into small pieces, blanched at 93℃ for 3 minutes, and subsequently dried at 50℃ for 8 hours. Afterward, the mixture was milled further and sifted. Similarly, coconut was washed and cut into small peace and converted into flour (Obinna-Echem et al., 2018).

Recipe formulation

Composite flours were formulated by blending the processed flours in the following ration below:

Raw materials	A %	B %	C %	D %
Maize-flour	70	60	50	40
Finger-millet-flour	10	15	20	25
Soybean-flour	10	15	20	25
Carrot-flour	5	5	5	5
Coconut-flour	5	5	5	5

The samples were mixed thoroughly for the formulations to blend well. Each sample was packaged, sealed and labeled in an airtight food grade polythene bag for analysis.

Proximate Analysis

All the parameter for determination of proximate composition of the composite flour samples were followed from the method adopted by AOAC, (2005).

Sensory evaluation

Complementary foods were evaluated by 10 semi-trained panelists including teachers, staffs and students of Pokhara Bigyan Tatha Prabidhi Campus, Pokhara. The panelists were asked to judge the samples for appearance, texture, aroma, taste and overall acceptability by using 9-point hedonic rating scale.

Statistical analysis

Data were statistically processed by SPSS (version 25) for Analysis of Variance (ANOVA). Means of the data were separated whether they are significant or not by using Least Significant Difference (LSD) method at 5% level of significance.

RESULT AND DISCUSSION

Proximate composition of nutritious complementary food blended with germinated (maize, millet and soybean), carrot, and coconut flour.

Parameters	A	B	C	D
Moisture	6.76± 0.02^a	7.15± 0.03^b	6.55± 0.02^c	6.67± 0.03^d
Crude protein	17.18± 0.04^a	19.97± 0.04^b	21.28± 0.05^c	18.29± 0.04^d
Crude fat	7.35± 0.03^a	7.74± 0.03^b	8.36± 0.02^c	6.44± 0.02^d
Crude fiber	3.61± 0.1^a	4.57± 0.02^b	4.73± 0.02^c	1.89± 0.01^d
Total ash	1.54± 0.02^a	1.98± 0.01^b	2.01± 0.01^c	2.38± 0.01^d
Carbohydrate	63.60± 0.08^a	58.62± 0.07^b	57.10± 0.09^c	64.37± 0.06^d

Values shown are mean ± standard deviation of triplicate measurements.

A*(70:10:10: 5:5), B* (60:15:15:5:5), C* (50:20:20:5:5), and D* (40:25:25:5:5) of maize flour, millet flour, soybean flour, carrot and coconut flour

The proximate composition plays a crucial role in assessing the quality of raw materials and is frequently utilized to determine the nutritional value and general acceptance of developed food products (Menon et al., 2023). The outcomes of the proximate composition—moisture, crude protein, crude fat, crude fiber, total ash, and carbohydrates—for the nutritious complementary food that combines germinated maize, millet, and soybean with carrot and coconut flour are presented in Table 2. The moisture levels varied from 6.55% to 7.15%, with sample C containing 50% maize flour exhibiting the highest moisture content, while sample D with 40% maize flour showed the lowest moisture content. A significant difference ($p<0.05$) was observed among all the analyzed samples. Maintaining low moisture levels in complementary foods is critical to prevent nutrient degradation and to ensure the product has a satisfactory shelf life (Amankwah et al., 2009). The United Nations' Protein Advisory Group suggests that moisture levels should remain below 10% to ensure that a flour product is preserved for a sufficient duration (Adeoti and Osundahunsi, 2017). As such, the moisture levels in the samples fell within the advised range of 5-10%. However, the moisture content of the developed diet was greater than the 1.52% and 2.55% values found by (Kumkum et al., 2010) in their weaning mixes that included roasted components. The protein levels of the newly created complementary food samples varied according to the different proportions of germinated maize, soybean, and millet flour. A significant ($p<0.05$) difference was observed among each of the analyzed samples. The protein content values of all samples exceeded the 15% threshold recommended by the World Health Organization for complementary food (Adeoti and Osundahunsi, 2017).

Based on the Protein Advisory Group Guidelines for weaning foods, a protein content of 20% is required; our samples C and D comply with this criterion (Adepeju et al., 2024). The observed increase in protein can also be attributed to the germination technique used. Research has demonstrated that sprouting enhances the available lysine levels in soybean flour (Ademulegun et al., 2021). Nevertheless, this requires further investigation. An increase in lysine and tryptophan levels during the germination of maize has also been documented (Onaolapo et al., 2024). Numerous studies indicate that germinated grains have improved digestibility, meaning that the amino acids are more accessible to digestive enzymes (Benincasa et al., 2019). The fat content generally influences the shelf-life stability of flour products (Ohizua et al., 2017). The fat content of the complementary food samples varied between 6.44% and 8.58%. A significant difference ($p<0.05$) was found among all the samples analyzed. The fat content of the complementary food samples made from maize, soybean, and millet flour was highest in sample A and lowest in sample E. The Recommended Daily Allowance (RDA) for infant foods is 10-25% (Adeoti et al., 2017). The experimental crude fat values align with the reported range of 4.80% to 9.42% found by Ikujenlola and Fashakin (2005) for complementary diets made from high-quality protein maize-soy blends. Additionally, Ukeyima et al. (2019) indicated that the fat content in complementary food made from maize and garden peas was 10.16%, which falls within the range obtained in this study. A high-fat complimentary food indicates that it can enhance the energy levels in the diet, providing a nutritional benefit. However, foods rich in fat may also be prone to oxidative rancidity, which can decrease the storage stability of the food product over time (Ukeyima et al., 2019). The measurement of crude fiber indicates the presence of cellulose, hemicelluloses, and lignin in food (Ajala et al., 2014). The range of crude fiber content varied from 1.89% to 4.73%, with sample D showing the highest level and sample E the lowest. All samples contained fiber amounts that are compliant with the recommended limit of no more than 5 g of dietary fiber per 100 g of dry matter (Shima et al., 2019). It is essential for weaning foods to have low fiber content so that children can consume more nutrient-rich foods and meet their daily energy and vital nutrient needs (Ijarotimi and Keshinro, 2013).

According to Onaolapo et al. (2024), the crude fiber levels in the complementary food ranged from 6.7 to

7.09%, which is higher than the findings reported by Akubor (2016) regarding blends of germinated cowpea and sweet potato flour, as well as higher than our previously mentioned results. A significant difference ($p<0.05$) was observed among all the analyzed samples. The ash content of the formulated complementary food samples increased with the rising addition of maize, soybean, and millet flour. This increase may be attributed to the enhanced bioavailability of minerals during the germination process. The values found in this study were similar to those reported by Onaolapo et al. (2024) for complementary foods made from a blend of sorghum flour, soybean, and carrot flour. Carbohydrates make up a significant portion of the energy in the sample, making it a high-energy food that is suitable for the growth of infants (Adeoti et al., 2017). The energy in an infant's diet comes from proteins, fats, and carbohydrates, which are the primary components of complementary foods that assist in fulfilling the energy needs of developing infants, and a deficiency in any of these can result in malnutrition (Asma et al., 2006).

Sensory characteristics of nutritious complementary food blended with germinated (maize, millet and soybean), carrot, and coconut flour.

The average sensory score for appearance was determined to be 6.7±1.12, 7.44±0.96, 7.77±1.09, and 7.11±1.05 for samples A, B, C, and D respectively. The average sensory score for texture was measured at 6.44±0.71, 6.89±0.93, 7.44±1.33, and 7.11±1.16 for samples A, B, C, and D respectively. The statistical analysis indicated that the partial replacement of maize flour, finger millet flour, soybean flour, carrot flour, and coconut powder significantly affected the texture ($p\leq 0.05$). The fineness of grinding results in a smoother texture (Okoye and Egbujie, 2018). The average sensory score for aroma was 7.0±1.22, 7.0±0.86, 8.22±0.83, and 7.0±1.23 for samples A, B, C, and D respectively. The statistical analysis revealed that the partial substitution of maize flour, finger millet flour, soybean flour, carrot flour, and coconut powder significantly impacted the aroma ($p\leq$ 0.05The roasting of legumes significantly enhanced the flavor of the formulations (Muhimbula et al., 2011). The average sensory score for taste was found to be 6.11±1.16, 7.22±0.83, 8.33±0.53, and 7.33±1.12 for samples A, B, C, and D respectively. The statistical analysis indicated that the partial substitution of maize flour, finger millet flour, soybean flour, carrot flour, and coconut powder had a significant impact on the taste ($p\leq 0.05$). The addition of a small amount of sugar and salt also improved the taste. Germination further enhances the consistency, mouthfeel, and taste of the product (Helland et al., 2002). The average sensory score for overall acceptability was recorded at 6.44±1.10, 7.33±0.86, 8.44±0.53, and 7.33±1.22 for samples A, B, C, and D respectively. Statistical analysis showed that the partial substitution of maize flour, finger millet flour, soybean flour, carrot flour, and coconut powder significantly influenced the overall acceptability ($p\leq 0.05$). Sugar not only contributes sweetness to the product but is also essential for enhancing the flavor of food products, while germination improves the consistency, mouthfeel, and taste of the product (Muhimbula et al., 2011).

CONCLUSION

This research has demonstrated that the complementary foods prepared at home contain significant amounts of carbohydrates, protein, fat, fiber, and ash. Legumes such as soybean, along with maize and millet, which are readily available in Nepal, offer great potential for enhancing cereal-based complementary foods at the household level to combat malnutrition in infants, particularly in low-resource environments. Adding vitamin, A-rich foods like carrots to complementary meals will help reduce and prevent vitamin A deficiency disorders in infants and children.

Conflict of interest: The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Author Contribution: First, third and fourth author contributed in raw material collection, analysis, and other related work. Fourth author helps in data analysis statistically using SPSS version 20. Co-author helps in writing the article and submitting the paper for final publication.

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