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# Effect of Traditional Processing on Beta-Carotene Content of Sweet Potato Products: A Systematic Review with Implications for Vitamin A Deficiency in Nigeria

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**Systematic Review**

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## Abstract

# Background

Vitamin A deficiency (VAD) remains a severe public health problem in Nigeria, contributing to childhood blindness, compromised immunity, and maternal mortality. Orange-fleshed sweet potato (OFSP) is a rich source of β-carotene, the primary provitamin A carotenoid. However, traditional processing methods—boiling, roasting, frying, drying, and fermentation—may degrade β-carotene, potentially limiting the nutritional impact of OFSP products such as sweet potato garri. This systematic review synthesises available evidence on β-carotene retention in sweet potato subjected to traditional processing methods relevant to Nigeria.

# Methods

A systematic search was conducted in PubMed, Google Scholar, and African Journals Online using keywords related to sweet potato, β-carotene, processing, and retention. Studies reporting quantitative β-carotene retention after boiling, roasting, frying, drying, or fermentation were included. Data were extracted on processing conditions, retention percentages, and factors affecting degradation.

# Results

Fifteen studies met the inclusion criteria. Retention varied widely by method: boiling (65–85% retention), roasting (50–75%), frying (60–80%), sun drying (30–55%), oven drying (40–70%), and fermentation (50–70%). Key factors influencing retention included temperature, duration, exposure to light and oxygen, and matrix composition (e.g., fat content). No study directly examined β-carotene retention during traditional Garri processing (fermentation + dewatering + roasting) of sweet potato.

# Conclusion

Traditional processing methods cause moderate to substantial losses of β-carotene in sweet potato, but significant provitamin A activity can still remain, especially with optimised conditions. For sweet potato Garri to serve as a meaningful VAD intervention, processing parameters (short fermentation, moderate roasting, addition of palm oil) should be standardised. Direct measurement of β-carotene retention in sweet potato Garri is an urgent research priority.

## 1. INTRODUCTION

# 1.1 Vitamin A Deficiency in Nigeria

Vitamin A deficiency (VAD) is a major public health concern in Nigeria, affecting an estimated 30% of children under five years and 25% of pregnant women (UNICEF, 2021; WHO, 2019). VAD is the leading cause of preventable childhood blindness and increases the risk of infectious diseases, including measles, diarrhea, and respiratory infections (Stevens et al., 2015). Despite national supplementation programs and food fortification efforts, coverage remains incomplete, and sustainable, food-based solutions are urgently needed.

## 1.2 Orange-Fleshed Sweet Potato as a Solution

Orange-fleshed sweet potato (*Ipomoea batatas*) is a biofortified staple crop with exceptionally high levels of β-carotene, the most potent provitamin A carotenoid (Alam, 2021; Laveriano-Santos et al., 2022). Unlike synthetic supplements or fortified foods, OFSP provides vitamin A precursors within a familiar, culturally acceptable food matrix. Randomized controlled trials in sub-Saharan Africa have demonstrated that regular OFSP consumption improves vitamin A status in children and women (Low et al., 2017; Laurie et al., 2015).

## 1.3 Processing and β-Carotene Retention

However, sweet potato is rarely consumed raw. Traditional processing methods - boiling, roasting, frying, sun drying, and fermentation - are applied to improve palatability, digestibility, and shelf life. These processes expose β-carotene to heat, light, oxygen, and acidic conditions, all of which can induce isomerization and oxidative degradation (Rodriguez-Amaya, 2015). The extent of retention determines whether processed OFSP products can still deliver meaningful amounts of provitamin A.

## 1.4 The Case of Sweet Potato Garri

Garri production involves grating, fermentation (typically 24–72 hours), dewatering (pressing), and dry-roasting at ~ 120°C (Akpoghelie et al., 2025). Each step may affect β-carotene stability. Fermentation introduces organic acids and microbial activity; roasting applies sustained heat. To date, no published study has directly measured β-carotene retention during sweet potato Garri processing (Bello et al., 2026) identified this as a key limitation.

## 1.5 Aim of This Review

This systematic review aims to: (i) collate and synthesize existing evidence on β-carotene retention in sweet potato subjected to traditional processing methods (boiling, roasting, frying, drying, fermentation), (ii) identify factors that enhance or reduce retention, (iii) synthesize findings to the Garri processing context, and (iv) provide evidence-based recommendations for optimizing Sweet potato Garri as a VAD intervention in Nigeria.

# 2. METHODS

## 2.1 Search Strategy

A systematic literature search was conducted in PubMed, Google Scholar, and African Journals Online (AJOL) from inception to March 2026. The search strategy combined terms for sweet potato, processing, and β-carotene:

- *Sweet potato* OR *Ipomoea batatas* OR *orange-fleshed sweet potato*
- *β-carotene* OR *beta-carotene* OR *provitamin A* OR *carotenoid*
- *Processing* OR *retention* OR *degradation* OR *stability*
- *Boiling* OR *roasting* OR *frying* OR *drying* OR *fermentation*

## 2.2 Inclusion and Exclusion Criteria

**Inclusion criteria**:

- Original research quantifying β-carotene content before and after a defined traditional processing method.
- Sweet potato as the raw material (any variety, but OFSP preferred).
- Processing methods relevant to Nigerian traditional food preparation (boiling, roasting, frying, sun/oven drying, fermentation).
- Retention percentage reported or calculable.
- Full-text available in English.

**Exclusion criteria**:

- Studies on other crops (e.g., carrot, pumpkin) or synthetic β-carotene.
- Studies only on raw, unprocessed sweet potato.
- Reviews, conference abstracts, or opinion pieces.
- Processing methods not relevant to Garri (e.g., canning, extrusion, high-pressure processing).

## 2.3 Data Extraction and Quality Assessment

Data were extracted using a standardized form: author, year, country, sweet potato variety, processing method, conditions (temperature, time, presence of fat, etc.), analytical method (HPLC preferred), retention percentage, and key findings. Quality was assessed using a modified version of the Joanna Briggs Institute checklist for analytical studies, focusing on sample description, analytical validation, replication, and reporting of variability.

## 2.4 Data Synthesis

Results were qualitatively synthesized and presented in tables showing median retention ranges for each processing method, with factors influencing retention.

# 3. RESULTS

# 3.1 Study Selection

The initial search yielded 487 records. After removing duplicates and screening titles/abstracts, 52 full-text articles were assessed. Fifteen studies met the inclusion criteria and were included in the review. Most studies were conducted in sub-Saharan Africa (including Nigeria, Kenya, Uganda), Asia (Bangladesh, China), and Latin America (Brazil, Peru).

# 3.2 Characteristics of Included Studies

All 15 studies used HPLC or spectrophotometric methods for β-carotene quantification. Sweet potato varieties included OFSP cultivars (e.g., 'Ejumula', 'Kakamega', 'Tainung', 'Beauregard') and, in a few cases, white- or cream-fleshed controls (with negligible baseline β-carotene). Retention was typically calculated as (β-carotene content after processing / β-carotene before processing) × 100%, corrected for moisture loss or dry matter where applicable.

# 3.3 β-Carotene Retention by Processing Method

Table 1 summarizes the retention ranges for each traditional processing method.

Table 1
β-Carotene retention in sweet potato Garri after different traditional processing methods.

| Processing Method | Typical Conditions | Retention Range (%) | Mean ± SD (%) | Number of Studies | Key Factors Affecting Retention |
|---|---|---|---|---|---|
| Boiling | Whole or cut pieces, water, 100°C, 15–30 min | 65–85 | 75 ± 6 | 8 | Retention higher with skin on; shorter time; minimal water |
| Roasting | Whole or cut, dry heat, 150–200°C, 20–40 min | 50–75 | 62 ± 8 | 6 | Surface charring reduces retention; lower temperature (150°C) better |
| Deep frying | Cut pieces, oil (palm or vegetable), 160–180°C, 3–10 min | 60–80 | 70 ± 7 | 5 | Fat increases bioaccessibility; but high temp causes degradation |
| Sun drying | Thin slices, open sun, 2–5 days | 30–55 | 42 ± 9 | 7 | UV light and oxygen cause major losses |
| Oven drying | Thin slices, 50–70°C, 6–12 h | 40–70 | 58 ± 10 | 6 | Lower temperature (< 60°C) and dark conditions improve retention |
| Fermentation | Mash or slices, ambient (25–30°C), 24–72 h | 50–70 | 60 ± 8 | 4 | Short fermentation (< 48 h) better; addition of fat (palm oil) protects |

### Notes

Retention percentages are corrected for moisture/dry matter changes. Ranges represent reported values across studies. Data compiled from Vimala et al. (2011), Bengtsson et al. (2008), Donado-Pestana et al. (2012), Laurie et al. (2018), and others.

# 3.4 Factors Influencing β-Carotene Retention

### Thermal degradation

β-Carotene degradation follows first-order kinetics, with half-lives decreasing exponentially as temperature increases (Rodriguez-Amaya, 2015). Boiling (100°C) causes moderate losses (15–35%), while roasting at > 180°C can cause losses exceeding 50%.q qqz

### Light and oxygen

Sun drying exposes sweet potato slices to intense UV radiation and atmospheric oxygen, leading to isomerization from the biologically active *all-trans* form to less active *cis* isomers, as well as oxidative cleavage (Bengtsson et al., 2008). This explains the poor retention (30–55%) observed with sun drying.

### Matrix effects

The presence of fat significantly enhances β-carotene stability during thermal processing. In studies where palm oil (rich in saturated fats and tocopherols) was added before roasting or drying, retention improved by 15–25% (Laurie et al., 2018). Fat may protect carotenoids by reducing oxygen exposure and acting as a solvent.

### Fermentation

Lactic acid fermentation, as used in Garri production, creates an acidic environment (pH 3.5–4.5). β-Carotene is relatively stable at acidic pH, but prolonged fermentation (≥ 72 h) leads to gradual degradation, possibly due to enzymatic activity from fermenting microbes or residual oxygen (Vimala et al., 2011). Retention of 50–70% has been reported for 24–48 h fermentation.

### Processing order

Sequential processing (e.g., fermentation followed by roasting) may have additive or interactive effects. No study has systematically examined the full sequence of Garri processing (grating → fermentation → dewatering → roasting) on β-carotene retention.

# 3.5 Extrapolation to Sweet Potato Garri Processing

Garri processing involves four main steps, each potentially affecting β-carotene:

| Step | Typical conditions | Estimated retention (based on individual step data) |
|---|---|---|
| Grating | Mechanical, minimal heat | ~ 95–100% (negligible loss) |
| Fermentation | 24–48 h, ambient, pH 4–5 | 60–70% |
| Dewatering (pressing) | Mechanical, room temperature | 90–95% (some loss in expelled liquid) |
| Roasting | ~ 120°C, 15–20 min, with/without palm oil | 50–70% (depending on oil) |

If each step is considered multiplicatively (and conservatively), overall retention could be as low as **0.95 × 0.60 × 0.95 × 0.50 = 27%** (without palm oil) or as high as **0.95 × 0.70 × 0.95 × 0.70 = 44%** (with palm oil, short fermentation, moderate roasting). This suggests that a substantial portion of original β-carotene may be lost during Garri processing, but significant provitamin A activity could still remain if conditions are optimized.

## 3.6 Quality Assessment

Of the 15 included studies, 9 (60%) were rated high quality (HPLC analysis, duplicate measurements, reporting of moisture correction, clear processing conditions). 5 (33%) were moderate (spectrophotometry without isomer differentiation, or limited replication). 1 (7%) was low quality (no correction for moisture loss). No study directly examined Garri processing, highlighting a critical evidence gap.

# 4. DISCUSSION

## 4.1 Main Findings

This systematic review demonstrates that traditional processing methods reduce β-carotene in sweet potato by 15–70%, depending on the method and conditions. Boiling (65–85% retention) and frying with oil (60–80% retention) are relatively mild, while sun drying (30–55% retention) is most destructive. Fermentation (24–48 h) retains 50–70%, and roasting (50–75%) is intermediate. Extrapolation to Garri processing suggests overall retention in the range of 27–44%, though direct measurement is urgently needed.

## 4.2 Comparison with Existing Literature

Our findings align with previous systematic reviews on carotenoid stability in processed fruits and vegetables (Rodriguez-Amaya, 2015; Ngamwonglumlert&Devahastin, 2019). The protective effect of fat is well established: β-carotene is lipophilic, and oil facilitates its extraction from the food matrix while reducing oxygen exposure. This has practical implications for Nigerian Garri production: adding palm oil (already a common practice in some regions) during roasting could significantly enhance β-carotene retention.

# 4.3 Implications for Vitamin A Deficiency Interventions

The World Health Organization recommends food-based strategies, including dietary diversification and biofortification, as sustainable approaches to combat VAD (WHO, 2019). Orange-fleshed sweet potato has been successfully promoted in Uganda, Mozambique, and Malawi, with documented improvements in serum retinol among children and women (Low et al., 2017). However, those interventions primarily promoted boiled or roasted sweet potato as a whole food, not a processed product like Garri.

If Sweet potato Garri can deliver even 30–40% of original β-carotene, it could still be a meaningful source of provitamin A. For context, 100 g of raw OFSP contains approximately 5,000–15,000 µg of β-carotene (Alam, 2021). With 40% retention, processed Garri would provide 2,000–6,000 µg β-carotene per 100 g. The recommended daily allowance for vitamin A is 600 µg retinol activity equivalents (RAE) for children and 700–800 µg RAE for adults (IOM, 2001). Since 12 µg of β-carotene converts to 1 µg RAE (for cooked vegetables with fat), 100 g of optimized Sweet potato Garri could provide **160–500 µg RAE**, i.e., 20–70% of daily needs. This is not trivial.

# 4.4 Optimizing Sweet Potato Garri for β-Carotene Retention

Based on the evidence, we propose the following optimized processing parameters for sweet potato garri:

1. **Select high-β-carotene OFSP varieties** (e.g., 'UMUSPO 1', 'King J', 'Ejumula').
2. **Limit fermentation to ≤ 48 hours** (shorter if possible) to reduce degradation.
3. **Add palm oil (5–10%) before or during roasting** to protect carotenoids and enhance bio-accessibility.
4. **Roast at moderate temperature (≤ 120°C)** for 15–20 minutes, avoiding charring.
5. **Avoid sun drying as a pre-treatment** (not typical in Garri, but relevant for other products).

These parameters are feasible within traditional Garri production systems and could be disseminated through extension services.

# 4.5 Knowledge Gaps and Future Research

The most critical gap is the **absence of direct measurement** of β-carotene retention during Sweet potato Garri processing. The findings presented here is based on individual steps studied in other contexts. A single well-designed study measuring β-carotene (using HPLC) before and after each step (grating, fermentation, dewatering, roasting) would be of notable relevance. Furthermore, studies should assess bio-accessibility (i.e., how much β-carotene is actually absorbed) using in vitro digestion models or human trials.

Other gaps include:

- Effect of different cassava-sweet potato blends on retention.
- Impact of traditional fermentation microorganisms on carotenoid stability.

- Storage stability of β-carotene in finished Sweet potato Garri over time.
- Consumer sensory studies to ensure that optimized products are acceptable.

## 4.6 Strengths and Limitations

### Strengths

This is the first systematic review to synthesize β-carotene retention data specifically for traditional processing methods relevant to Nigerian sweet potato products, with explicit extrapolation to Garri. The review includes a rigorous search and quality assessment.

### Limitations

As stated, no study has directly examined Garri processing. Variability in analytical methods (HPLC vs. spectrophotometry) and processing conditions limited quantitative synthesis. Publication bias may exist, with studies reporting low retention less likely to be published.

# 5. CONCLUSION

Vitamin A deficiency remains a severe public health challenge in Nigeria, and orange-fleshed sweet potato offers a promising food-based solution. However, traditional processing methods - including those used in Garri production - reduce β-carotene content, with estimated overall retention of 27–44% under typical conditions. Despite these losses, optimized Sweet potato Garri (using high-carotenoid varieties, short fermentation, added palm oil, and moderate roasting) could still provide a meaningful contribution to daily vitamin A requirements. Direct measurement of β-carotene retention during Garri processing is the highest research priority. Finally, policymakers and extension agents should promote optimized processing methods to maximize the nutritional impact of sweet potato Garri as a sustainable VAD intervention in Nigeria.

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