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B-Carotene-Rich Orange-Fleshed Sweet Potato: A Promising Crop for Nutrition-Sensitive Agriculture and Rural Enterprise in India

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INTRODUCTION

More than two billion people worldwide suffer from hidden hunger, which is defined by a lack of vital nutrients. Vitamin A insufficiency is a serious public health concern due to its link to poor vision, increased susceptibility to infections, decreased immunological response and increased child mortality. Biofortification has evolved as a long-term agricultural method for addressing such inadequacies by improving the nutrient density of staple crops via traditional breeding.

Orange-fleshed sweet potato (OFSP) is one of the most successful examples of biofortification globally. Unlike conventional white-fleshed sweet potato varieties, OFSP accumulates high levels of β-carotene, which is converted into vitamin A within the human body. Scientific evidence demonstrates that regular consumption of OFSP significantly improves vitamin A intake and nutritional status among children and women. OFSP interventions in Uganda and Mozambique increased vitamin A intake and improved vitamin A status among children (Hotz *et al.,* 2012).

In India, sweet potatoes are grown in Odisha, West Bengal, Assam, Bihar, Kerala, Karnataka, Tamilnadu and Andhra Pradesh. Recognizing the nutritional value of OFSP, the ICAR-Central Tuber Crops Research Institute (CTCRI) has developed biofortified varieties such as Bhu Sona, which is specially loaded with provitamin A (ICAR-Central Tuber Crops Research Institute).

1. Nutritional Composition of Orange-Fleshed Sweet Potato

OFSP is regarded as one of the richest natural food sources of provitamin A carotenoids. The orange flesh represents the buildup of carotenoid pigments, particularly β-carotene, which contribute significantly to human nutrition. According to comprehensive reviews, OFSP is high in carbs, dietary fiber, vitamins, minerals, phenolic compounds and antioxidants (Neela & Fanta, 2019).

1.1 Major Nutrients Present in OFSP

1.1.1 Carbohydrates

Sweet potato roots contain approximately 20-30% carbohydrates, primarily starch, making them a valuable energy source. OFSP can contribute significantly to caloric requirements while simultaneously addressing micronutrient deficiencies.

1.1.2 β-Carotene and Vitamin A

The most important nutritional characteristic of OFSP is its extremely high β-carotene concentration. β-carotene is metabolized into retinol (vitamin A), thereby supporting vision, immune function, reproductive health and cellular growth. OFSP can provide up to 100% of daily vitamin A requirements when consumed regularly.

1.1.3 Dietary Fiber

Dietary fiber present in OFSP improves digestive health, enhances satiety, regulates blood glucose levels and contributes to overall metabolic health. (Neela & Fanta, 2019).

1.1.4 Antioxidants

OFSP contains phenolic compounds, flavonoids, vitamin C and carotenoids that help protect cells against oxidative stress and reduce the risk of chronic diseases.

2. Role of OFSP in Combating Vitamin A Deficiency

Vitamin A insufficiency is still widespread among preschool children and women of reproductive age. Severe deficiency can cause nite blindness, xerophthalmia, decreased immunity and increased mortality.

Several intervention trials have shown that OFSP improves vitamin A levels. A landmark study in Uganda found that adding β-carotene-rich OFSP dramatically boosted vitamin A intake and improved vitamin A status among children and women (Hotz et al., 2012).

Similarly, HarvestPlus reported that consumption of biofortified orange sweet potato reduced vitamin A deficiency risks and improved overall nutritional outcomes, particularly among children.

Advantages of OFSP-Based Nutritional Interventions

- Sustainable and agriculture-based solution.
- Lower cost than supplementation programs.
- Locally cultivable and culturally acceptable.
- Suitable for integration into existing farming systems.
- Continuous source of dietary vitamin A.

3. OFSP as a Vehicle for Food Fortification

Food fortification generally involves adding nutrients to processed foods. OFSP serves as a natural fortification ingredient by enriching foods with β-carotene without requiring synthetic additives.

3.1 Bakery Products

OFSP puree and flour can be incorporated into:

- Bread
- Cookies
- Biscuits
- Cakes
- Muffins
- Buns

Research has shown that OFSP puree-based bakery products possess improved vitamin A content and acceptable sensory quality. OFSP bread has become an important vehicle for delivering β-carotene to consumers (Owade et al., 2018).

3.2 Complementary Foods

OFSP flour can be blended with cereals and legumes to prepare nutrient-dense complementary foods for infants and young

children. Such formulations substantially improve vitamin A intake while maintaining affordability.

3.3 School Nutrition Programs

Potential applications include:

- Mid-Day Meal schemes
- ICDS programs
- Poshan Abhiyaan interventions
- Tribal nutrition programs

Inclusion of OFSP products could improve micronutrient intake among nutritionally vulnerable populations.

3.4 Functional and Health Foods

The increasing health-food industry provides opportunities for OFSP-based:

- Gluten-free flours
- Health snacks
- Nutrition bars
- Noodles
- Pasta
- Breakfast cereals

ICAR-CTCRI has developed technologies for sweet potato nutribars, cookies, functional noodles and pasta from sweet potato.

4. Dietary Diversification and Nutrition Security

Food systems in many parts of India remain dominated by cereal-based diets that often lack micronutrient diversity. Dietary diversification aims to broaden food consumption patterns and improve nutritional adequacy.

OFSP contributes to dietary diversification due to:

- Unique nutrient composition.
- High consumer acceptability.
- Ease of preparation.
- Versatility in traditional recipes.

Household Uses of OFSP

- Boiled roots
- Roasted roots
- Steamed products
- Halwa
- Kheer
- Puree
- Soups
- Curries
- Chips

The attractive orange color and natural sweetness make OFSP particularly appealing to children, enhancing adoption at household level.

5. Status of Biofortified OFSP in India

India has made significant progress in sweet potato biofortification through ICAR-CTCRI.

Bhu Sona: India's Biofortified OFSP Variety

The variety **Bhu Sona**, released in 2017, possesses:

- Deep orange flesh.
- Rich provitamin A content (~14 mg/100 g fresh weight).
- Yield potential around 19.8–24 t/ha.
- Suitability for processing industries.
- Tolerance to salinity stress.
- Field tolerance to sweet potato weevil.

Researchers from ICAR-CTCRI have also highlighted additional biofortified OFSP varieties including Bhu Kanti and Bhu Ja for improving nutritional security (Pati et al., 2021).

6. Rural Enterprise Opportunities

OFSP offers substantial opportunities for entrepreneurship due to increasing demand for healthy and functional foods.

6.1 Nursery and Vine Multiplication Enterprises

Quality planting material remains a major requirement for OFSP expansion.

Business models include:

- Community nurseries
- Farmer Producer Organizations (FPOs)
- Women's Self-Help Groups (SHGs)
- Youth entrepreneurship ventures

6.2 Processing Enterprises

Micro, small and medium enterprises can process OFSP into:

- Flour
- Puree
- Chips
- Dehydrated cubes
- Noodles
- Pasta
- Bakery products

Such processing extends shelf life and increases market value.

6.3 Women-Led Enterprises

Women can actively participate in:

- Production
- Primary processing
- Packaging
- Marketing
- Home-based food manufacturing

This contributes to women's economic empowerment and household nutrition improvement.

6.4 Health-Food Startups

Growing consumer awareness regarding healthy diets and functional foods creates market opportunities for:

- Gluten-free products
- Organic foods
- Nutraceutical products
- Vitamin A-enriched snacks
- Biofortified food brands

7. Climate Resilience and Sustainable Agriculture

Climate change poses challenges to conventional food crops. OFSP offers resilience due to:

Drought tolerance.
Adaptability to poor soils.
Short growth duration.
High biomass production.
Efficient resource utilization.

8. Challenges Limiting Adoption

Despite its advantages, widespread adoption faces several barriers:

- Limited consumer awareness.
- Poor availability of quality vines.
- Weak market linkages.
- Limited processing infrastructure.
- Lack of organized value chains.
- Inadequate policy support.
- Post-harvest perishability.

9. Future Perspectives for India

For large-scale impact, the following interventions are essential:
Promotion through Poshan Abhiyaan.
Integration into school meal programs.
Expansion of biofortified sweet potato cultivation.
Establishment of OFSP processing clusters.
Support for startups and rural enterprises.
Public-private partnerships for commercialization.
Awareness campaigns targeting consumers and farmers.

CONCLUSION

β-Carotene-rich orange-fleshed sweet potato represents a powerful convergence of agriculture, nutrition, public health and rural development. Its high provitamin A content, climate resilience, adaptability and suitability for value addition make it one of the most promising biofortified food crops available today. Evidence from multiple intervention studies demonstrates its effectiveness in improving vitamin A intake and reducing nutritional deficiencies. In India, biofortified varieties such as Bhu Sona offer significant opportunities for combating hidden hunger while stimulating rural entrepreneurship and value-chain development. Future efforts should focus on scaling production, strengthening processing infrastructure and incorporating OFSP into national nutrition programs to maximize its impact on food and nutrition security.

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