Research Article

Valorizing Rejected Bananas for Child Nutrition: A Community-Based Pre-Post Study of Daily Banana Powder Supplementation in Children Aged 7-10 Years in Jalgaon, India

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Abstract

Introduction: Jalgaon district in Maharashtra produces bananas at a scale matched by few regions in the world, yet undernutrition persists among children in its rural blocks. Each season, a substantial share of the harvest is rejected for cosmetic reasons, even though its nutritional value is unchanged. This study examined whether a powder made from these rejected bananas could serve as a low-cost dietary supplement for undernourished school-age children. Methods: A community-based, single-arm, pre-post interventional study was conducted in rural Jalgaon. Fifty children aged 7-10 years were enrolled: 40 classified as malnourished and 10 as adequately nourished, the latter serving as an internal reference group. Each child received 50 g of sun-dried banana powder daily (approximately 173 kcal), in two divided servings, for 90 consecutive days. Body weight was measured at baseline and at the end of the intervention. Fatigue, appetite, and activity were assessed from caregiver reports, and skin condition by clinical examination. Results: Mean weight increased by 0.8 ± 0.3 kg in the malnourished group (20.1 ± 2.3 to 20.9 ± 2.4 kg; $p < 0.001$) and by 0.3 ± 0.2 kg in the reference group ($p = 0.001$). The difference in gain between groups was 0.5 kg (95% CI 0.34-0.66; $p < 0.001$). Of the 35 children with fatigue at baseline, 28 (80.0%) improved markedly. Skin complaints improved visibly in 20 of 30 children (66.7%), and appetite increased in 37 of 50 (74.0%). Adherence exceeded 90%, and no adverse events were recorded. Conclusions: Banana powder made from rejected fruit was well accepted. Over three month, its use was associated with weight gain and improved functional well-being, most clearly in undernourished children. These preliminary findings support a waste-to-nutrition model for banana-growing regions, but they need confirmation in adequately powered randomized trials.

Keywords: Child undernutrition, banana powder, food-based intervention, food loss and waste, school-age children, community nutrition, India

1. Introduction

Undernutrition in childhood is not a single deficit but a cluster of overlapping ones: inadequate energy, insufficient high-quality protein, and shortfalls in micronutrients such as iron, zinc, and vitamin A. Its effects go well beyond low weight. Undernourished children have weaker immunity, lower physical capacity, and poorer school performance, and these disadvantages can persist into adult life [1,2]. Undernutrition is estimated to underlie nearly half of all deaths among children under five in low- and middle-income countries [2].

India carries a disproportionate share of this burden. According to the fifth National Family Health Survey (NFHS-5, 2019-21), 35.5% of children under five are stunted, 32.1% are underweight, and 67.1% of those aged 6-59 months are anemic; anemia also affects 57.0% of women of reproductive age [3]. Policy attention has focused mainly on the first 1,000 days of life, but the problem continues into school age. The Comprehensive National Nutrition Survey found that about one in five Indian children aged 5-9 years was stunted and nearly one in four was thin for age [4]. This middle-childhood group receives relatively little attention in research and programs, even though it remains a period of catch-up growth and heavy demands from schooling.

Maharashtra illustrates a persistent paradox: economic growth and agricultural surplus alongside widespread undernutrition in rural and tribal communities [3]. In Jalgaon district, households in blocks such as Yawal, Raver, and Jamner eat diets dominated by cereals, with limited access to fruit, pulses, and animal-source foods.

This produces what has been termed hidden hunger, in which energy intake may be close to adequate while intake of essential micronutrients is consistently deficient [5].

The paradox is especially striking because Jalgaon is among India's foremost banana-producing districts, and India is the largest banana producer in the world [6,7]. A considerable share of each harvest is excluded from export and retail chains because of irregular size, shape, or superficial blemishes. These criteria are cosmetic and have no bearing on nutritional quality. The rejected fruit is sold far below market value or left to decay, adding to national post-harvest fruit losses estimated at 6.7% to 15.9% [8]. Reducing such losses is now an explicit global priority, and redirecting surplus food to people who need it is ranked among the most valuable ways to do so [9].

Bananas are well suited to this kind of redirection. They are inexpensive, culturally familiar, and naturally sweet, which makes them acceptable to children. Through simple steps of peeling, slicing, sun-drying, and milling, they can be turned into a shelf-stable powder that keeps for several months when stored airtight. Each 100 g of dried banana provides approximately 80-88 g of carbohydrate, 8-10 g of dietary fiber, 1,200-1,500 mg of potassium, and appreciable vitamin B6 [10,11]. Clinical evidence also supports banana-based foods: a systematic review documented gastrointestinal and metabolic benefits of green banana products [12], and a randomized trial in Bangladeshi infants showed that green banana substantially hastened recovery from persistent diarrhea [13].

Despite this background, few studies have tested rejected bananas as a nutritional resource for school-age children in the communities where the fruit is grown. Such a model would address food loss and child undernutrition together, at almost no cost for raw material. The present study was therefore designed to evaluate the effect of 90 days of daily banana powder supplementation on body weight, fatigue, skin condition, appetite, and acceptability among children aged 7-10 years in rural Jalgaon, and to compare the response of malnourished children with that of adequately nourished peers.

2. Materials and Methods

2.1. Study design and setting This community-based, single-arm, pre-post interventional study was conducted in rural villages of Jalgaon district, Maharashtra, India, over a period of three months (90 days). The study area is predominantly agricultural, and banana cultivation is the main source of livelihood for most households.

2.2. Participants Children aged 7-10 years presenting with features suggestive of nutritional inadequacy, such as fatigue, poor weight gain, or skin complaints, were identified in the community and screened for eligibility. Children were classified as malnourished if they had low body weight for age, assessed against the WHO growth reference [14], and/or visible clinical signs of undernutrition. Children who did not meet these criteria formed an adequately nourished internal reference group. Children with acute illness, chronic systemic disease, or a condition requiring medical treatment were excluded. A total of 50 children were enrolled, of whom 40 were malnourished and 10 were adequately nourished.

2.3. Preparation of banana powder Edible bananas [cultivar, e.g., Grand Naine] rejected on cosmetic grounds were collected from local farms. The fruit was washed in potable water, peeled by hand, cut into slices of uniform thickness (approximately [3-5] mm), and sun-dried on clean trays for two to three days until brittle. The dried slices were milled into a fine powder in a mechanical grinder, sieved, and packed in airtight food-grade containers at ambient temperature. No preservatives, sweeteners, or other additives were used. Using standard composition data, a 50 g portion was estimated to supply approximately 173 kcal [11].

2.4. Intervention Each child received 50 g of banana powder daily for 90 consecutive days, divided into two 25 g servings. The morning serving was mixed into milk, water, or porridge, and the evening serving was given as a beverage or snack. Caregivers were trained at enrollment on preparation and hygienic handling. Pre-weighed weekly rations were supplied to each household. Adherence was assessed at [weekly] home visits by caregiver recall and by counting returned rations, and a child was considered adherent if at least [80%] of the scheduled doses were consumed. Families were advised to continue the child's usual diet.

2.5.Outcome measures All outcomes were assessed at baseline and on day 90.

- **Primary outcome:** change in body weight, measured to the nearest 0.1 kg on a calibrated [digital/beam] scale, with the child barefoot and in light clothing. Measurements were taken at the same time of day on both occasions.

- **Secondary outcomes:** caregiver-reported fatigue and activity level; clinically assessed skin condition (dryness, dullness, minor lesions); caregiver-reported appetite and general well-being; acceptability; and adverse events.
  Change in each secondary outcome was graded on a four-point scale: marked improvement, partial improvement, no change, or worsening.

Statistical analysis Continuous variables are summarized as mean ± standard deviation (SD) and categorical variables as frequency and percentage. Within-group change in weight was assessed with the paired t-test. The between-group difference in weight gain was assessed with Welch's t-test, given the unequal group sizes and variances, and reported with its 95% confidence interval (CI). Statistical significance was set at a two-sided p-value of less than 0.05. Analyses were performed using [software, version].

Ethical considerations Written informed consent was obtained from a parent or guardian of each child, and verbal assent was obtained from the children. Children found to need further medical care were referred to local health facilities.

3. Results

All 50 children completed the intervention and follow-up, with no attrition. At baseline, 35 children (70%) had fatigue and 30 (60%) had skin complaints. Reduced appetite and low activity were common in the malnourished group.
Body weight Weight increased significantly in both groups. The gain in malnourished children was nearly three times that seen in the reference group, both in absolute terms and relative to baseline weight (Table 1). Among the 40 malnourished children, 34 (85%) gained weight; the remaining six (15%) maintained weight, with a change of less than 0.2 kg. No child lost weight.

Table 1: Change in body weight after 90 days of banana powder supplementation

Group	n	Baseline (kg)	Day 90 (kg)	Gain (kg)	Gain (%)	p-value
Malnourished	40	20.1 ± 2.3	20.9 ± 2.4	0.8 ± 0.3	4.0	<0.001*
Adequately nourished	10	24.5 ± 2.0	24.8 ± 2.1	0.3 ± 0.2	1.2	0.001*
Between-group difference (95% CI)				0.5 (0.34-0.66)		<0.001†

Values are mean ± SD. *Paired t-test; †Welch's t-test.

Functional and clinical outcomes
Improvement was common across all secondary outcomes, and no child worsened on any measure (Table 2). Caregivers described greater participation in play, better attentiveness at school, larger and more frequent meals, and improved mood. On examination, the skin changes consisted of reduced dryness, smoother texture, and fewer minor lesions.

Table 2: Change in fatigue, skin condition, and appetite after 90 days

Outcome	Affected at baseline (n)	Marked improvement, n (%)	Partial improvement, n (%)	No change, n (%)
Fatigue	35	28 (80.0)	5 (14.3)	2 (5.7)
Skin complaints	30	20 (66.7)	7 (23.3)	3 (10.0)
Appetite (all children)	50	37 (74.0) increased	–	–

Adherence and safety Adherence exceeded 90%. Caregivers found the powder palatable and easy to add to familiar foods. No adverse events, gastrointestinal intolerance, or allergic reactions were reported.

4. Discussion

This study provides preliminary evidence that bananas rejected from commercial supply chains can be turned, with minimal technology, into an acceptable supplement for school-age children. Over 90 days, supplementation was associated with weight gain, less fatigue, and better appetite. The response was clearly larger in children who were undernourished at enrollment than in their adequately nourished peers.

Interpretation of the weight response The most plausible mechanism is a net increase in energy intake. At approximately 173 kcal per day, the supplement provides close to one-tenth of the estimated energy requirement of a child aged 7-10 years [15]. In a child whose usual diet falls short, this margin is large enough to change energy balance. Adequate non-protein energy also spares dietary protein from being oxidized for fuel, freeing it for tissue synthesis [2,16]. The larger response in malnourished children (a 4.0% gain in body weight versus 1.2%) is consistent with catch-up growth, in which energy-depleted children use additional energy more efficiently than those already in balance. This gradient is one of the stronger internal signals in our data, because it is hard to explain by measurement artifact alone. It also suggests that banana powder may work best as a targeted intervention rather than a universal one.

The magnitude of the gain should still be interpreted with care. Over 90 days the supplement supplied about 5,200 kcal in total. Given the energy cost of depositing new tissue during catch-up [16], the observed gain of 0.8 kg is close to the upper limit of what this amount of energy could produce and would require almost no compensatory reduction in usual food intake. Two factors probably contributed. The first is the increase in appetite reported in 74% of children, which suggests that total intake rose beyond the supplement itself.

The second is short-term variation in hydration and gut contents, which can affect weights measured over a short interval. For comparison, a Cochrane review of school feeding in lower-income countries found a mean additional gain of 0.39 kg over an average of 19 months in randomized trials, and 0.71 kg over about 11 months in controlled before-after studies [17]. Those programs differed in design and population. Even so, the contrast underlines that our one-month estimate is likely to shrink in a controlled setting and should be regarded as an upper bound rather than a precise effect size.

Functional outcomes The reductions in fatigue and the increased activity reported by caregivers fit with improved energy availability, and from a family's perspective these may matter more than the change on the scale. The skin findings call for caution. Bananas are not a meaningful source of zinc, vitamin A, or essential fatty acids, the nutrients most closely tied to skin integrity in undernutrition [2]. Any improvement is therefore better explained by better overall nutritional status and possibly hydration than by a specific nutrient effect. Because skin was assessed by unblinded visual examination, this outcome is the most susceptible to observer bias.

Programmatic relevance The strength of this model is its alignment with local conditions. The raw material costs almost nothing in a banana-growing district. Processing requires only sunlight, basic hygiene, and a grinder, and the

product keeps well without refrigeration. These features make it suitable for women's self-help groups, Anganwadi centers, or school meal programs such as PM POSHAN. The same activity also generates income and reduces food loss, in line with global strategies that place redirecting surplus food to people in need near the top of the food-waste hierarchy [9]. Banana-based foods also have a well-established safety record in pediatric feeding, including their therapeutic use in diarrheal disease [12,13], and no adverse events occurred in our cohort.

The main nutritional weakness of banana powder is its low protein content. A logical next step is a composite formulation with locally available protein sources. Edible mushrooms, which contain 20-30% protein on a dry-weight basis along with B vitamins and minerals, are one candidate [18], and pulse flours are another. Composite products of this kind could address protein-energy and micronutrient deficits together, and they warrant formal development and testing.

Mushroom powder offers a promising nutritional complement to banana powder because of its relatively high protein content, dietary fiber, B-complex vitamins, and essential minerals such as potassium, selenium, and phosphorus. Edible mushrooms contain approximately 20–30% protein on a dry-weight basis, depending on the species, and provide bioactive compounds with potential antioxidant and immunomodulatory properties [18]. Combining mushroom powder with banana powder may improve the protein and micronutrient profile of the supplement, potentially supporting growth, immunity, and overall nutritional status in undernourished children. However, the nutritional composition, acceptability, safety, and effectiveness of such a formulation require further evaluation.

5. Limitations

These findings should be read as hypothesis-generating. First, without a randomized control group, the observed changes cannot be attributed to the supplement with confidence. Seasonal variations in food availability, regression toward the mean, and the Hawthorne effect may have influenced the results. Second, although the three-month follow-up allows assessment of short-term nutritional improvements, it is insufficient to establish long-term effects, and the absence of height measurements limits assessment of linear growth. Third, nutritional classification did not consistently rely on standardized z-scores, and biochemical markers were not assessed. Fourth, secondary outcomes depended on unblinded caregiver and examiner judgment. Fifth, background dietary intake was not quantified, making it difficult to isolate the effects of supplementation. Additionally, the proposed use of mushrooms in future composite formulations may face drying difficulties during the rainy season due to high humidity and limited sunlight, increasing the risk of moisture retention and microbial contamination. Finally, the small, single-site sample and limited reference group restrict generalizability and robust comparisons.

6. Future research

Future research should include adequately powered cluster-randomized controlled trials with matched comparison groups and follow-up extending to at least six to twelve months. Standardized anthropometric measurements, dietary intake assessments, biochemical nutritional indicators, and long-term monitoring would help establish the effectiveness, safety, and sustainability of banana powder supplementation. Studies should also report on cost-effectiveness, product safety (moisture content and microbial load), and the comparative performance of banana-only and composite formulations. Future studies should also evaluate banana–mushroom composite powders for their nutritional composition, protein enrichment, acceptability, microbial safety, and effectiveness in improving nutritional outcomes among undernourished children.

7. Conclusions

Banana powder made from cosmetically rejected bananas was simple to prepare, well accepted by families, and safe. Given at 50 g a day for three months, it was associated with weight gain and better functional well-being in children aged 7-10 years, most clearly among the undernourished. By turning agricultural loss into a nutritional resource, this approach offers a low-cost, locally owned model for regions where food abundance and child undernutrition coexist. Rigorous randomized evaluation is now needed to establish its true effect and whether it can be scaled.

8. References

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