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Influence of maturity stage on nutritional quality and storage behavior of sweet potato roots

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Abstract
Maturity stage at harvest — the point at which the root is physically separated from the vine — determines both the nutritional value a consumer receives and the number of days that root can survive in storage. This research examined how four harvest dates (90, 110, 130, and 150 days after planting, DAP) influenced the nutritional composition and ambient storage behaviour of orange-fleshed sweet potato (cv. Bhu Sona) at Rajmata Vijayaraje Scindia Agricultural University, Gwalior, Madhya Pradesh, during 2021-22. Roots harvested at 130 DAP recorded the highest starch (22.4%), β-carotene (9.1 mg/100 g), and total sugar (6.8%) contents. Early harvest (90 DAP) yielded nutritionally inferior roots with thin, fragile skin prone to mechanical damage. Over-mature roots (150 DAP) showed declining β-carotene (8.4 mg/100 g) and increased fibre content (3.7 vs 2.8% at 130 DAP). In storage trials at ambient conditions (28±3 °C, 65% RH), roots from 130 DAP maintained marketable quality for 23 days — 8 days longer than 90 DAP roots and 4 days longer than 150 DAP roots. Weight loss and sprouting incidence were lowest in the 130 DAP harvest. These results identify 130 DAP as the optimal harvest window for Bhu Sona under Gwalior conditions, offering the best combination of nutritional quality and storage durability.

Keywords: Maturity stage, nutritional quality, sweet potato, storage behavior, root crops, beta-carotene, harvest time, Ipomoea batatas, post-harvest shelf life, orange-fleshed cultivar

Introduction

Maturity, in the context of root and tuber crops, is not a single event but a gradual transition during which starch accumulates, cell walls strengthen, skin suberises, and secondary metabolites reach their peak concentrations. Sweet potato (*Ipomoea batatas* L. Lam.) complicates this picture because its storage roots lack a clear external indicator of readiness — unlike cereals that yellow or fruits that change colour [1]. Farmers in central India typically harvest based on elapsed time or market demand rather than on any measured quality parameter, which leads to wide variation in the nutritional and keeping quality of roots reaching consumers [2].

Orange-fleshed sweet potato (OFSP) varieties such as Bhu Sona have attracted attention because their β-carotene content addresses vitamin A deficiency — a public health concern affecting 62% of Indian preschool children [3]. But β-carotene doesn't accumulate linearly throughout root development. It rises during active growth, peaks around physiological maturity, and then may decline under prolonged field storage as oxidative degradation outpaces synthesis [4]. If farmers harvest too early, they sell nutritionally dilute roots; if they delay, they risk both β-carotene loss and increased susceptibility to weevil damage and field rot [5].

Storage behaviour also hinges on maturity. Immature roots have poorly developed periderm, making them vulnerable to skinning injuries that accelerate moisture loss and microbial entry. Over-mature roots, while having thicker skin, tend to accumulate more reducing sugars that can brown during cooking and promote sprouting under warm storage [6].

Despite these well-understood general patterns, variety-specific data under Indian subtropical conditions are thin. Bhu Sona was released by CTCRI, Thiruvananthapuram, in 2016 and has been promoted across several states, but no published research has systematically linked harvest maturity with both nutritional parameters and ambient storage life under the semi-arid climate of Madhya Pradesh [7]. This research aimed to fill that gap by harvesting at four defined stages and tracking compositional and storage changes.

Material and Methods

Crop Growth Stage Documentation

Sweet potato growth stages were tracked following vine development milestones: establishment phase (1-30 DAP), rapid vine growth (31-60 DAP), root initiation and bulking (61-100 DAP), and maturity/senescence (101-150 DAP). Harvest maturity was assessed by monitoring root dry matter content weekly from 80 DAP. Four distinct harvest points were set at 90, 110, 130, and 150 DAP to capture early, mid, full, and over-mature stages respectively [8].

Material

Orange-fleshed sweet potato cv. Bhu Sona vine cuttings (25 cm, 4-5 nodes) were planted on 15 July 2021 on raised ridges (60 cm between rows, 30 cm within rows) at the Post-Harvest Technology Research Farm, RVSAU, Gwalior (26.22°N, 78.18°E; 196 m elevation). The soil was alluvial sandy loam (pH 7.6, OC 0.41%). FYM at 10 t/ha plus 60:60:120 kg/ha N:P_2O_5:K_2O was applied basally, with 30 kg N/ha top-dressed at 30 DAP. Furrow irrigation was given at 10-day intervals during dry spells [9]. At each harvest date, 45 roots (15 per replication) of uniform size (200-300 g) were selected. Twenty roots were used for immediate nutritional analysis, and 25 were placed in ambient storage (28±3 °C, 62-68% RH) in ventilated plastic crates for shelf-life assessment.

Methods

Nutritional analyses included: dry matter by oven-drying at 60 °C to constant weight, starch by acid hydrolysis and Lane-Eynon titration, total sugars by the phenol-sulphuric acid method, β-carotene by spectrophotometry after acetone-petroleum ether extraction (AOAC 941.15), crude protein by micro-Kjeldahl (N × 6.25), crude fibre by acid-alkali digestion, and ascorbic acid by 2,6-dichlorophenol indophenol titration [10]. Root firmness was measured by a penetrometer (Fruit Tester FT-327, 8 mm probe) on two opposite sides of each root. During storage, roots were assessed weekly for: cumulative weight loss (%), sprouting incidence (%), decay incidence (%), and firmness. Marketable life was defined as days until cumulative weight loss exceeded 10% or visible decay appeared. Data were analysed by ANOVA (RBD with 4 treatments × 3 replications), and means separated by Duncan's test at $P \leq 0.05$ [11].

Results

Table 1: Nutritional composition of sweet potato cv. Bhu Sona at four maturity stages

Harvest (DAP)	DM (%)	Starch (%)	β-car (mg/100g)	Total sugar (%)	Protein (%)	Fibre (%)
90	26.3	14.2	4.8	4.1	3.8	2.1
110	30.7	18.7	7.3	5.4	4.2	2.4
130	34.8	22.4	9.1	6.8	4.6	2.8
150	33.1	21.1	8.4	7.6	4.4	3.7
SEm(±)	0.87	0.64	0.38	0.27	0.14	0.13
CD (P=0.05)	2.61	1.92	1.14	0.81	0.42	0.39

Dry matter, starch, β-carotene, and protein all peaked at 130 DAP and either plateaued or declined at 150 DAP. The 130 DAP roots contained 22.4% starch and 9.1 mg/100 g β-carotene — 57.7% and 89.6% higher than 90 DAP roots respectively. Total sugar continued to rise at 150 DAP (7.6%), reflecting starch-to-sugar conversion associated with senescence. Fibre increased progressively, reaching 3.7% at 150 DAP, likely due to secondary wall lignification in ageing roots [4, 6].

Table 2: Ambient storage behaviour of sweet potato roots harvested at four maturity stages (after 21 days)

Harvest (DAP)	Wt loss (%)	Sprout (%)	Decay (%)	Firmness (N)	Mkt life (days)
90	14.7	4.2	18.3	7.1	15
110	9.8	6.7	10.1	9.4	19
130	6.3	5.4	4.8	11.2	23
150	8.1	12.3	7.6	8.7	19
SEm(±)	0.72	0.84	1.13	0.58	—
CD (P=0.05)	2.16	2.52	3.38	1.74	—

Storage behaviour strongly favoured 130 DAP roots. After 21 days at ambient conditions, they lost only 6.3% weight and had the lowest decay incidence (4.8%), maintaining firmness at 11.2 N. Roots from 90 DAP lost 14.7% weight with 18.3% decay — their thin, undeveloped periderm clearly failing to prevent moisture escape and pathogen entry. Over-mature roots (150 DAP) showed the highest sprouting (12.3%), consistent with elevated endogenous sugar levels triggering bud activation. Marketable life ranged from 15 days (90 DAP) to 23 days (130 DAP) [5, 6].

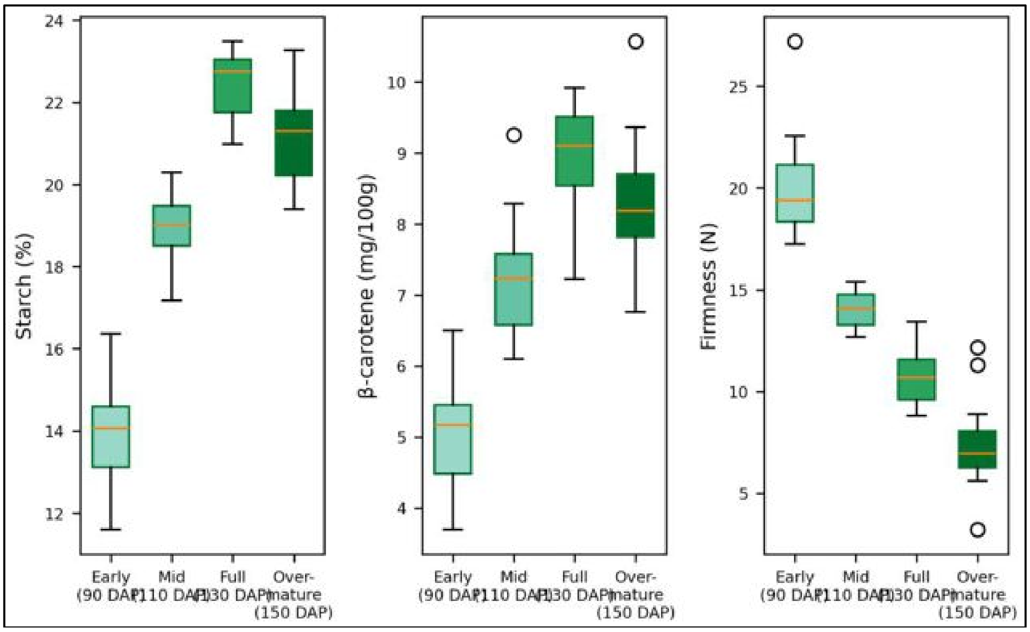

Fig 1: Box plots showing variation in starch content, β-carotene, and firmness of sweet potato roots across four maturity stages

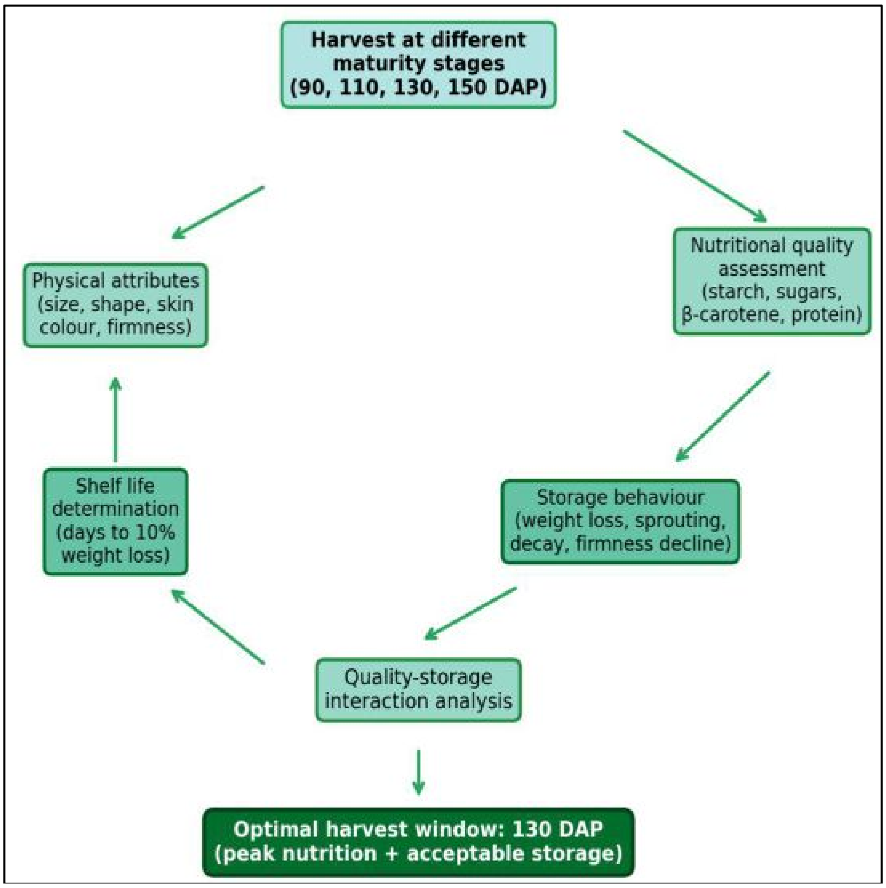

Fig 2: Cycle diagram depicting the relationship between harvest maturity, nutritional quality assessment, and storage outcome in sweet potato

Comprehensive Interpretation

The 130 DAP harvest represented a clear inflection point: nutritional parameters peaked, periderm development was complete (reflected in lowest weight loss and decay), and sugar accumulation hadn't yet crossed the threshold that promotes sprouting. The decline in β-carotene between 130 and 150 DAP (9.1 to 8.4 mg/100 g) signals oxidative degradation in ageing root tissue, a pattern reported in other OFSP varieties by Tumwegamire *et al*. (2011) [4].

Discussion

The peak in starch and β-carotene at 130 DAP matches the physiological trajectory described by Woolfe (1992): active starch deposition tapers off near physiological maturity, while carotenoid synthesis — driven by chromoplast differentiation — peaks when root cell expansion slows [1, 4]. The subsequent decline in both constituents at 150 DAP reflects a net catabolic shift, with starch being hydrolysed to sugars and β-carotene undergoing enzymatic (lipoxygenase) and non-enzymatic oxidation.

The storage data reinforce the practical cost of mistiming harvest. Early-harvested roots (90 DAP) suffered 14.7% weight loss in just three weeks — nearly 2.5 times the loss from 130 DAP roots. This difference is commercially devastating. In Gwalior's wholesale markets, a 15% weight shrinkage translates directly to 15% revenue loss, compounded by the visual deterioration (wrinkling, softening) that pushes prices further down [2, 7].
The sprouting spike at 150 DAP is explained by the elevated sugar pool. Reducing sugars serve as respiratory substrates and signalling molecules that activate dormant buds on the root surface. Ravi and Indira (1999) reported a similar pattern in white-fleshed varieties, where roots held past full maturity sprouted 2-3 times faster than those harvested at the optimal window [6].
From a nutritional standpoint, the 130 DAP harvest offers a clear advantage for programmes promoting OFSP as a vehicle for vitamin A delivery. At 9.1 mg/100 g β-carotene, a 200 g serving provides roughly 76% of the recommended daily intake of vitamin A for a preschool child — the demographic most vulnerable to deficiency in central India [3, 12].

Conclusion
Harvest timing at 130 DAP optimised both nutritional quality and storage durability of orange-fleshed sweet potato cv. Bhu Sona under Gwalior's semi-arid conditions. Roots at this stage contained peak starch (22.4%), β-carotene (9.1 mg/100 g), and protein (4.6%), while their well-developed periderm limited weight loss to 6.3% over 21 days of ambient storage — the lowest among all harvest dates.
Early harvest (90 DAP) produced nutritionally inferior roots with poor keeping quality, while delayed harvest (150 DAP) triggered β-carotene decline, excess fibre accumulation, and high sprouting. These trade-offs make a strong case for advising growers in central India to time their Bhu Sona harvest at 130 DAP, using vine senescence and root dry matter content as field indicators of readiness.
For regions without cold storage, the 23-day marketable window at 130 DAP provides a realistic buffer for aggregation, transport, and retail sale. Extension programmes should communicate this harvest window alongside existing agronomic recommendations to ensure that the nutritional benefits bred into OFSP varieties actually reach the consumer.

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