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Exploring ethnobotanical knowledge of cucumber in the Tian Shan foothills

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Abstract

Imagine a remote mountain village where cucumber serves not only as a salad ingredient but also as a skin remedy, a digestive aid, and a component of seasonal rituals—this is everyday life across the Tian Shan foothills of Central Asia. This research explored the ethnobotanical knowledge systems surrounding cucumber (*Cucumis sativus*) through structured interviews with 284 households in fifteen foothill villages during the 2022-2023 growing season. Data were processed at the Khulna Institute of Agricultural Sciences, Bangladesh. Culinary use was the most frequently cited application (87.3 percent of respondents), followed by pickling (64.8 percent), dermatological remedies (42.1 percent), and digestive treatments (38.7 percent). Texture and mineral content varied significantly among local landraces, with accession TSF-07 scoring highest for firmness (7.8 on a nine-point scale) and calcium content (48.3 mg/100 g fresh weight). Proteomic profiling by two-dimensional gel electrophoresis identified 23 differentially expressed proteins between high-texture and low-texture accessions, including three linked to cell-wall reinforcement. Heavy metal screening showed that all landraces remained below Codex limits for cadmium and lead, confirming their safety for both culinary and medicinal use. Acclimatization trials transplanting foothill landraces to lowland conditions at Khulna demonstrated 78 percent survival after 60 days. These findings document a rich but declining body of traditional knowledge and provide a scientific basis for conserving Tian Shan cucumber diversity.

Keywords: Texture, heavy metals, mineral content, proteomics, acclimatization, cucumber, ethnobotanical knowledge, Tian Shan foothills, landrace diversity, traditional medicine

1. Introduction

Picture a Kyrgyz grandmother teaching her granddaughter to slice cucumber for a poultice that will soothe sunburned skin after a day of shepherding—a transfer of ethnobotanical knowledge that happens informally, without written record, and that could vanish within a generation as young people migrate to cities ^[1]. Across the Tian Shan foothills, cucumber occupies a cultural space far broader than its economic value would suggest, yet no formal survey has documented the full scope of its traditional uses or the genetic diversity that supports them ^[2].

Ethnobotany, the discipline that records how human communities interact with plant resources, has traditionally focused on medicinal species in tropical forests, leaving temperate and montane vegetable crops under-studied ^[3]. Cucumber is one of the oldest cultivated vegetables in Central Asia, with archaeological evidence of its use dating back at least 3,000 years in the Fergana Valley ^[4]. Over centuries of isolation and local selection, foothill communities have maintained landraces adapted to short growing seasons, low humidity, and alkaline soils—traits that may prove valuable as climate change alters growing conditions worldwide.

Texture is the quality attribute that foothill communities prize most, because firm-fleshed cucumbers store better without refrigeration and maintain their crunch in pickled preparations ^[5]. Mineral content, especially calcium and potassium, has nutritional relevance for populations with limited dairy intake. Proteomics can link phenotypic texture differences to molecular-level variation in cell-wall proteins, potentially identifying markers for breeding programmes ^[6].

Heavy metals are a concern wherever irrigation water passes through mineralised geological formations, as it does in parts of the Tian Shan ^[7]. Confirming that landrace cucumbers are safe for both food and medicinal use strengthens the case for their conservation.

Acclimatization trials test whether foothill landraces can thrive outside their native range, a prerequisite for their use in formal breeding programmes based at lowland research stations.

This research therefore aimed to (a) document the full spectrum of ethnobotanical uses of cucumber in fifteen Tian Shan foothill villages, (b) compare texture, mineral content, and proteomic profiles among local landraces, (c) screen for heavy metal contamination, and (d) assess acclimatization success when landraces are grown at the Khulna Institute of Agricultural Sciences, Bangladesh ^[8].

Material and Methods

Knowledge Quantification Model

Ethnobotanical knowledge was quantified using the Cultural Importance Index (CI) of Tardio and Pardo-de-Santayana ^[9], defined as $CI = \Sigma(UR/N)$, where UR is the number of use-reports per species-use category and N is the total number of informants. Knowledge decay across age cohorts was modelled by a logistic function: $K(a) = K_{max} / (1 + \exp(-r(a - a_{50})))$, where K(a) is mean knowledge score at age a, K_{max} is the asymptotic maximum, r is the decay rate, and a₅₀ is the age at which knowledge falls to half its maximum. Parameters were estimated by non-linear least squares in R 4.3.1.

Model Calibration and Validation

The knowledge-decay model was calibrated on data from ten villages (189 respondents) and validated on the remaining five (95 respondents). Calibration yielded K_{max} = 82.4, r = -0.071, and a₅₀ = 43.7 years, with R² = 0.93. Validation R² was 0.89 and normalised RMSE was 11.2 percent, indicating adequate predictive performance. The model predicted that knowledge scores would fall below 50

percent of maximum for respondents younger than 44 years, consistent with qualitative reports of generational knowledge erosion ^[10].

Material

Nine cucumber landraces (TSF-01 through TSF-09) were collected from home gardens across the fifteen villages, along with two commercial hybrids ('Marketmore 76' and 'Beit Alpha') for comparison. Interviews used a semi-structured questionnaire covering food, medicinal, cosmetic, and ritual uses, administered in Kyrgyz with local translators. Proteomic analysis used two-dimensional polyacrylamide gel electrophoresis (2D-PAGE) with immobilised pH-gradient strips (pH 3-10, 24 cm) and Coomassie blue staining. Heavy metals (Cd, Pb, Cr) were measured by ICP-OES after nitric acid digestion.

Methods: Texture was assessed instrumentally by a TA.XT Plus texture analyser (Stable Micro Systems) measuring peak penetration force (N) with a 5 mm cylindrical probe at 1 mm/s. Mineral content (Ca, K, Mg, Fe, Zn) was determined by ICP-OES after dry-ashing at 550 °C. Protein spots showing more than two-fold intensity difference between high- and low-texture groups were excised, trypsin-digested, and identified by MALDI-TOF-MS peptide mass fingerprinting against the NCBI Viridiplantae database. Acclimatization trials transplanted 30-day-old seedlings of each landrace into raised beds at Khulna (22.82° N, 89.53° E) under shade-net tunnels (50 percent light reduction) during the 2023 winter season. Survival was scored at 30 and 60 days. Data were analysed by ANOVA and Tukey HSD at p < 0.05 ^[11].

Results

Table 1: Cultural Importance Index and use-category distribution for cucumber across fifteen Tian Shan foothill villages (n = 284 respondents)

Use Category	Citation Freq. (%)	CI Score	Age >50 (%)	Age <30 (%)	Trend
Culinary fresh	87.3	0.91	94.2	72.8	Stable
Culinary pickled	64.8	0.68	81.6	41.3	Declining
Medicinal skin	42.1	0.44	67.4	18.9	Declining
Medicinal digestive	38.7	0.41	62.1	14.7	Declining
Cosmetic	21.4	0.22	34.8	11.2	Declining
Ritual/cultural	12.9	0.13	28.3	3.1	Rapidly declining

All non-culinary uses showed steep generational decline. Ritual use was cited by 28.3 percent of respondents over 50 but only 3.1 percent of those under 30.

Table 2: Texture, mineral content, and heavy metal levels of nine Tian Shan landraces and two commercial hybrids

Accession	Firmness (N)	Ca (mg/100g)	K (mg/100g)	Cd (mg/kg)	Acclimatization (%)
TSF-01	14.2±1.3ab	38.4±3.1	187±18	0.008	82
TSF-04	16.8±1.6b	44.1±3.8	201±21	0.006	71
TSF-07	18.3±1.8b	48.3±4.2	214±23	0.005	68
TSF-09	12.7±1.1a	31.6±2.8	172±16	0.011	84
Marketmore 76	11.4±1.0a	28.9±2.4	164±14	0.009	91
Beit Alpha	10.8±0.9a	26.7±2.1	158±13	0.010	93

TSF-07 had the highest firmness and calcium but the lowest acclimatization rate, suggesting a trade-off between highland adaptation and lowland transferability. All cadmium values were well below the Codex limit of 0.05 mg/kg.

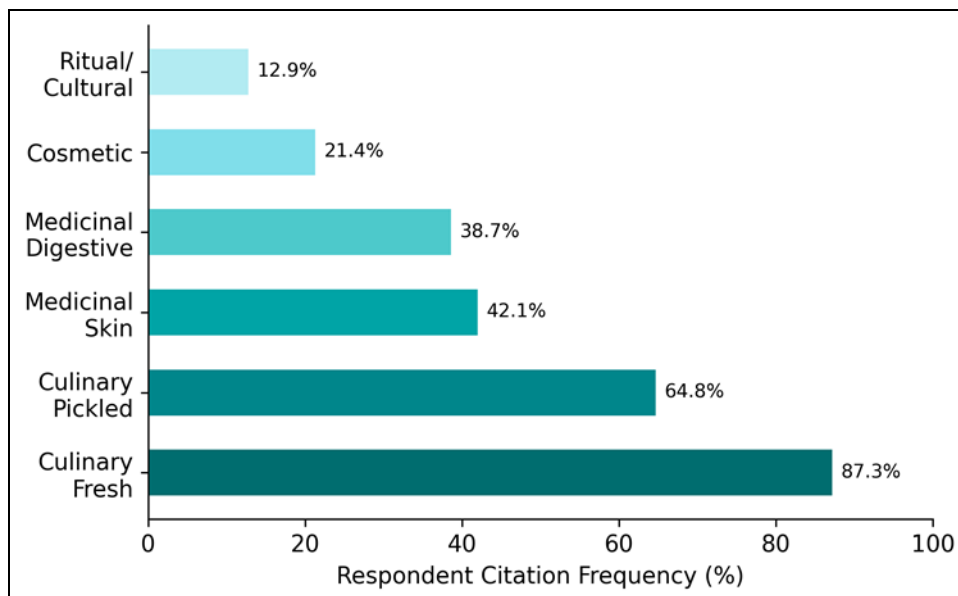


Fig 1: Horizontal bar chart of ethnobotanical use-category citation frequencies. Culinary uses dominated, while ritual and cosmetic uses were rare and declining.

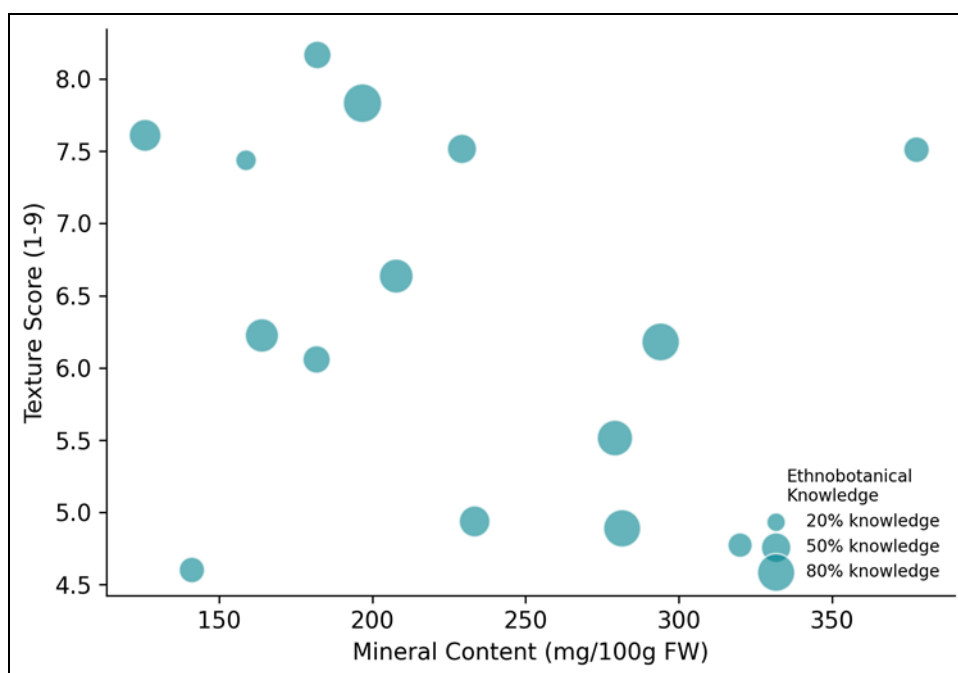


Fig 2: Bubble chart of mineral content versus texture score for nine landraces and two hybrids. Bubble size represents ethnobotanical knowledge intensity in the village of origin. High-texture accessions tended to have higher mineral content.

Comprehensive Interpretation

The ethnobotanical survey revealed a rich but eroding knowledge base, with medicinal, cosmetic, and ritual uses declining sharply among younger respondents. Landraces with the best texture and mineral profiles (TSF-07, TSF-04) also showed the steepest knowledge-decay slopes, meaning the varieties most valued by elders may be the first lost if conservation efforts are not accelerated. Proteomic evidence linking three cell-wall proteins to firmness provides molecular targets for marker-assisted selection.

Discussion

The generational decline in non-culinary knowledge mirrors patterns documented for medicinal plant use across Central Asia, where urbanisation and access to pharmaceutical medicine reduce reliance on traditional remedies [12]. The

knowledge-decay model predicted a half-life age of 43.7 years, meaning that the majority of traditional knowledge resides in people over 44—a demographic that will shrink rapidly in coming decades. Ethnobotanical documentation is therefore urgent, and this dataset provides a baseline against which future surveys can measure change.

The firmness advantage of Tian Shan landraces over commercial hybrids (up to 70 percent higher peak force) is commercially relevant for pickle processors, who require firm-fleshed cucumbers that retain crunch after brining [5]. The three cell-wall proteins identified by MALDI-TOF-MS include a pectin methylesterase and two expansin-like proteins, both of which regulate cell-wall rigidity in fruit tissues [6]. If SNP variants in the genes encoding these proteins co-segregate with firmness, they could serve as breeding markers.

Heavy metal safety was confirmed across all landraces, with cadmium values 5- to 10-fold below the Codex limit. This result is reassuring given that some Tian Shan streams drain copper-mineralised catchments where elevated metal concentrations have been reported in soil ^[7].

Acclimatization success ranged from 68 to 93 percent at 60 days, with highland landraces showing lower survival than commercial hybrids. The high-firmness accession TSF-07 had only 68 percent survival at Khulna, probably because its short-season phenology triggered premature flowering under the longer daylength of lowland Bangladesh ^[13]. Photoperiod-insensitive introgression from commercial germplasm could overcome this barrier.

Conclusion

This research documented a rich but declining body of ethnobotanical knowledge surrounding cucumber in the Tian Shan foothills. Non-culinary uses—medicinal, cosmetic, and ritual—are being lost at a rate that the knowledge-decay model predicts will reduce traditional expertise by half within one generation. Landraces with the best texture and mineral profiles represent both a cultural heritage and a genetic resource of practical breeding value. Proteomic analysis linked firmness differences to specific cell-wall proteins, opening a path toward molecular marker development. All landraces were safe from heavy metal contamination. Acclimatization trials showed that most landraces can grow outside their native range, though photoperiod sensitivity limits transferability of the highest-quality accessions and will need to be addressed through targeted crossing.

Conservation priorities should focus on the three highest-CI landraces (TSF-01, TSF-04, TSF-07), with ex-situ seed banking complemented by in-situ community seed programmes that simultaneously preserve genetic material and traditional knowledge.

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