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Quality, integrity and safety of Medicinal and Aromatic Plants (MAPs) and Wild Edibles from Indian Himalayan Arid Regions

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Abstract: The arid region of the Indian Himalayas is abundant in medicinal and aromatic plants (MAPs) as well as wild edible plants, which are vital to traditional healthcare systems, local livelihoods, and the growing nutraceutical and related markets. The challenging climate, delicate ecosystem, and limited farming practices make the wild populations susceptible to over harvesting, adulteration, and loss of authenticity. Deficiencies in the standardization of post-harvest processing and value addition practices undermine product integrity. This paper presents an opinion on the current quality assurance frameworks and the necessity for customized ones suited to the harsh conditions of the Himalayan arid regions.

Key words: Himalayan arid zone, quality control and standardization, Good Agricultural and Collection Practices, Biological Diversity (Amendment) Rules.

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Ladakh (UT), the Lahaul and Spiti district of Himachal Pradesh, and parts of Tibet come under the Himalayan arid zone. The area is characterized by low rainfall, intense solar radiation, and significant temperature fluctuations, due to which the distinctive and resilient plant life rich in secondary metabolites is found in the region. Many medicinal and aromatic plants (MAPs), as well as wild edibles, have been documented in these areas (Kumar *et al*., 2021), some of which are enlisted in Table 1. Plants like *Rhodiola rosea*, Seabuckthorn (*Hippophae rhamnoides*), *Artemisia brevifolia*, and *Ephedra* spp., found in the arid regions of the Indian Himalaya, are also internationally acknowledged for their medicinal, nutritional, and industrial uses.

The rising demand for natural products is rapidly influencing the harvesting and commercialization of these plant resources. Many of these plants are traded, with their values differing based on the product form and concentration of active constituents. For example, *Rhodiola rosea* plant part extract powder with a high active constituent content is sold at around `Rs. 13000 $kg^{-1}$, while that with a lower concentration of these constituents is priced less (www.tradeindia.com). Similarly, the cost of *Hippophae rhamnoides* dried berries varies based on quality, which varies from < Rs. 190 to > `Rs. kg^{-1} (Source: www.tradeindia.com). The price of *Hippophae rhamnoides* seed oil also varies between 35-130 USD kg^{-1},

Table 1. Information on various medicinal and aromatic plants, along with wild edibles, found in the arid regions of the Indian Himalayas (Batool et al., 2023; Batool et al., 2024; Devi et al., 2023; Pandith et al., 2018; Batool and Gairola, 2024)

Scientific name	Vernacular/ common names	Edible part	Medicinal / traditional use (short)	Conservation notes
Rheum australe	Himalayan rhubarb (local: 'paashaan')	Root, young shoots	Laxative, digestive, wound applications	Endangered in parts of NW Himalaya; high harvesting pressure
Rhodiola rosea	Golden root (local: 'roseroot')	Root/rhizome	Adaptogen — fatigue, altitude sickness	IUCN: Least Concern (global); checked locally
Berberis aristata	Indian barberry (locally: 'Kilmora')	Roots, bark, berries	Antimicrobial, tonic, digestive	Locally common; harvested for roots
Ephedra gerardiana	Soma, 'Jora' (ephedra)	Stems	Stimulant, decongestant	Holds active alkaloids; regulated use
Hippophae rhamnoides	Sea-buckthorn (locally: 'Thol/ Tholma')	Berries, leaves	High Vitamin C; nutritional, medicinal	Locally abundant; cultivated in places
Allium carolinianum	Wild onion	Bulbs, leaves	Culinary, stimulant, digestive	Common wild food
Chenopodium album	Bathua / wild spinach	Leaves	Edible leafy vegetable; nutritive	Common
Thymus linearis	Wild thyme	Leaves	Flavoring; digestive, antiseptic	Culturally important wild herb
Capparis spinosa	Caper bush	Flower buds, fruits	Used as condiment; digestive	Found in rocky habitats; valued as flavoring
Mentha longifolia	Wild mint (local: 'pudina')	Leaves	Digestive, carminative	Common
Potentilla anserina	Silverweed	Roots, young leaves	Edible parts: traditional uses recorded	Localized occurrences
Bistorta vivipara	Sheeps sorrel/ 'Peshkar'	Young shoots, roots	Edible shoots; mild medicinal uses	Used traditionally
Oxyria digyna	Mountain sorrel	Leaves	Edible, souring agent	Common in alpine meadows
Aconitum heterophyllum	Atis/ monkshood (toxic)	Roots (toxic if unprocessed)	Used in traditional medicine after careful processing; analgesic	Toxic if misused; medicinal value under strict prep
Prunus armeniaca	Wild apricot (locally: 'Khumani')	Fruits	Nutritional; oil from kernels	Widely used; domesticated and wild forms
Juglans regia	Walnut (local name varies)	Nuts, kernels	Nutritional; traditional uses	Cultivated and wild trees present
Bunium persicum	Black cumin (locally: 'Shilajit?'/ 'Kala zeera')	Seeds	Condiment; aromatic; digestive	Valued spice: wild populations collected
Urtica hyperborea	Mountain nettle	Leaves	Cooked as leafy vegetables; nutritive	Common seasonal green
Thalictrum foliosum	Meadow rue	Leaves/roots (limited edible use)	Used in traditional remedies locally	Recorded in Lahaul-Spiti ethnobotanies

and it is influenced by factors such as grade, form, volume, and destination (Source: https://www.go4worldbusiness.com; www.tradeindia.com). Numerous other plant products are also available for purchase, primarily traded through local collectors, herbal aggregators, or specialized exporters.

By examining trade values, one can assess the significance of preserving the quality of plant materials and their value-added products in commerce. Unlike well-established agricultural industries, the processing and trading of plant products from the Himalayan arid zone often lack standardized procedures, which poses

risks to both consumers and producers and jeopardizes the long-term sustainability of the resources being utilized.

The levels of bioactive compounds in *Hippophae rhamnoides* berries are affected by factors like harvest timing, geographical location, post-harvest treatment, and the specific plant part used (Andersson *et al*., 2008; Christaki, 2012; Danielski and Shahidi, 2024; Lukša *et al*., 2020). These berries are sourced from various regions in Ladakh and the Lahaul & Spiti district of Himachal Pradesh, but there are no uniform methods for their collection and processing. As a result, different batches of the same product may have inconsistent amounts of active ingredients, which can compromise their efficacy and market standing (Sławińska *et al*., 2023). This issue is also prevalent in other medicinal and aromatic plants and wild edible products. The high value of some MAPs makes them susceptible to being adulterated with less potent substances. Without proper identification and authentication measures, misidentified or substandard plant materials can infiltrate the supply chain. For example, *Carum carvi* (caraway) is occasionally mixed with *Bunium persicum* (Black Caraway) seeds (Agnihotri *et al*., 2024). Such adulteration can result in adverse health effects (Jităreanu *et al*., 2022). Many plants are cultivated due to biodiversity conservation concerns, but their yield can be affected by contamination from human activities. Most of the arid regions in the Himalayas are popular tourist spots, which can degrade the quality of the final products due to increased pollution in these areas (Wani *et al*., 2025). Without proper post-harvest processes, such as cleaning, drying, and storage, the products do not meet international safety standards, making them unsuitable for export or even local use (Sharma *et al*., 2022). Often, the origin of plant materials is not documented, making it challenging to verify the authenticity and quality of the products or raw materials (Fong, 2002). To address these challenges, a quality control system involving stakeholders from local farmers to regulatory bodies is essential.

Adopting effective agricultural and collection practices (GACPs), along with post-harvest processing, standardization, certification, and traceability, can help tackle these issues. GACPs encompass training in plant identification, sustainable harvesting, and setting a standard harvesting season to ensure best levels of desired phytochemicals. To ensure efficient post-harvest processing of plant materials and their value-added products, it is important to develop or follow existing standard operating procedures (SOPs) for drying, cleaning, sorting, and primary processing to minimize contamination and degradation (Agnihotri *et al*., 2017; Agnihotri *et al*., 2020). Third-party certification, specifically designed for the Himalayan region and its unique challenges, along with compliance with GACPs and processing SOPs, would help keep the quality of plant materials and their value-added products. Along with these, the recent changes to the Biological Diversity (Amendment) Rules, 2025 (effective from November 1, 2025), have introduced digital issuance of Certificates of Origin for cultivated MAPs. This modification aims to simplify documentation of the MAP produces for small-scale growers in the Himalayas, improving traceability and easing smoother trade (Spina *et al*., 2023). The Access and Benefit Sharing (ABS) regulations of 2025 have introduced a tiered benefit-sharing requirement for plant materials sourced from the wild (Lachenmeier and Montagnon, 2024), while cultivated MAPs are exempted. This exemption is designed to ease the burden on small-scale cultivators in the Himalayan region. As a result, MAP cultivators in the Indian Himalayan arid region can integrate their traditional cultivation and post-harvest processing techniques with modern quality standards. The digital certification of their plant materials could lead to the production of high-value herbal products, helping both the communities and biodiversity. To achieve the goals of the updated rules and regulations, it is essential to develop or enhance infrastructure facilities, testing laboratories, and trained personnel.

In India, there are many rules and guidelines for processing wild edible fruits, enhancing their value, and ensuring quality control, which are relevant to the Indian Himalayan arid region. The Food Safety and Standards (FSS) Act of 2006 requires all food businesses to obtain licenses, while the FSS (Licensing & Registration) Regulation of 2011 (amended in 2020) outlines Good Manufacturing Practices (GMP) and Good Hygiene Practices (GHP),

addressing aspects like pest management, the use of potable water, proper storage, and equipment cleanliness. The Food Safety and Standards (Food Products Standards and Food Additives) Second Amendment Regulations, 2023 set up product-specific standards to keep the quality of processed foods, including approved preservatives and microbiological limits. The FSS (Contaminants, Toxins, and Residues) Regulations of 2020 define the maximum allowable levels for heavy metals, pesticides, and mycotoxins. Additionally, other rules or acts, such as the Biodiversity Act of 2002 (amended in 2023) and the Himachal Pradesh Forest Produce Transit Rules of 2013, govern various aspects, including the harvesting of wild bioresources, transit permissions, and benefit sharing, while the Wildlife (Protection) Act of 1972 oversees the extraction of wild resources from protected areas. The Geographical Indications of Goods (Registration and Protection) (Amendment) Rules of 2023 also safeguard certain local products, like the *Raktsey Karpo* apricot and *Hippophae rhamnoides* from Ladakh (UT). Despite these regulations, the practical implementation in the Indian Himalayan arid regions meets some challenges. These include limited facilities for quality testing of perishable plant produces and a lack of region-specific guidelines for plant produce processing and awareness among small producers. Some of these challenges can be mitigated by setting up mobile facilities for basic testing labs and creating simplified licensing and related training programs. The Indian government has undertaken many initiatives, yet it is essential to enhance awareness and build the ability of relevant stakeholders to effectively implement the rules and regulations.

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