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Development And Evaluation Of A Spirulina-Millet Based Smoothie Mix To Combat Malnutrition: A Research

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Abstract: Developing nations still face major public health challenges due to protein-energy malnutrition and lack of vital micronutrients. Targeting disadvantaged groups, the goal of this study was to create and assess a nutrient-enriched, readily reconstituted smoothie mix that included almonds, barnyard millet, proso millet, and spirulina. Different ratios of millet and spirulina powders were used to create three different formulations. A 9-point hedonic scale was used for sensory evaluation, and the proximate and micronutrient content of the most palatable formulation (Variation 2) was further examined. With 24.3 g protein, 9.39 g fat, and 549 mg calcium per 100 g, as well as notable amounts of iron, zinc, and vitamins A, C, and E, the chosen smoothie mix had a good nutritional profile. The product was affordable, stable on the shelf, and appropriate for use as a dietary supplement. The findings provide credence to the functional food's promise as a locally derived, sustainable means of addressing hunger in environments with limited resources.

Keywords: Spirulina, Barnyard millet, Proso millet, Nutrient-enriched smoothie mix, Functional food, Malnutrition, Micronutrients, Sensory evaluation, Ready-to-reconstitute mix, Sustainable nutrition, Spirulina Millet-based smoothie, Malnutrition, Functional food, Micronutrient supplement, Sensory evaluation, Ready-to-reconstitute mix.

INTRODUCTION

Many people consider the blue-green microalga spirulina (*Arthrospira platensis*) to be a superfood because of its remarkable nutritional makeup. In addition to important amino acids, vitamins (especially B12 and provitamin A), minerals (iron, calcium, and magnesium), and bioactive substances like phycocyanin and β -carotene, it has between 60 and 70 percent protein (Karkos et al., 2011). It is perfect for treating iron-deficiency anaemia and protein-energy malnutrition because of its high iron and protein content. Spirulina's immunomodulatory and antioxidant qualities have also been shown, adding to its importance as a functional food (Wu et al., 2016).

Dietary fibre, resistant starch, and micronutrients like iron, zinc, magnesium, and B-complex vitamins are all abundant in barnyard millet. Because of its low glycaemic index, it can be used to treat metabolic diseases like diabetes (Saleh et al., 2013). Its high antioxidant content and gluten-free status make it a popular choice for people of all ages, especially young children and older people with weakened digestive systems.

Proso millet is distinguished by its high percentage of carbohydrates (60–70%), moderate protein content (11–13%), and high concentrations of leucine and methionine, two important amino acids. Additionally, it offers substantial levels of antioxidants, phosphorus, and magnesium, all of which support improved bone health and cellular defence (Sharma & Niranjana, 2018). It's a great base for smoothie blends because of its neutral taste and light texture.

Nuts are rich in protein, vitamin E, zinc, polyphenols, and good fats, mostly monounsaturated and polyunsaturated fatty acids. Walnuts offer omega-3 fatty acids, which are known to play a function in brain development, while almonds and peanuts greatly contribute to protein and calorie needs (Ros, 2010). Additionally, nuts help to improve the nutritional interventions' calorie density, satiety, and palatability.

The study's suggested formulation is in line with the POSHAN Abhiyaan and the National Nutrition Strategy (NITI Aayog, 2017), which place a strong emphasis on using locally available, nutrient-dense food sources to combat malnutrition, especially in children, adolescents, and women of reproductive age.

This formulation is interesting because it combines two different varieties of millets, each with its own unique nutrient profile, with nuts, which are not only high in nutrients but also improve the smoothie mix's organoleptic appeal. A creative, regionally flexible, and climate-resilient approach to the development of functional foods is demonstrated by the utilisation of barnyard and proso millets, which are frequently underutilised while having a rich nutritional profile.

MATERIALS AND METHOD

OBTAINING RAW MATERIALS

Local farmers provided the barnyard millet (*Echinochloa frumentacea*) and proso millet (*Panicum miliaceum*) required to make the smoothie mix. A commercial spirulina farming facility provided the spirulina (*Arthrospira platensis*). Additional components were bought from local stores, such as milk powder, cashew nuts (*Anacardium occidentale*), peanuts (*Arachis hypogaea*), almonds (*Prunus dulcis*), and brown sugar.

MAKING THE RAW INGREDIENTS FOR THE READY-TO-RECONSTITUTE SMOOTHIE MIX BASED ON SPIRULINA AND MILLET

Choosing premium proso millet and barnyard millet seeds is the first step in the preparation process. To get rid of any dirt, dust, or foreign objects, the seeds are properly washed. After that, they are immersed for eight to twelve hours in clean water to start the process of absorbing moisture, which makes sprouting easier. After soaking, the seeds are moved to a sprouting tray or stored in a moist cloth at a regulated temperature (18–25°C) for 24–48 hours, or until visible sprouts appear. The excess water is then drained. Protein digestibility is increased, mineral bioavailability is increased, and starch is simplified for better digestion through sprouting. If not utilised right away, the seeds can be dried after sprouting and rinsed in cold water to get rid of any leftover residue.

Barnyard millet is treated in a similar way. To promote sprouting, the cleaned seeds are soaked for eight to twelve hours and stored in a warm, humid atmosphere. The development of tiny shoots occurs throughout the 24- to 48-hour sprouting phase. This procedure improves the bioavailability of vital minerals including iron, calcium, and zinc while lowering antinutritional elements like phytates. After sprouting, the seeds are cleaned and dried to stop microbial growth and spoiling.

The purpose of roasting is to improve the millets' nutritional value, flavour, and perfume. To guarantee even heating and prevent burning, the cleaned millet grains are dry-roasted in a skillet over medium heat for five to ten minutes while being constantly stirred. Roasting the grains improves their digestibility and lowers antinutritional elements like phytates and tannins. Before being processed further, roasted grains are allowed to cool.

Additionally, nuts like peanuts, cashew nuts, and almonds are cleaned and roasted to enhance their flavour, texture, and nutritional value. After being rinsed with cold water, the nuts are dried. After that, they are spread out evenly on a tray and baked for 8 to 12 minutes at 160 to 180°C in a preheated oven, stirring occasionally to guarantee even roasting. The nuts' overall nutritional profile is improved by this process, which also releases natural oils and lowers antinutritional substances.

For the finished smoothie mixture to have a consistent, smooth texture, grinding is an essential step. A dry grinder or blender is used to grind the cleaned and pre-treated (roasted or sprouted) millets into a fine powder. After cooling, roasted nuts are similarly ground into a fine powder. As the main components of the Spirulina-Millet Smoothie Mix, the resultant millet and nut powders give the product both nutritional and practical benefits.

FORMULATION OF SPIRULINA-MILLET BASED READY-TO-RECONSTITUTE SMOOTHIE MIX

Three smoothie mix variations were developed by varying the amounts of spirulina and millet powders while keeping the quantities of nuts, milk powder, and brown sugar constant. The composition is shown in Table 1.

Table 1. Composition of Smoothie Mix Variants (g/100g)

Prepared/ Processed material	Variation 1 (g)	Variation 2 (g)	Variation 3 (g)
Spirulina	10g	20g	30g
Barnyard millet powder	20g	15g	10g
Proso millet powder	20g	15g	10g
Nuts powder	10g	10g	10g
Milk powder	30g	30g	30g

Brown sugar	10g	10g	10g
TOTAL VOLUME	100g	100g	100g

All ingredients were accurately weighed, mixed thoroughly using a food-grade blender, and sieved for uniformity. The final mixes were packed in air-tight, food-grade pouches and stored at ambient temperature ($25 \pm 2^\circ\text{C}$) until analysis.

RESULTS AND DISCUSSION

SENSORY EVALUATION

Three formulations of Spirulina-Millet Smoothie Mix (Variations 1, 2, and 3) were developed by altering the proportions of spirulina and millet powders. A sensory evaluation was carried out using the 9-point hedonic scale by a semi-trained panel consisting of 30 members. The parameters evaluated included appearance, colour, texture, flavour, taste, and overall acceptability.

Variation 2 (20g spirulina, 15g barnyard millet, 15g proso millet) received the highest overall acceptability score. Variation 1, with lower spirulina content, had a milder flavour and smoother texture. In contrast, Variation 3, though nutritionally rich with 30 g of spirulina, had a darker colour and stronger taste, slightly affecting its preference level.

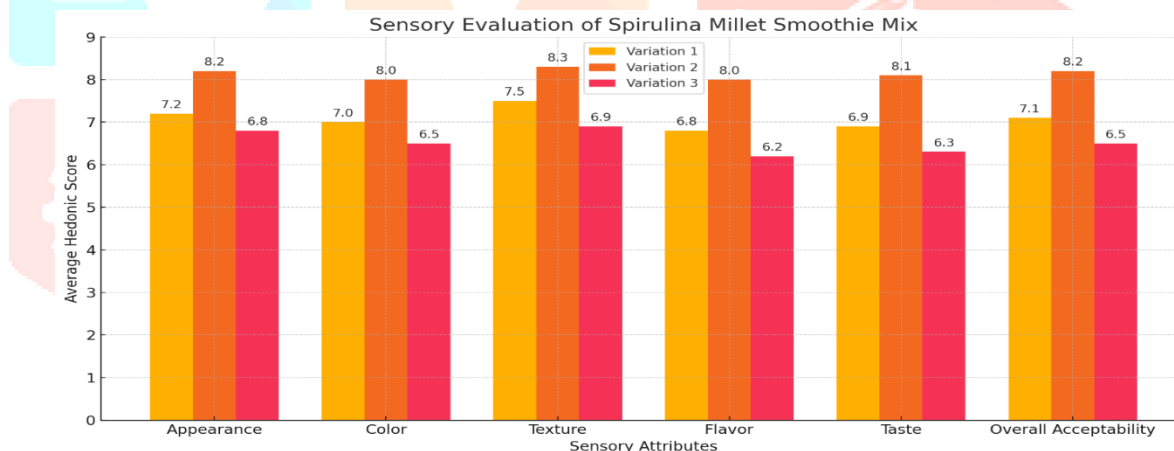


Fig 2. Sensory evaluation of three different formulations of ready to reconstitute spirulina-millet smoothie mix

Fig. 1 illustrates the sensory scores of all three variations. Based on superior sensory attributes, Variation 2 was selected for further analysis, including proximate composition, micronutrient profiling, and cost evaluation.

PROXIMATE COMPOSITION OF SELECTED SMOOTHIE MIX

The proximate analysis of the selected formulation (Variation 2) confirmed its high nutritional value. The results are summarised below:

S.No	Proximate components	Amount(per 100g)
1	Moisture	4.42 g
2	Fat	9.39 g
3	Protein	24.3 g
4	Carbohydrates	13.6 g
5	Crude Fibre	0.42 g
6	Total Ash	3.49 g
7	Bulk Density	0.69 g

Table 2

ORGANOLEPTIC EVALUATION

To assess sensory quality, 25g of smoothie mix was reconstituted with 200 mL of warm or cold water/milk and blended for 30–60 seconds. A semi-trained panel of 10 members evaluated the samples using a 9-point hedonic scale for attributes including appearance, colour, texture, taste, flavour, and overall acceptability. The formulation with the highest average score was selected as the most preferred.

PROXIMATE COMPOSITION ANALYSIS

The selected smoothie mix was analysed for bulk density, moisture, ash, protein, fat, crude fibre, carbohydrate, and energy content using standard analytical procedures.

MICRONUTRIENT ESTIMATION

Atomic Absorption Spectroscopy (AAS) is a commonly used technique to determine the concentration of metal elements like phosphorus, iron, calcium, and zinc in various samples. Vitamin A (as β -carotene): The concentrations of Vitamin C and Vitamin E were determined using standard spectrophotometric methods.

COST ESTIMATION

The cost of production was calculated based on current market prices of raw ingredients. Costs per gram were used to compute ingredient-wise expenses. Additional costs, including processing, packaging, electricity, and labour, were added to estimate the total production cost. This helped in determining the product's affordability and market feasibility.

CONCLUSION:

The Spirulina-Millet ready-to-reconstitute smoothie mix was successfully developed in three variations by varying spirulina and millet proportions. Sensory evaluation identified Variation 2 (20g spirulina, 15g barnyard millet, 15g proso millet) as the most acceptable, balancing taste, texture, and appearance. Nutritional analysis showed this mix to be rich in protein, essential minerals like iron and calcium, and vitamins A, C, and E, making it a highly nutritious product suitable for addressing dietary deficiencies.

The product's low moisture content and appropriate bulk density support good shelf life and ease of preparation. Combining spirulina, millets, and nuts created a synergistic, nutrient-dense food ideal for vulnerable populations. Economically viable and easy to store, this smoothie mix can be used in community nutrition programs, school feeding schemes, and emergency relief efforts.

Future studies should explore clinical benefits, microbial safety, and pilot-scale production for commercial use. Overall, this Spirulina-Millet smoothie mix offers a practical, affordable, and nutritious solution to improve health and nutrition in diverse settings.

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