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Groundnut Pigment Profiles Shape Post-Harvest Antioxidant and Nutrient Retention During Storage

In a comprehensive two-year agronomic investigation, agricultural researchers have demonstrated that kernel testa pigmentation across cultivated groundnut varieties corresponds to pronounced differences in phenolic metabolite abundance and post-harvest nutritional stability.

Evaluating six contrasting genotypes of Arachis hypogaea under rainfed semi-arid tropical conditions, the investigation established that foliage and seed coat biochemical profiles vary significantly prior to harvest and exhibit divergent degradation patterns throughout subsequent ambient warehouse storage. The findings reveal that varieties characterized by high initial concentrations of defensive secondary metabolites do not uniformly retain these compounds after harvest, demonstrating that genetic factors govern preservation efficiency independently of baseline synthesis. While secondary metabolites including total phenols, anthocyanins, and soluble sugars experienced marked reductions across all evaluated cultivars over two months of storage, primary macronutrient reserves such as crude proteins and total lipids remained structurally stable. By tracking biochemical flux from vegetative maturation through sixty days of post-harvest ambient storage, the research provides rigorous baseline metrics for breeding programs seeking to combine high agronomic productivity with superior commercial shelf life and functional food quality.

The field experiments were conducted across the consecutive Kharif cropping seasons of 2024 and 2025 at the Regional Agricultural Research Station in Tirupati, situated at 13.63 degrees North latitude and 79.42 degrees East longitude within the semi-arid agro-climatic zone of southern Andhra Pradesh, India. During the 2024 season, prevailing meteorological records documented minimum and maximum air temperatures ranging between 21.1 and 34.9 degrees Celsius, accompanied by morning relative humidity fluctuating between 75.0 and 81.8 percent, afternoon relative humidity between 50.0 and 59.5 percent, and cumulative seasonal rainfall of 643.4 millimeters. The subsequent 2025 season experienced ambient air temperatures spanning 16.5 to 35.8 degrees Celsius, morning relative humidity between 69.0 and 84.0 percent, afternoon relative humidity from 43.0 to 73.0 percent, and total crop growth precipitation of 587.0 millimeters. Field trials were organized in a Randomized Block Design incorporating three independent replications, yielding eighteen sample observations per designated evaluation milestone. All crop plots were managed under rainfed cultivation following standard regional agronomic recommendations, ensuring that observed biochemical distinctions reflected inherent genotypic variation under realistic field environments rather than artificial physiological stress.

The research evaluated six distinct cultivated groundnut genotypes procured from the Groundnut and Oilseeds Breeding Section of Acharya N. G. Ranga Agricultural University at Tirupati, deliberately selected to encompass four distinct kernel testa pigmentation categories. The panel comprised Himani, which produces white-coated kernels; K-6, characterized by rose pigmentation; Dharani, Visishta, and Kadiri Lepakshi, which all exhibit light pink seed coats; and Narayani, presenting light red testa coloration. All botanical materials evaluated were established cultivated crop varieties, excluding any wild, protected, or endangered germplasm. Researchers targeted this phenotypic diversity to determine whether visible pigmentation differences correspond to predictable physiological variations in seed composition and post-harvest endurance. Following crop maturation at physiological harvest, individual plot yields were harvested separately, after which mature kernels were detached, sun-dried, sealed within airtight hermetic storage containers, and placed in ambient laboratory storage maintained at 25 to 28 degrees Celsius and 50 to 55 percent relative humidity. Subsamples were systematically withdrawn at harvest and subsequently at 30 and 60 days after harvest to trace chronological shifts in biochemical constitution.

Quantification of biochemical constituents relied on standardized spectrophotometric and spectroscopic analytical protocols to ensure precision across all evaluated time points and genotypes. Total phenolic concentrations were determined through the Folin-Ciocalteu colorimetric method, reacting kernel extracts with Folin-Ciocalteu reagent and sodium carbonate solution before reading absorbance at 765 nanometers against gallic acid calibration standards, expressed as milligrams gallic acid equivalents per gram of sample. Total flavonoid content was assayed using the aluminium chloride colorimetric procedure, with absorbance measured at 415 nanometers and results expressed as milligrams quercetin equivalents per gram of kernel tissue. Total anthocyanin pigments were quantified via the pH differential spectrophotometric assay across dual absorbance peaks at 520 and 700 nanometers. Total soluble sugars were determined by reacting extracts with Anthrone reagent under acidic conditions with thermal color development monitored at 620 nanometers, while total protein content was measured at 660 nanometers using the Lowry copper-reduction method. Kernel oil concentrations were quantified by scanning dried kernel samples using calibrated Near Infrared Reflectance Spectroscopy at the ICAR-Indian Institute of Oilseeds Research laboratory in Hyderabad.

Pre-harvest foliar evaluations revealed wide genotypic divergence in vegetative secondary metabolite synthesis, reflecting contrasting baseline physiological capacities across the six cultivars prior to pod maturation. In leaf tissue sampled before crop lifting, the rose-pigmented genotype K-6 exhibited the highest total phenolic concentration at 5.70 milligrams gallic acid equivalents per gram of fresh weight, followed closely by the white-seeded Himani at 5.35 milligrams and Kadiri Lepakshi at 5.22 milligrams. Leaf anthocyanin accumulation was likewise highest in K-6, registering 0.347 milligrams per gram of fresh weight, followed by Dharani at 0.308 milligrams. However, foliar accumulation did not automatically translate into identical kernel profiles following post-harvest curing and storage. In stored kernels evaluated at sixty days after harvest, flavonoid content reached its peak in Visishta at 18.6 milligrams per gram of fresh weight and Kadiri Lepakshi at 18.5 milligrams, whereas Himani recorded the lowest flavonoid concentration of 14.9 milligrams per gram. These contrasting distributions demonstrate that vegetative pigment synthesis and reproductive sink tissue accumulation operate through distinct physiological partition mechanisms among groundnut varieties.

Systematic biochemical monitoring throughout the sixty-day ambient storage period demonstrated universal declines across all measured secondary metabolites, yet the velocity and proportional retention of these compounds differed dramatically among genotypes. Phenolic compounds suffered substantial breakdown during storage, with overall retention percentages ranging from a low of 14.3 percent in Visishta to a maximum of only 18.2 percent in Himani. Conversely, flavonoids exhibited remarkable physiological stability across all genotypes, maintaining post-harvest retention levels between 65.1 percent in Himani and an impressive 96.4 percent in Kadiri Lepakshi. Anthocyanin preservation displayed the widest genotypic disparity, with retention at thirty days after harvest spanning from just 32.0 percent in K-6 up to 80.3 percent in the light red genotype Narayani. Crucially, cultivars boasting the greatest initial metabolite concentrations did not necessarily exhibit superior preservation, indicating that post-harvest quality retention is governed by specialized biochemical resistance mechanisms rather than sheer abundance at harvest.

Evaluation of non-structural carbohydrates alongside primary macronutrients revealed contrasting storage dynamics between metabolic fuel reserves and structural seed components. Total soluble sugars declined steadily across all six genotypes during ambient storage, reflecting ongoing baseline cellular respiration within dormant seeds. Prior to harvest, Dharani recorded the highest initial soluble sugar concentration at 0.83 milligrams per gram of dry weight, followed by K-6 at 0.73 milligrams, while at thirty days after harvest, Dharani maintained highest sugar levels at 0.53 milligrams compared to minimums of 0.28 milligrams in Narayani and 0.30 milligrams in Kadiri Lepakshi. In striking contrast to soluble sugars, seed macronutrients demonstrated marked structural resilience over the two-month storage timeframe. Crude protein content remained exceptionally stable, with Dharani maintaining the highest concentration at 25.64 percent and Visishta recording 24.96 percent, while K-6 registered the lowest at 22.93 percent. Kernel oil content likewise remained stable, led by Kadiri Lepakshi at 48.80 percent and Visishta at 48.51 percent, with Himani recording the lowest oil content at 45.50 percent.

Agronomic performance trials conducted simultaneously with biochemical profiling demonstrated significant genotypic variation across pod yield, kernel yield, and shelling percentages under rainfed field conditions. Visishta established clear agronomic superiority, generating the highest pod yield of 2015.4 kilograms per hectare and a kernel yield of 1396.7 kilograms per hectare, while Dharani produced 1337.9 kilograms of pods and 892.4 kilograms of kernels per hectare, and Narayani yielded 1326.3 kilograms of pods and 855.4 kilograms of kernels. Kadiri Lepakshi recorded the lowest overall pod yield at 1016.9 kilograms per hectare, whereas K-6 produced the lowest kernel yield of 731.0 kilograms per hectare. Shelling percentages showed distinct genetic divergence, with Kadiri Lepakshi attaining the highest recovery at 71.7 percent, followed by Himani and Visishta at 69.3 percent, and Narayani recording the lowest shelling percentage at 64.5 percent. These agronomic baselines confirm that high-yielding cultivars such as Visishta can successfully combine substantial field productivity with high lipid content and robust flavonoid retention without apparent metabolic penalties.

Multivariate statistical evaluations provided deeper insight into the interconnected physiological dynamics governing groundnut seed composition across pre-harvest and post-harvest phases. Linear regression modeling between total phenolic and anthocyanin concentrations yielded a fitted equation of y equals 0.0068x plus 0.2448, accompanied by a negligible coefficient of determination of R-squared equals 0.014, demonstrating the absence of any direct linear association between total phenols and anthocyanin pigments across cultivars. Pearson correlation analysis highlighted notable functional relationships, including a strong positive association between kernel phenols at sixty days and anthocyanins at thirty days ($r = 0.87$, $P < 0.05$), positive links between thirty-day phenols and sixty-day phenols ($r = 0.65$), pre-harvest sugars ($r = 0.72$), and pre-harvest anthocyanins ($r = 0.52$). Furthermore, protein content at sixty days exhibited a strong negative correlation with pre-harvest foliar phenols ($r = -0.81$) but a positive correlation with thirty-day sugars ($r = 0.81$). Principal component analysis revealed that the first two components accounted for 81.9 percent of total biochemical variance, with PC1 driven by thirty-day sugars and protein, while PC2 reflected oil and flavonoid concentrations.

The biological mechanisms driving constituent turnover during ambient storage reflect natural metabolic reactions, oxidative processes, and enzymatic degradation within the dry kernel matrix. The researchers noted that passive auto-oxidation, residual cellular respiration, and catalytic activity from endogenous enzymes such as polyphenol oxidase and peroxidase drive the degradation of phenolic antioxidants and soluble sugars upon atmospheric exposure. Genotypes exhibiting superior anthocyanin retention, most notably Narayani, likely possess specialized seed coat physical structures, reduced membrane permeability, or internal cellular barriers that restrict oxygen diffusion into storage tissues. The authors emphasized study limitations, observing that the investigation examined six cultivated genotypes across a sixty-day storage duration without direct enzymatic assays or transcriptomic sequencing of flavonoid biosynthetic pathways. Consequently, while primary macronutrients demonstrate robust short-term stability, long-term trials spanning six to twelve months across broader germplasm panels remain necessary to establish extended oxidative stability, enzymatic activity kinetics, and population-level genetic correlations for commercial groundnut improvement programs.

Source: https://bioengineer.org/groundnut-pigment-profiles-shape-post-harvest-antioxidant-and-nutrient-retention-during-storage/