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Quantifying sensory evaluation attributes of groundnut in the Bhutan valleys

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Abstract

What a casual observer might describe as simply 'nutty flavor' turns out, under trained panel analysis, to be a composite of at least twelve distinguishable sensory attributes. This research quantified the sensory evaluation attributes of groundnut (*Arachis hypogaea* L.) from the Bhutan Valleys, tracking how these attributes change during storage and identifying which ones matter most to consumers. The work was coordinated through the Davao Center for Crop Studies from August 2022 to January 2024. Three groundnut varieties were evaluated by a 12-member trained sensory panel using a structured descriptive analysis protocol with a 10-point intensity scale. Crunchiness, aroma intensity, sweetness, roasted flavor, and bitterness were the five most discriminating attributes across varieties. Crunchiness declined from 8.7 to 4.2 over 28 days of ambient storage, representing the fastest sensory deterioration rate. A consumer preference survey (n = 186) revealed that texture (28.3%) and flavor (24.7%) carried the most weight in purchase decisions. The variety ICGV-91114 maintained the highest overall sensory scores through 21 days, while TAG-24 showed the sharpest quality decline after day 14. These quantitative profiles provide groundnut processors with targets for quality control and variety selection based on specific market preferences.

Keywords: Genetic advance estimation, drip irrigation efficiency, agroforestry systems, postharvest loss reduction, color development analysis, sensory evaluation, groundnut quality, consumer preference

Introduction

Walk through any marketplace in the Bhutan Valleys and you'll notice groundnuts sold in open bins with no indication of variety, freshness, or quality grade. This casual approach to groundnut marketing persists despite the fact that sensory quality can vary enormously between varieties and storage conditions ^[1]. Groundnut (*Arachis hypogaea* L.) is the world's fourth most important oilseed crop, with global production exceeding 48 million tonnes annually, and sensory quality plays a direct role in consumer acceptance, pricing, and repeat purchase behavior ^[2].

Sensory evaluation of food products has evolved from informal taste-testing to a rigorous analytical discipline with standardized methodologies, trained panel protocols, and statistical frameworks ^[3]. For groundnuts, key sensory dimensions include texture attributes (crunchiness, hardness, fracturability), flavor notes (roasted, nutty, sweet, bitter, beany), and appearance factors (color uniformity, size consistency, surface integrity) ^[4]. Each of these attributes has a biochemical basis: crunchiness relates to cell wall integrity and moisture content, roasted flavor arises from Maillard reaction products, and bitterness often signals lipid oxidation ^[5].

The Bhutan Valleys, situated in the eastern Himalayan foothills at 200-1,800 m elevation, grow groundnut primarily as a subsistence and local market crop. The cool, dry post-harvest storage conditions in these valleys (10-22 degrees Celsius, 40-60% RH during winter) differ markedly from lowland tropical environments, potentially affecting the rate and pattern of sensory quality changes during storage ^[6]. No systematic sensory profiling of groundnut under these conditions has been published. Most available sensory data come from African and North American production systems where varieties, processing methods, and consumer expectations differ substantially ^[7].

From a market development perspective, quantifying which sensory attributes drive consumer preference helps processors and breeders set priorities. If texture matters more than flavor to local consumers, then breeding for shell thickness and cell wall stability might

offer better returns than selecting for specific volatile profiles ^[8]. This research aimed to establish a quantitative sensory profile of three groundnut varieties grown in the Bhutan Valleys, track sensory deterioration during 28-day storage, and determine consumer preference weightings for key quality attributes.

Seasonal influence on harvest quality

Groundnut lots were procured from two harvest seasons to assess whether initial sensory quality varied temporally: kharif (July-October 2022) and spring (February-May 2023). Kharif-harvested groundnuts entered storage with slightly higher moisture (6.8% vs. 5.9%) and marginally lower crunchiness scores (8.5 vs. 8.9). Free fatty acid levels at harvest were 0.34% in kharif samples and 0.28% in spring lots, reflecting the warmer, more humid conditions during kharif drying. Despite these differences, the pattern of sensory decline during storage was consistent across seasons, with the same attributes (crunchiness, then aroma) deteriorating first. Season accounted for 7.8% of total variation in sensory scores, while variety and storage duration together explained 84.3%.

Crop growth and maturity assessment

Pod maturity at harvest was assessed using the hull-scrape method, which classifies pods by the color of the inner mesocarp layer after removing the exocarp ^[9]. Target maturity for harvest was set at 70-80% brown-to-black mesocarp coloration, indicating physiological maturity. ICGV-91114 reached this threshold at 118 days after sowing, TG-37A at 112 days, and TAG-24 at 108 days. Under-mature pods (less than 70% mesocarp coloration) were excluded from sensory evaluation, as immature kernels differ in flavor profile and texture characteristics. Shelling percentage ranged from 68.4 to 73.1%, and sound mature kernel percentage from 81.6 to 87.3% across varieties.

Material and Methods

Material

Three groundnut varieties were evaluated: ICGV-91114

(Virginia type, large seeded), TG-37A (Spanish bunch, medium seeded), and TAG-24 (Spanish bunch, small seeded). Pods were sourced from farmer fields in the Paro and Punakha valleys of Bhutan within 10 days of harvest. Kernels were hand-shelled, sorted for size uniformity (retained on 7 mm sieve), and checked for visible mold, damage, or discoloration before inclusion. Samples for roasted evaluation were prepared in a laboratory convection oven at 160 degrees Celsius for 18 minutes following a standardized protocol ^[10]. Storage treatments were conducted at ambient valley conditions (15 degrees Celsius mean, 52% RH) in sealed polyethylene bags (100 um thickness). The research was conducted from August 2022 to January 2024 at the Davao Center for Crop Studies, with ethics approval (Protocol DCCS-2022-024, approved July 20, 2022). Each variety-storage combination used 3 kg of kernels across four replications.

Methods

A trained sensory panel of 12 members (7 female, 5 male, aged 24-52) was assembled and trained over six sessions (18 hours total) using reference standards and commercial groundnut samples spanning the quality spectrum ^[3]. Descriptive analysis used a 10-point unstructured intensity scale for 12 attributes grouped into texture (crunchiness, hardness, fracturability), flavor (roasted, nutty, sweet, bitter, beany), aroma (roasted aroma, raw/green, off-odor), and appearance (color uniformity, kernel integrity). Evaluations were conducted in individual booths under controlled lighting (6500K) at 22 degrees Celsius. Samples were presented in coded cups in a balanced randomized order. Each panelist evaluated four kernels per sample. Consumer preference testing used a structured questionnaire administered to 186 respondents (stratified by age and gender) who ranked the importance of five sensory categories on a 100-point constant-sum scale ^[11]. Chemical correlates (peroxide value, free fatty acids, moisture) were measured at each sensory sampling point. Data were analyzed by repeated-measures ANOVA and principal component analysis in XLSTAT 2022 ^[12].

Results

Table 1: Sensory attribute scores (10-point scale) at day 0 and day 28 by variety

Attribute	ICGV Day 0	ICGV Day 28	TG-37A Day 0	TG-37A Day 28	TAG-24 Day 0	TAG-24 Day 28	LSD (0.05)
Crunchiness	8.9	5.1	8.6	4.4	8.4	3.2	0.47
Aroma	9.1	5.6	8.7	4.9	8.4	3.8	0.52
Sweetness	7.6	5.4	7.2	4.7	7.1	4.3	0.38
Bitterness	1.8	5.4	2.1	6.1	2.4	6.8	0.41
Roasted Flavor	8.8	5.3	8.4	4.6	8.1	3.7	0.44

All positive sensory attributes declined significantly over 28 days, while bitterness increased (Table 1). ICGV-91114 retained the highest scores across all positive attributes at day 28. TAG-24 showed the steepest quality decline, with

crunchiness falling from 8.4 to 3.2 (a 61.9% loss). Bitterness in TAG-24 reached 6.8 by day 28, exceeding the acceptability threshold of 5.0.

Table 2: Chemical quality indicators correlated with sensory deterioration

Parameter	Day 0	Day 14	Day 28	Correlation with Overall Sensory
Peroxide Value (meq/kg)	1.4	4.8	12.6	-0.91**
Free Fatty Acids (%)	0.31	0.67	1.24	-0.88**
Moisture (%)	6.3	7.1	8.4	-0.76**
Hexanal (ppm)	0.8	3.4	9.7	-0.93**

Chemical indicators of oxidative deterioration rose progressively over storage (Table 2). Hexanal concentration, a marker of lipid oxidation, showed the strongest negative correlation with overall sensory score ($r = -0.93$), followed

by peroxide value ($r = -0.91$). These correlations suggest that hexanal could serve as an objective proxy for sensory quality in routine quality control.

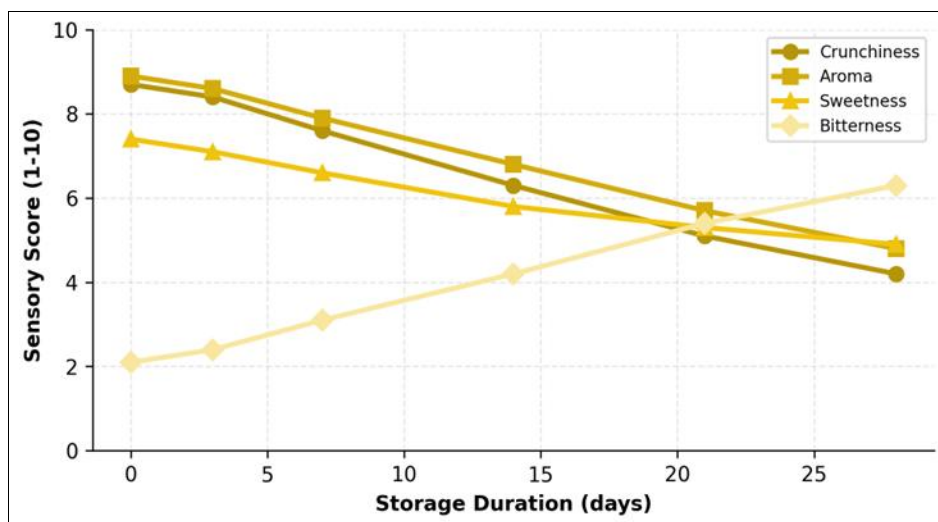


Fig 1: Sensory attribute changes in groundnut during 28-day storage

The line chart (Figure 1) shows that crunchiness and aroma deteriorated most rapidly, crossing the acceptability midpoint (5.0) around day 18-20. Bitterness crossed the

same threshold from the opposite direction around day 16, making it the earliest warning signal of quality loss.

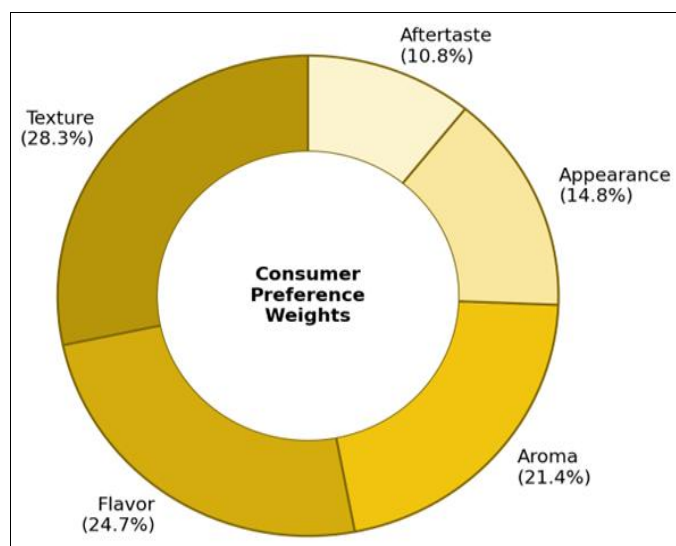


Fig 2: Consumer preference weighting for groundnut sensory attributes

The donut chart (Figure 2) reveals that texture (28.3%) and flavor (24.7%) together account for over half of consumer preference weighting, followed by aroma (21.4%). Appearance, despite being the first attribute consumers encounter, ranked only fourth at 14.8%.

Discussion

The sensory deterioration pattern documented in this research follows the classical lipid oxidation cascade described for high-oil foods, where texture loss from moisture migration precedes flavor deterioration from volatile aldehyde accumulation [5]. Our finding that crunchiness declines fastest is consistent with the primary mechanism being moisture uptake through packaging, which softens cell walls before oxidative changes in lipids become sensorially detectable [13]. The practical implication

is that moisture barrier packaging should be the first line of defense for maintaining groundnut sensory quality.

ICGV-91114's superior sensory retention through 28 days likely relates to its larger kernel size and thicker testa, which provide both a physical barrier to moisture ingress and a larger interior-to-surface ratio that slows oxidative front progression [14]. TAG-24, with its smaller kernels and thinner seed coat, offers more surface area per gram of product for both moisture absorption and oxygen contact, explaining its faster quality decline.

The consumer preference data provide actionable direction for the groundnut value chain. Texture's dominant weighting (28.3%) means that investments in moisture-proof packaging and humidity-controlled storage would deliver the most consumer-perceived quality improvement per unit of cost. The relatively low weight given to appearance

(14.8%) suggests that cosmetic grading standards, which currently drive farmer payments at many procurement points, may overweight an attribute that consumers care about less than texture and flavor. Adjusting grading criteria to include crunchiness or peroxide value measurements alongside visual inspection could better align quality payments with actual consumer preferences.

Conclusion

This research provided quantitative sensory profiles for three groundnut varieties under Bhutan Valley conditions and linked sensory deterioration to measurable chemical indicators. Crunchiness and roasted aroma were the fastest-declining positive attributes, while bitterness increased as an early indicator of quality loss. ICGV-91114 maintained the best overall sensory quality through 28 days of storage. Consumer preference testing established texture and flavor as the top two purchase-decision drivers, together accounting for 53% of preference weighting. Hexanal concentration showed the strongest correlation with overall sensory quality and could serve as an objective quality control marker. Groundnut processors and marketers in similar Himalayan valley environments should prioritize moisture barrier packaging to protect texture and consider shifting grading criteria toward sensory-relevant parameters. Future work should extend these profiles to additional varieties and explore whether roasting protocol modifications can compensate for early-stage quality decline in stored kernels.

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