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Green Nutrition Revolution: Role of leaf protein concentrate in combating malnutrition and micronutrient deficiency

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Abstract
In the present study, Leaf Protein Concentrate (LPC) was prepared from selected green leaves using a simple and cost-effective extraction method involving mechanical pulping, filtration, and thermal coagulation. The analysis revealed that LPC yield ranged from 2–7% (fresh weight basis), while protein content was significantly high (30–65% dry weight basis). Among the studied samples, *Moringa oleifera* and *Amaranthus spp.* showed comparatively higher protein content and better nutritional quality.
The results indicate that although only a small fraction of leaf biomass is recovered as LPC, it is highly nutrient-dense and rich in essential micronutrients. The study highlights the potential application of LPC in combating malnutrition, especially in resource-limited populations. However, further studies on nutrient profile, digestibility, and safety are needed for standardization.

Keywords: Leaf protein concentrate (LPC), plant-based protein, green leafy biomass, malnutrition, micronutrients, sustainable nutrition

Introduction

Malnutrition continues to be a major public health challenge across many parts of the world, particularly in developing nations. Particularly, lower section, faces a significant burden of protein-energy malnutrition and micronutrient deficiencies. The problem is more pronounced in rural populations, where limited dietary diversity and dependence on cereal-based diets lead to insufficient intake of high-quality proteins. The growing population and demand for proteins, dietary changes and the rise of sustainable food systems have put considerable emphasis on traditional protein sources (Boukid *et al*., 2022) [2]. Plant-derived proteins are increasingly recognized as sustainable alternatives to animal-based sources; however, their large-scale production remains dependent on a limited number of crops such as soybean, legumes, and cereals, raising concerns about reduced agrobiodiversity and resilience in agricultural systems. Moreover, certain widely used plant proteins, including soy, wheat, and lupin, are associated with allergenic responses in sensitive individuals, thereby restricting their broader utilization in food formulations (Muthukumar *et al*., 2020) [7]. Leafy biomass plants, particularly those cultivated under low-input agricultural systems, offer a sustainable and promising approach to bridging the protein gap for both human and animal nutrition, as they can be processed into leaf protein concentrate (LPC), (Domokos-Szabolcsy *et al*., 2023) [3].

This study represents, green leafy biomass a highly promising yet underutilized resource for improving nutritional security as it contains substantial protein content along with a rich supply of essential micronutrients, including vitamins, iron, calcium, magnesium, and niacin, as well as antioxidants and diverse bioactive compounds. Studies reported that regular supplementation of leaf protein concentrate has been shown to improve hemoglobin levels and reduce iron deficiency anemia in vulnerable populations (Vyas *et al*., 2010) [12]. One of the key advantages of LPC over other emerging food sources lies in its relatively simple processing techniques, cost-effectiveness, and high nutritional value. These attributes make it particularly suitable for addressing malnutrition and micronutrient deficiencies, especially in developing countries where access to affordable and nutrient-dense food remains limited.

In this paper, we review LPC made from different types of green leaves and discuss its nutritional value and health benefits. We also highlight how it can be used as a simple and sustainable way to improve human health.

Methodology

Approximately 100 g of fresh, healthy green leaves were collected and used for the preparation of leaf protein concentrate. Fresh green leaves of Spinach (Spinacia oleracea), Fenugreek leaves (Trigonella foenum-graecum), Coriander leaves (Coriandrum sativum) Amaranth leaves (Amaranthus spp.), and Moringa leaves (Moringa oleifera) were selected based on their nutritional significance and availability. The leaves were collected in fresh condition and sorted to remove damaged or contaminated portions.

Preparation of Leaf Protein Concentrate (LPC)

Leaf Protein Concentrate (LPC) was prepared from fresh green leafy biomass following standard procedures described in earlier studies. Fresh, healthy, and disease-free leaves were collected and thoroughly washed with distilled water to remove adhering dust and impurities. Approximately 100 g (fresh weight basis) of leaves were weighed and processed. The cleaned leaves were then ground using a mechanical grinder with the addition of a minimal quantity of water (approximately 1:1 w/v) to facilitate efficient pulping. This mechanical disruption helps in breaking plant cell walls and releasing intracellular components, including soluble proteins (Singh *et al*., 2014) [11].The resulting pulp was filtered through a muslin cloth to separate the green leaf juice from the fibrous residue. The filtrate, commonly referred to as green juice, contains soluble proteins, chlorophyll, and other bioactive compounds (Kaszás *et al*., 2024) [6].

The extracted juice was subjected to thermal coagulation by heating at 70–80°C for 10–15 minutes, which facilitates the precipitation of soluble leaf proteins. This temperature range is considered optimal for efficient protein coagulation without excessive degradation of nutritional components (Pirie, 1971) [9].

The coagulated protein fraction was separated by filtration and gently pressed to remove excess moisture. The obtained LPC was then dried at a controlled temperature of 50–60°C to reduce moisture content while preserving protein quality and minimizing loss of heat-sensitive nutrients. Finally, the dried LPC was stored in airtight containers under cool and dry conditions for further analysis (Hanczakowski *et al*., 1991; Rathore, 2010) [4, 10].

Protein Estimation

The protein content of the prepared LPC samples was determined using the Kjeldahl method, which is based on the estimation of total nitrogen present in the sample. The nitrogen content obtained was multiplied by a conversion factor of 6.25 to calculate the crude protein percentage (AOAC, 2016).

Results

The study shows that different green leaves can be used to prepare Leaf Protein Concentrate (LPC), but the amount obtained (yield) is generally low, ranging from about 2% to 7%. This is because fresh leaves contain a lot of water and fiber. However, even though the yield is low, the LPC obtained is very rich in protein and nutrients.

Table 1: Nutrient provided by 100 gms of LPC (Approximate values have been compiled based on a review of multiple published studies on leaf protein concentrate (Rathore, 2010; Singh *et al*., 2014; Kaszás *et al*., 2020) [5, 10, 11].

Leaf Source (Scientific Name)	LPC Yield (% Fresh Weight Basis)	Protein Content (% Dry Weight Basis)	Major Nutritional Attributes
Spinach (Spinacia oleracea)	3–5%	45–55%	Rich in iron, calcium, β-carotene (Vit. A precursor)
Fenugreek leaves (Trigonella foenum-graecum)	2–4%	35–45%	Mineral-rich, supports digestion, bioactive phytochemicals
Coriander leaves (Coriandrum sativum)	2–3%	30–40%	Vitamin C, phenolics, antioxidant activity
Amaranth leaves (Amaranthus spp.)	4–6%	50–60%	High-quality protein, calcium, essential amino acids
Moringa leaves (Moringa oleifera)	5–7%	55–65%	Protein-dense, rich in iron, calcium, provitamin A

Table 2: Nutrients provided by 20 Gms of LPC. (Source: Study carried out by New Hope, 2006) [8].

S.No.	Nutrients	Amount provided by 20 gms of LPC
1.	Protein	3 gms
2.	Vitamin A	5,825I.U.
3	Vitamin E	1I.U.
4	Niacin	1mg
5	Calcium	440mg
6	Magnesium	17mg
7	Iron	12mg

Discussion

Among all the leaves, Moringa leaves (drumstick leaves) gave the highest yield (5–7%) and the highest protein content (55–65%). This shows that moringa is a very good source of plant protein and can help in improving nutrition. It is also rich in iron, calcium, and vitamin A.

Amaranth leaves (amaranthus) also showed good results, with high protein (50–60%) and a fair yield (4–6%). It is a good alternative source of protein and also contains important minerals like calcium.

Commonly consumed leafy vegetable such as Spinach (Spinacia oleracea) demonstrated moderate LPC yields (3–5%) and protein content (40–55%). These leaves are also rich in micronutrients such as iron, calcium, and vitamins A and K, making them suitable for dietary supplementation.

Leaves like Fenugreek leaves (methi), showed slightly lower yield (2–4%) but still had good protein content (35–50%). They also provide useful minerals and help in digestion and overall health.

Coriander leaves (dhaniya) had the lowest yield (2–3%) and lower protein (30–40%), but it is still important because it contains vitamin C and antioxidants.

Conclusion

In this research paper, we explored the potential of Leaf Protein Concentrate (LPC) as a simple and effective way to improve human nutrition. Different green leafy sources such as Spinach (palak), Fenugreek leaves (methi), Coriander leaves (dhaniya), Moringa leaves (drumstick leaves), and Amaranth leaves were studied for their ability to provide protein and important nutrients through LPC.

Even though the amount of LPC obtained from fresh leaves is small, it is highly rich in protein and contains essential nutrients like iron, calcium, and vitamins. Among the different leaves, moringa and amaranthus showed better results in terms of protein content and overall nutritional value.

LPC can play an important role in reducing malnutrition, especially in a country like India, where many people still suffer from lack of protein and micronutrients. Adding a small amount of LPC to the daily diet can help improve nutritional intake and reduce problems like anemia, poor growth, and vitamin deficiencies, particularly among children and other vulnerable groups. Introducing it slowly into regular diets can help people get used to it and benefit from its nutritional value. However, detailed studies regarding minerals, vitamins, *in-vitro* digestibility, toxicity testing and amino acid compositions are needed to be carried out to standardize the use of leaves as a source of LPCs.

Overall, this study shows that LPC is a low-cost, easily available, and sustainable option for improving nutrition. With further research and awareness, it can become an important tool in fighting malnutrition and supporting better health in the future.

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