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RESEARCH ARTICLE

Filling the Gaps: Advancing Neglected and Underutilised Species and Knowledge Systems in Thailand for Food Security and Environmental Sustainability

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Abstract

Neglected and underutilised species (NUS) offer potential to enhance nutrition, food security, and environmental sustainability. Of the over 30,000 edible plant species that exist globally, fewer than 150 are commercially cultivated, accelerating the loss of agrobiodiversity and the homogenisation of food systems. Using Thailand as a case study, this review highlights five NUS—yellow burrhead (*Limnocharis flava* Buch.), Ceylon oak (*Schleichera oleosa* (Lour.) Merr.), bastard oleaster (*Elaeagnus latifolia* L.), star apple (*Chrysophyllum cainito* L.) and hogweed (*Physalis angulata* var. *angulata*)—for their high nutritional and medicinal potential. These species can diversify diets, promote sustainable agriculture, and revive indigenous food cultures, but their adoption is hindered by limited infrastructure, low consumer awareness, and insufficient inclusion in food composition databases. Integrating NUS into these databases supports accurate dietary assessment, informed public health policies and product innovation. By combining scientific research with traditional knowledge, NUS can contribute to resilient, culturally relevant, and sustainable food systems in Thailand and globally.

Keywords: Biodiversity · Environmental Sustainability · Food Systems · Nutrition · Neglected and Underutilised Species · Food Composition Data · Traditional Knowledge

1. Introduction

Neglected and underutilised species (NUS)—encompassing not only plants but also underutilised animal breeds, insects, fungi, and other components of agrobiodiversity—have long played a pivotal yet under-recognised role in global food systems, offering valuable contributions to nutrition, food security, and environmental sustainability. For example, despite the identification of 30,000 edible plant species worldwide, both cultivated and wild, fewer than 150 are cultivated on a commercial scale (Mokria et al., 2022). Moreover, only four crops—sugarcane, maize, wheat, and rice— account for nearly half of global primary crop production (Knez et al., 2023). This extreme concentration of production, mirrored in livestock and aquaculture systems dominated by a small number of breeds and species, heightens the vulnerability of current

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agricultural systems to climate variability, pest and disease outbreaks and to market shocks, while narrowing the diversity of foods available for healthy diets.

Global policy agendas explicitly call for diversification. Sustainable Development Goal (SDG) 2 urges the identification and promotion of alternative food sources to end hunger and all forms of malnutrition by 2030. NUS directly support this objective by expanding the range of nutrient-dense foods available to populations and reducing reliance on a limited number of staples. Their contributions also extend to SDG 3 (Good Health and Well-Being), through their potential to diversify diets and address micronutrient deficiencies; SDG 12 (Responsible Consumption and Production), by encouraging sustainable and locally adapted food systems; and SDG 15 (Life on Land), through the conservation of agrobiodiversity and restoration of degraded ecosystems.

The United Nations Decade of Action on Nutrition (2016-2025) similarly emphasises the need for resilient, nutrition-focused food systems capable of feeding a growing global population without exacerbating environmental degradation (Miller, 2019). NUS are central to this vision: they offer climate-adaptive traits, support ecological sustainability, and provide culturally relevant, nutrient-rich foods. These qualities make them particularly important in regions where demographic pressures, environmental stress, and nutrition transitions are rapidly reshaping food-system needs—setting the stage for a closer examination of their relevance in Southeast Asia.

The underutilisation of indigenous crops comes at a time when global food systems face increasing pressure. The world's population, now about 8.2 billion and projected to approach nearly 10 billion by 2050, will see particularly rapid growth in Southeast Asia (Costlow et al., 2025), where urbanisation and rising incomes are driving changed dietary demand (Ghosh et al., 2024; Miladinov, 2023). Recent analyses emphasise not just the need to increase food production, but to ensure the availability and accessibility of nutritious, diverse foods: global supply still falls short of dietary guidelines for key food groups like fruits, vegetables, legumes, nuts and seeds, and large regional gaps persist (Costlow et al. 2025). In the Southeast Asia region, failure to mainstream underutilised local crops could mean that meeting future food demand will intensify pressure on soil, water and forests while also failing to close the nutrition gap — thereby risking higher burdens of diet-related disease and reduced food-system resilience in an ecologically sensitive and densely populated part of the world.

Southeast Asia is known for its diversity of rice varieties, tropical fruits, spices, and many unique indigenous foods. The region, however, faces numerous threats to agrobiodiversity, including the loss of traditional knowledge among the numerous ethnic and indigenous groups living throughout the region (Estoque et al., 2019; Procheş et al., 2021; Savini et al., 2021; Sodhi et al., 2004; Tan et al., 2022). Agrobiodiversity loss in Southeast Asia has intensified in recent decades, driven by the compounded effects of the global climate crisis, land-use change, and habitat degradation. Unsustainable agricultural practices—particularly the expansion of monoculture systems—have further accelerated genetic erosion and increased vulnerability to pests and invasive species. These trends are exacerbated by weak regulatory frameworks and economic pressures that prioritise short-term productivity over long-term sustainability (Struebig et al., 2025). Although Southeast Asian (SEA) countries and the ASEAN Secretariat have developed multiple initiatives and policy frameworks for agrobiodiversity conservation, there has been limited emphasis on preserving and promoting indigenous food cultures as a strategy for achieving these goals (ASEAN Centre for Biodiversity, 2023; ASEAN Secretariat, 2021, 2022).

This gap presents an opportunity to re-examine the role of NUS. As demonstrated by Knez, Ranić, et al. (2023), these species offer diverse advantages, including enhanced nutritional profiles, resilience to abiotic stresses, and adaptability to marginal environments—traits that are increasingly critical in the face of climate change and biodiversity loss. Their comprehensive review highlights a range of NUS—such as buckwheat (*Fagopyrum esculentum*), sow thistle (*Sonchus* spp.), Armenian cucumber (*Cucumis melo* var. *flexuosus*), and underutilised landraces or cultivars of staple crops like tomato, grass pea, eggplant, and lentils—which not only diversify diets but also offer ecological benefits, such as low input requirements and compatibility with agroecological farming practices. Many NUS are also well adapted to local agroecological conditions and thrive in harsher environments, often requiring fewer inputs, such as pesticides and fertilisers (Mabhaudhi et

al., 2019). Consequently, these NUS present opportunities for diversifying agricultural systems, improving food security, and reducing the environmental impact of farming practices.

In addition to their environmental benefits, NUS are essential for improving nutritional outcomes and livelihoods, particularly in rural and indigenous communities. In Northern Thailand, wild edible fruit plants, for example, play a vital role in local subsistence, especially during seasonal food shortages. In provinces like Roi Et, these fruits are also integral to traditional medicine, used in herbal remedies and therapeutic practices (Saensouk et al., 2025). Indigenous peoples possess rich traditional knowledge of local food systems, often relying on foods sourced directly from their natural surroundings through farming, wild harvesting, or foraging. These NUS are diverse, nutrient-rich, and important for maintaining dietary diversity, which is crucial for preventing malnutrition and micronutrient deficiencies. Studies show that NUS, including wild plants (Mishra et al., 2021), fungi (Sileshi et al., 2023), and edible insects (Devi et al., 2023), provide valuable sources of vitamins, minerals, and other essential nutrients. Developing NUS can also provide critical market access to otherwise economically marginalised indigenous populations (Benton et al., 2021). However, much of the potential of these foods remains unexplored, and research on their nutritional value is still limited.

Despite their demonstrated agronomic and nutritional value, NUS remain marginalised in mainstream agriculture and research. Promoting their cultivation and inclusion in food systems could simultaneously address nutritional security, support local economies—especially in low-input or resource-poor settings—and reduce dependence on a narrow set of globally dominant crops. The work of Akinola et al. (2020) and Knez, Ranić, et al. (2023) underscores the urgent need to revalorise NUS within both scientific agendas and policy frameworks aimed at achieving sustainable food systems (Akinola et al., 2020; Knez et al., 2023). By reintroducing NUS into mainstream agriculture and food systems, we can improve both the sustainability of food production and the nutritional quality of diets worldwide. Investing in research, development, and promotion of NUS will not only benefit the health of individuals but also contribute to a more sustainable and equitable global food system, ensuring that future generations have access to nutritious and environmentally sustainable food sources. In this review, we summarise the existing evidence on the nutritional and health benefits of five selected NUS using Thailand as a case study. We also highlight the primary nutritional and dietary challenges associated with their reintroduction in this geography and propose strategies to overcome these obstacles.

2. Identification of NUS

2.1. Study design

This study employed a mixed-methods approach, integrating quantitative survey data on public awareness and consumption with qualitative literature-based assessments of nutritional, medicinal, ecological, economic, and cultural significance (Figure 1). The combined methodology allowed for a comprehensive evaluation of neglected and underutilised plant and insect species (NUS) in Thailand, facilitating the identification of species with the highest potential for reintroduction and dietary integration.

2.2. Data sources and compilation of NUS

An initial list of 177 NUS native to Thailand was compiled from Local Vegetables: Meaning and Wisdom of Thai Common People[4], and Edible Insects as Human Food in the Future[5], both published by the Thai Traditional Medicine Council. These sources were selected due to their comprehensive ethnobotanical coverage and emphasis on species recognised within Thai traditional knowledge systems. Additional verification and supplementation of species names were conducted through cross-referencing with the Royal

[4] Local Vegetables: Meaning and Wisdom of Thai Common People (ISBN 974-7758-47-4)
[5] Edible Insects as Human Food in the Future (ISBN 974-291-735-3)

Botanic Gardens Kew's Plants of the World Online database (POWO, 2025) to ensure taxonomic accuracy and current nomenclature.

Each species was documented for its nutritional, medicinal, ecological, economic, and cultural roles based on prior research and ethnobotanical literature. Most species exhibited nutritional or medicinal value; over half held economic or community significance, including uses in traditional medicine or cultural gatherings. Approximately 20% carried ecological or cultural importance, such as roles in ceremonial, spiritual or sacred practices. Notably, only 47% were included in the Thai Food Composition Database (Judprasong et al., 2025) or the ASEANFOODS Food Composition Table (Institute of Nutrition, Mahidol University, 2014), highlighting gaps in regional nutrition data.

2.3. Survey of Public Awareness and Consumption

To quantitatively assess underutilisation, a cross-sectional survey was conducted among 80 participants (mean age: 22 years; 58% female; 90% students) randomly selected from Mahidol University's Salaya Campus, a peri-urban area west of Bangkok. Inclusion criteria required participants to be Thai nationals residing in Thailand for at least five years. Recruitment was via university email lists, and informed consent was obtained prior to participation. The study protocol was approved by the Mahidol University Central Institutional Review Board (MU-CIRB), Protocol No.: MU-CIRB 2024/083.0403.

The survey tool included: demographic questions (gender, age, status, education and area of residence) as well as familiarity and consumption questions for each of the 177 NUS, accompanied by images to reduce misidentification. Participants indicated whether they were familiar with each item and whether they had consumed it in the past 12 months. Responses of "unfamiliar" and "never consumed" were treated as indicators of underutilisation. The survey was pilot tested with 80 participants to ensure clarity and adjust terminology. Participant demographics are presented in Table 1.

Table 1. Descriptive Statistics of the Participants (*Note: N = 80.*)

Demographic characteristics	
Gender, n (%)	
Female	46 (58%)
Male	31 (39%)
Unknown	3 (3.8%)
Age, Mean (SD)	22 (2.9)
Status, n (%)	
Student	72 (90%)
University staff	8 (10%)
Education, n (%)	
High school	6 (7.5%)
Bachelor	69 (86%)
Master	4 (5.0%)
Doctorate	1 (1.3%)
Region, n (%)	
Central	49 (61%)
Northeastern	12 (15%)
Northern	11 (14%)
Southern	8 (10%)
Response patterns, Mean (SD)	
"Familiar" and "consumed"	46 (23)
"Familiar" but "never consumed"	48 (21)
"Unfamiliar" and "never consumed"	83 (28)

2.4. Data Analysis

A composite utilisation score was calculated for each species based on combined familiarity and consumption rates. Species were categorised into quartiles, with the first quartile (n = 47) representing the most underutilised species (NUS). Descriptive statistics summarised participant demographics and response patterns. Spearman's rank correlation assessed associations between familiarity and consumption. All analyses were conducted using R software (version 4.4.2) in the R Studio environment (version 2024.12.0+467).

Survey data were then integrated with literature-based qualitative information on each species' nutritional, medicinal, ecological, economic and cultural roles using a matrix approach. This mixed-methods integration enabled the identification of species with high potential for dietary reintegration while considering multidimensional functional significance. A full list of species ranked by utilisation frequency is provided in Supplementary Table S1. In addition, the correlation between familiarity and consumption of 177 food items is shown in Figure 2. Overall, the scatter plot demonstrated a positive correlation between familiarity and consumption across the four food groups. The correlation coefficient was used to identify trends among the food categories. The results show that the correlation coefficient decreases from the most utilised species group ($r = 0.63$) to the most underutilised species group ($r = 0.29$). Notably, although a weak positive correlation was observed in the group of most underutilised species, it is still statistically significant. This result implies that increasing familiarity with NUS could lead to higher consumption rates.

From this minimally known and used group, five NUS plants were selected for further analysis: yellow burrhead (*Limnocharis flava* Buch.), Ceylon oak (*Schleichera oleosa* (Lour.) Merr.), bastard oleaster (*Elaeagnus latifolia* L.), star apple (*Chrysophyllum cainito* L.) and hogweed or cutleaf groundcherry (*Physalis angulata* var. *angulata*). Selection was based on three key criteria: (1) availability of supporting data (e.g., peer-reviewed literature, nutritional composition), (2) high nutritional value—particularly with respect to vitamin C and mineral content, and (3) documented medicinal properties. These selections were informed by a comprehensive review of an AI-generated database (Saiyasombat et al., 2025) and reflect a combination of low utilisation and high nutritional and medicinal value (Table 2, Figure 3).

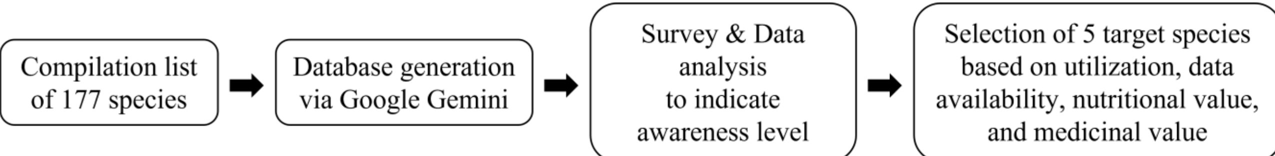

Figure 1. Research framework diagram for NUS identification.

To assess the potential for reintroduction and identify associated challenges, detailed information on each selected species was compiled and reviewed. A literature search was conducted using Google Scholar, employing the scientific names of each species as search terms. The review focused on the nutritional composition, traditional and medicinal uses, and phytochemical properties of each species. Table 3 summarises the key nutrients present in the selected NUS and their associated health benefits, which range from supporting immune function and cardiovascular health to promoting bone strength, healthy vision, and optimal digestive function. Additional sources included reports from regional and national organisations, conference proceedings, and ethnobotanical literature. Finally, 37 articles were included in this review. Based on this synthesis, strategies were proposed to address key barriers and promote the consumption of these NUS, with the goal of enhancing food security and public health.

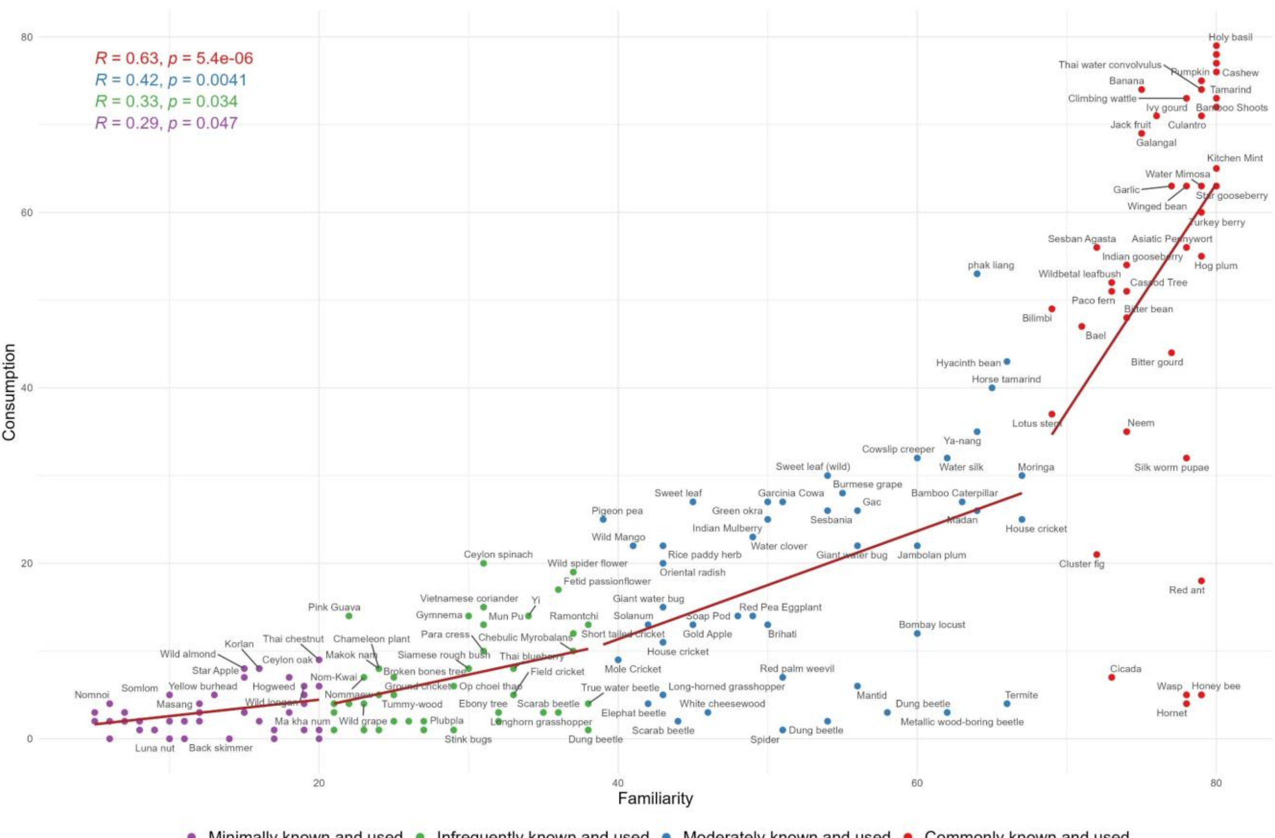

Figure 2. Correlation between familiarity and consumption of 177 food items.

The results of this analysis have some limitations since the study's sample was small and geographically restricted, limiting generalisability to other Thai regions or age groups. Additionally, nutrient composition data were incomplete for many species, emphasising the need for future biochemical analyses. Despite these limitations, the mixed-methods design allowed robust triangulation of survey and literature data to identify priority NUS for further research and promotion.

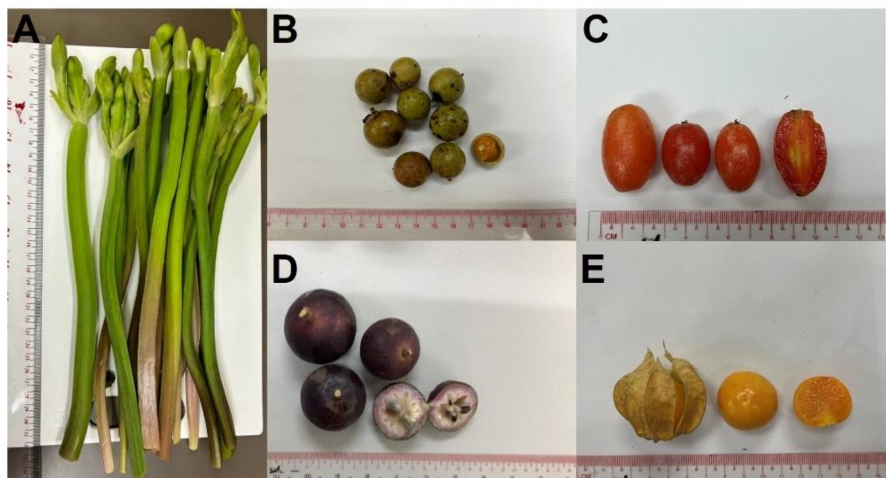

Figure 3. A) Yellow burrhead (*L. flava* Buch.), B) Ceylon oak or Kusum fruits (*S. oleosa* (Lour.) Merr.), C) Bastard oleaster (*E. latifolia* L.), D) Star Apple (*C. cainito* L.) and E) Hogweed (*P. angulata* var. *angulata*).

Table 2. Ethnobotanical information on selected underutilised vegetables and fruits

Species	Family	Local name	Food categories	Part consumed	Preparation method
Limnocharis flava Buch.	*Limnocharitaceae*	Yellow burrhead	Vegetable	Young leaf stalks and young flowers	Fresh, blanched, stir-fried
Schleichera oleosa (Lour.) Merr.	*Sapindaceae*	Ceylon oak, Kusum tree	Fruit	Fruit and bark	Fresh fruit, scour (bark)
Elaeagnus latifolia L.	*Elaeagnaceae*	Bastard oleaster	Fruit	Fruit pulp	Fresh, pickled
Chrysophyllum cainito L.	*Saporaceae*	Star apple, milk fruit	Fruit	Fruit	Fresh fruit
Physalis angulata var. *angulata*	*Solanaceae*	Hogweed, cutleaf ground cherry	Fruit	Fruit	Fresh fruit

Table 3. Summary of nutritional and medicinal benefits

Nutrient	Benefits
Vitamin C	Enhances immune response, promotes wound healing, protects against oxidative stress, and may reduce the risk of chronic diseases such as cardiovascular disorders and cancers
Provitamin A (β-carotene)	Supports eye health, enhances immune function, maintains healthy skin and mucous membranes
Dietary Fiber	Aids digestion, lowers cholesterol, supports weight management, prevents constipation, and reduces the risk of type 2 diabetes, cardiovascular disease, and colon cancer
Potassium	Regulates blood pressure, supports cardiovascular health, and prevents muscle cramps
Calcium	Builds strong bones, prevents osteoporosis, supports heart and nerve function
Iron	Prevents anaemia, boosts energy, supports cognitive development and immune health

3. Selected NUS and their Documented Food Use, Nutritional and Medicinal Value

3.1. Yellow Burrhead

Yellow burrhead (*L. flava*) is a semi-aquatic plant widely consumed in SEA, particularly in Thailand. The plant is a rich source of essential nutrients and bioactive compounds, contributing to its nutritional and potential therapeutic significance (Figure 3A).

3.1.1. Food Use In countries such as Thailand, Vietnam, Indonesia, and Laos, *L. flava* is a valued component of traditional diets. The young leaves, petioles and flower buds are all edible and are prepared in a variety of ways. Typically, the tender leaves and petioles are boiled or steamed to reduce their inherent bitterness. In Thai and Vietnamese cuisine, these plant parts are commonly incorporated into soups, curries, and stir-fries, offering a crunchy texture like that of water spinach (*Ipomoea aquatica*). The unopened flower buds are particularly prized for their mild flavour and versatility. They can be blanched, cooked in soups, stir-fried with other

vegetables or preserved through pickling or fermentation. Such preservation methods extend the plant's availability and support dietary diversity during periods when fresh vegetables are scarce.

3.1.2. Nutritional Composition *L. flava* is notable for its high micronutrient content, particularly provitamin A carotenoids (Table 3). The β-carotene concentration reaches 5,550 µg per 100 grams of edible portion, making it a significant dietary source of vitamin A precursors (Ogle et al., 2001). When consumed with dietary fats, β-carotene can effectively support serum retinol levels, helping to reduce the risk of vitamin A deficiency (Huang et al., 2000). The plant also contributes important minerals, including calcium (87 mg/100 g) that supports bone health, and iron (1.1 mg/100 g), which, while moderate, remains valuable in predominantly plant-based diets where heme iron sources are limited (Ogle et al., 2001).

3.1.3. Medicinal Uses Emerging evidence highlights the medicinal potential of *L. flava*, largely attributed to its content of bioactive compounds such as phenolic acids (e.g., p-hydroxybenzoic acid and ferulic acid) and flavonoids (e.g. rutin and quercetin) (Ooh et al., 2015). These compounds exhibit antioxidant and anti-inflammatory properties, contributing to the mitigation of oxidative stress and inflammatory conditions in pre-clinical studies (Lee et al., 2012; Li et al., 2016; Rudrapal et al., 2022). Additionally, antibacterial activity has been observed in plant extracts, particularly against foodborne pathogens such as *Escherichia coli* and *Salmonella typhimurium* (Choopayak et al., 2022; Ooh et al., 2015). These findings suggest potential applications in both traditional medicine and food preservation. However, further research is needed to validate therapeutic efficacy and establish safety profiles for clinical or functional food use.

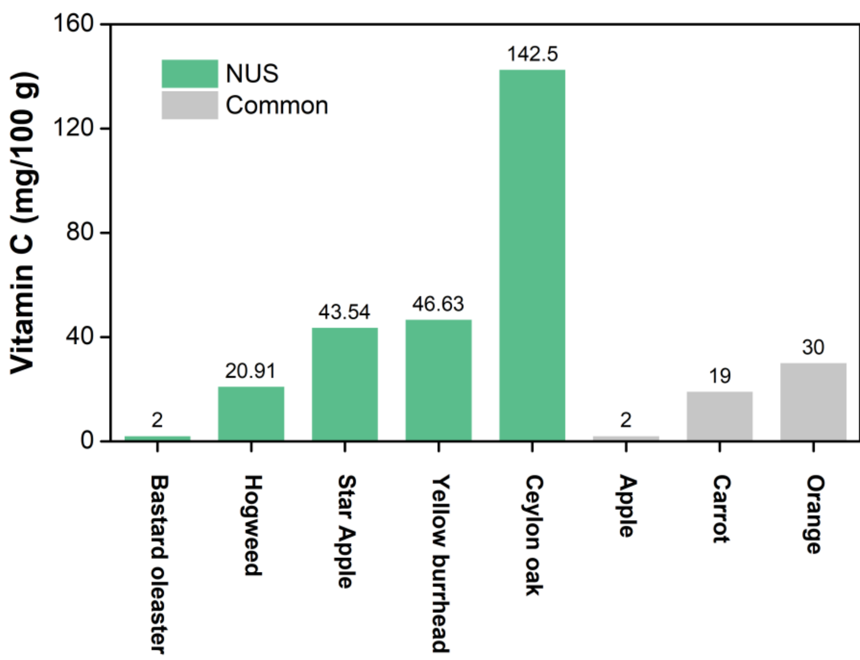

Figure 4. Vitamin C (mg/100 g) content of NUS selected in this study compared to commercially available fruits and vegetables: apple (*Malus domestica* (Suckow) Borkh.), orange (*Citrus × sinensis*) and carrot (*Daucus carota* subsp. *sativus*).

3.2. Ceylon Oak

The Ceylon oak (*S. oleosa*), also known as the Kusum tree, is a deciduous species native to tropical and subtropical regions of South and Southeast Asia, including India, Myanmar, Nepal, Sri Lanka, and Thailand.

Its fruit, typically a single-seeded berry (occasionally containing two seeds), features a juicy yellow aril enclosed by a tough, dry, smooth or spiny outer shell with a pointed tip (Figure 3B). Though not widely consumed in mainstream diets, the fruit's pulp is rich in antioxidants and bioactive compounds, making it a valuable, though underutilised, nutritional and medicinal resource, especially in rural communities (Mondal et al., 2023).

3.2.1. Food Use Various parts of *S. oleosa*, including the fruits, seeds, and young shoots, are traditionally consumed and hold potential for broader culinary application and commercialisation. The ripe fruit, mildly acidic and hydrating, is eaten fresh in local dishes or as a snack. Its high vitamin C content also supports its role as an antioxidant (Table 3). Unripe fruits are commonly pickled to enhance meals with their tangy flavour and extend shelf life, reflecting the fruit's importance in local food preservation practices. The seeds can be extracted to yield Kusum oil, which is rich in essential fatty acids like oleic and linoleic acid. This oil is sometimes used for cooking, hair dressing and lighting. However, the oil contains cyanogenic compounds, which can induce symptoms such as dizziness if consumed; therefore, these compounds must be removed prior to its use for human consumption (Sarkar et al., 2022; Sharma & Singh, 2010). Post-extraction seed cake is repurposed as livestock feed, though it requires proper processing for safety (Bhatia et al., 2013). Additionally, young shoots and tender leaves are consumed as vegetables —steamed, added to soups, or served with rice— providing dietary fibre and micronutrients (Jaiswal & Singh, 2015).

3.2.2. Nutritional Composition The fruit of *S. oleosa* has a high moisture content (~75%), contributing to its hydrating qualities (Kubola et al., 2011; Mondal et al., 2023). Its sugar profile includes 14.28% total sugars, comprising 8% reducing sugars and 5.96% non-reducing sugars, lending the fruit a naturally sweet flavour. It is also a rich source of vitamin C, with ascorbic acid levels reaching 142.5 mg per 100 g of pulp (Figure 4). This makes it a potent source of antioxidants, supporting immune health and protecting against oxidative stress. The fruit contains 1.35 mg of carotenoids per 100 grams, contributing to eye and skin health, and has a titratable acidity of 0.33%, giving it a balanced tartness. These properties suggest potential for value-added processing, including beverages and functional foods. Despite these advantages, the fruit remains underutilised outside of localised traditional contexts.

3.2.3. Medicinal Uses *S. oleosa* produces several oils with therapeutic and industrial applications. The seed oil, in addition to culinary uses, exhibits medicinal properties and has been explored as a potential biodiesel source (Gandhi et al., 2011; Silitonga et al., 2015). Traditionally, the bark has been used in folk medicine to manage a range of conditions, including inflammation, infections, and skin disorders. The bark is particularly valued for its anti-inflammatory properties, historically used for treating leprosy and inflammatory diseases (Bhatia et al., 2013). Extracts from the bark, roots, and seeds are rich in phenolic compounds, contributing to strong antioxidant activity and showing promise in cancer prevention and oxidative stress reduction (Bhatia et al., 2013; Ghosh et al., 2011). These findings support the species' relevance in both traditional healing systems and modern medicine. Additional research is essential to further validate its pharmacological potential and optimise safe use of its oil and extracts in functional foods and medicinal products (Palanuvej & Vipunngeun, 2008; Sarkar et al., 2022).

3.3. Bastard Oleaster

Commonly known as bastard oleaster, *E. latifolia* is a perennial shrub native to tropical and subtropical regions. The species has drawn increasing interest for its diverse applications in food, nutrition, and traditional medicine, particularly in rural and traditional settings.

3.3.1. Food Use *E. latifolia* produces small, fleshy, oval-shaped fruits that turn yellow to orange upon ripening (Figure 3C). The edible fruits have a sweet, slightly astringent flavour and are consumed fresh or processed into jams, jellies, and desserts (Panja et al., 2014). They are also incorporated into traditional dishes, valued for their distinctive taste and unique flavour profile. Their versatility makes them a promising supplementary food source, particularly in areas where conventional food resources may be scarce or seasonal.

3.3.2. Nutritional Composition The fruits of *E. latifolia* are rich in vitamin C and dietary fibre, which support gastrointestinal health and satiety (Table 3). In addition, the presence of phenolic compounds and flavonoids contributes to the fruits' antioxidant activity, offering potential protection against oxidative stress and related chronic conditions (Sasikumar et al., 2024).

3.3.3. Medicinal Uses *E. latifolia* has a long history of use in traditional medicine. The fruits are reported to possess diuretic properties and are commonly used in the management of urinary disorders. Their antioxidant and anti-inflammatory activities are thought to support general health and disease prevention (Munkong et al., 2024). The leaves are also used medicinally. Infusions or decoctions are traditionally prepared to alleviate respiratory ailments and promote digestive health. Furthermore, extracts from various plant parts have demonstrated antimicrobial activity, suggesting additional therapeutic potential (Bachheti et al., 2023; Nazir et al., 2020).

3.4. Star Apple

Star apple (*C. cainito* L.) is a tropical fruit recognised for its distinctive flavour and nutritional value (Doan & Le, 2020). Recent studies have highlighted its bioactive compound profile and potential health benefits (Figure 3D).

3.4.1. Food Use In the Philippines, where it is known locally as "kaimito", star apple is primarily consumed fresh as a cooling snack, especially in hot weather. The fruit is typically halved, and the sweet pulp is eaten with a spoon—sometimes enhanced with a pinch of salt or a drizzle of condensed milk. It is also added to fruit salads or desserts to contribute flavour and texture complexity. In Thailand, it is similarly enjoyed fresh and featured in chilled tropical fruit platters, often served in hotels and restaurants alongside mango, papaya, and dragon fruit. Although less commonly used in beverages, the pulp's creamy texture lends itself well to smoothies and blended fruit juice.

3.4.2. Nutritional Composition Star apple is a good source of dietary fibre and essential micronutrients. It contains significant levels of vitamin C, which supports immune function, collagen synthesis, and wound healing. The fruit also provides vitamin A, important for vision, growth, and immune regulation (Oranusi et al., 2015). In terms of minerals, star apple is a good source of potassium, which helps maintain electrolyte balance and supports cardiovascular and muscle function (Oranusi et al., 2015). Additionally, it provides calcium, phosphorus, and magnesium, which are essential for bone health, as well as trace amounts of iron, zinc, and copper (Doan & Le, 2020; Oranusi et al., 2015) (Table 3).

3.4.3. Medicinal Uses In addition to its nutritional properties, star apple contains various bioactive compounds, including phenolics, flavonoids, and carotenoids, which exhibit antioxidant, anti-inflammatory,

and potential anticancer activities (Li et al., 2015). The stem bark, in particular, has been shown to be rich in antioxidant compounds, suggesting its potential as a source of natural antioxidants (Doan et al., 2018).

3.5. Hogweed

Hogweed (*Physalis angulata* var. *angulata*), commonly referred to as cutleaf ground cherry, is an herbaceous species (Figure 3E). Widely distributed across tropical and subtropical regions, its fruits, leaves, and other parts have been traditionally used for both culinary and medicinal purposes by local communities in Asia, South America, and Africa (Rengifo & Vargas-Arana, 2013).

3.5.1. Food Use The ripe fruits of *P. angulata* are consumed fresh or dried, and appreciated for their mildly sweet-tart flavour (de Oliveira et al., 2020). While not cultivated on a large scale, the fruits are regularly collected for household consumption and local markets. They are sometimes incorporated into salads, jams, and desserts. In addition to the fruit, the young leaves are consumed as vegetables, typically boiled or added to soups and stews (Svobodová & Kuban, 2018).

3.5.2. Nutritional Composition Hogweed berries are low in calories yet rich in nutrients, making them a valuable addition to diets. They are particularly rich in vitamin C (Iwansyah et al., 2020). The fruits also contain moderate levels of vitamin A, primarily in the form of carotenoids (Guiné et al., 2024), along with small quantities of essential minerals such as potassium, calcium, and iron (Aliero & Usman, 2016). Dietary fibre is also present in meaningful amounts (Sholehah & Setiawan, 2019) (Table 3). Furthermore, *P. angulata* is rich in bioactive phytochemicals, especially phenolic compounds and flavonoids, which enhance the plant's antioxidant properties and may contribute to disease prevention (Ramakrishna Pillai et al., 2022).

3.5.3. Medicinal Uses *P. angulata* has a well-documented history of use in traditional medicine. Its therapeutic potential is attributed to the presence of alkaloids and flavonoids, and other phytochemicals with demonstrated anti-inflammatory and analgesic effects (Khikmatullaev et al., 2022). The plant has shown promise in alleviating pain and inflammation, particularly assisting in the treatment of conditions such as arthritis and gout. Additionally, extracts exhibit antimicrobial activity against *E. coli* and *Staphylococcus aureus*, and antiviral properties against the Herpes simplex virus (Ayodhyareddy & Rupa, 2016; Cobaleda Velasco et al., 2017).

The nutritional composition of *P. angulata* and the other selected NUS, compared with common fruits and vegetables, is summarised in Table 4.

Table 4. Some nutritional properties of the selected NUS compared with common fruits and vegetables

Plant Name	Vitamin C (mg/100 g)	Provitamin A (β-carotene) ug/100 g	Dietary fibre (g/100 g)	Potassium (mg/100 g)	Calcium (mg/100 g)	Iron (mg/100 g)	References
Yellow burrhead (*L. flava* Buch.)	46.63 (leaf)	5550	1.31	481	87	1.1	(Cut, 2021; Ogle et al., 2001), Thai Food Composition Database[c]
Ceylon oak (*S. oleosa* (Lour.) Merr.)	142.5	4400	1.1[a]	266[a]	1[a]	0.13[a]	(Khamphukdee et al., 2021; Mondal et al., 2023; Paul et al., 2021)
Bastard oleaster (*E. latifolia* L.)	2	17660[b]	10	212	42	4.8	(Magnusson et al., 2022; Sasikumar et al., 2024)
Star apple (*C. cainito* L.)	43.54	39	1.9	72.43	12.35	0.49	(Doan & Le, 2020; Realpe-López et al., 2025; Solomon et al., 2015)
Hogweed (*P. angulata* var. *angulata*)	20.91	1460	1	291.5	17.5	1.28	(Guiné et al., 2024; Sholehah et al., 2021)
Sweet orange (*C. x sinensis*)	30	137	3	193	16	0.14	Thai Food Composition Database[c]
Apple (*Malus domestica* (Suckow) Borkh.)	2	10	2.2	48	5	0.06	Thai Food Composition Database[c]
Carrot (*Daucus carota* subsp. *sativus*)	19	4472	3.4	306	35	0.58	Thai Food Composition Database[c]

[a] Due to the unavailability of nutritional data for this species, data from *Dimocarpus longan* Lour. (Family *Sapindaceae*) was used as a representative reference within the same botanical family.
[b] Value per 100 g extract.
[c] Thai Food Composition Database accessible at https://inmu.mahidol.ac.th/thaifcd/

4. Factors Contributing to the Decline in Plant Cultivation of the Studied Species

Despite their cultural, nutritional, and medicinal significance, the studied species remain largely underutilised due to a combination of agronomic, economic, and socio-cultural constraints. These plants are typically consumed locally, with limited large-scale cultivation or integration into commercial supply chains. Their seasonal availability and low market visibility further constrain their economic potential. For example, yellow burrhead and Ceylon oak are primarily found in the Northeast region of Thailand, limiting their reach and consumer familiarity in other regions.

A major barrier to wider adoption is the lack of investment in research and development. Although these plants have a long history of traditional use, there has been minimal innovation aimed at product development

or value addition. This absence of diversification reduces their market competitiveness and appeal to both producers and consumers. Compounding the issue is the lack of formal seed supply systems. Farmers often rely on wild harvesting or propagation from home gardens, restricting access to high-quality planting materials. This is particularly evident in Northeast Thailand, where farmers rely heavily on wild plants found in rice fields. Notably, over two-thirds of these species have multiple uses, and more than half are also recognised for their medicinal properties (Cruz-Garcia & Price, 2011). Seedlings are typically only available through small plant nurseries catering to rare plant collectors, which limits opportunities for broader cultivation. Scientific studies on agronomic performance, nutritional composition, and potential health benefits of these species remain scarce. This knowledge gap hampers efforts to develop optimised cultivation practices, pest and disease management protocols, and effective post-harvest handling methods. Consequently, farmers face uncertainty in adopting these crops at scale.

Consumer unfamiliarity with these plants, particularly outside their traditional regions, results in weak demand. Limited promotional efforts and the absence of consumer education further hinder market expansion. Nonetheless, there is a growing niche market driven by internal migration. Individuals from the Northeast familiar with these species are increasingly promoting them through online platforms. Yellow burrhead, for example, is now available in some wholesale markets, though its primary buyers are from the North and Northeast regions of Thailand.

Ecological constraints also play a critical role. Several of these species are adapted to specific agroecological niches or thrive in marginal environments, making them vulnerable to environmental changes. Ceylon oak, for instance, grows into a large, tall tree that requires specialised harvesting techniques, limiting its practicality for widespread cultivation. Moreover, threats such as deforestation, land degradation, soil erosion and climate change are altering the species' natural habitats, reducing their availability and threatening their genetic diversity.

Policy and regulatory gaps further exacerbate the issue. Most conservation efforts and agricultural incentives target commercially important crops, leaving NUS without adequate protection or support. For example, the Thai government introduced agricultural economic zoning, including 13 major crops such as rice, cassava, rubber, oil palm, sugarcane, and selected fruits. While this policy aimed to align production with market demand, it effectively prioritised these commodities and sidelined NUS. This focus creates an adverse policy environment by limiting support, incentives, and market access for NUS (Boonyanam, 2018; Ministry of Agriculture Cooperatives, 2017). As commercial agriculture, urban expansion and land use changes intensify, these lesser-known food species are increasingly marginalised.

Finally, the erosion of traditional knowledge systems presents a critical challenge. The declining transmission of ethnobotanical knowledge and cultural practices among younger generations diminishes the intrinsic value and continuity of these species in agricultural systems and diets. Without deliberate efforts to preserve and pass on this knowledge, there is a real risk of losing not only the species themselves but also the cultural heritage associated with them.

5. Strategies to Enhance the Commercial Viability and Mainstreaming of NUS

To improve the commercial viability and long-term sustainability of NUS, it is essential to strengthen connections between local producers and broader markets. One effective approach is the establishment of producer cooperatives, enabling smallholder farmers to pool resources, negotiate better pricing, and gain access to more efficient distribution channels. Such market-oriented mechanisms can enhance visibility, drive consumer demand and incentivise cultivation.

Innovation through research and development is a critical component in elevating the status of NUS. Collaboration between research institutions, private sector stakeholders, and local communities can lead to new food, health supplements, or cosmetic products derived from these plants. For example, modest product

innovations such as developing chutneys from bastard oleaster or producing jams, jellies, and refreshing beverages from the species' pulp can increase consumer curiosity and trial (Patel, 2008).

As the designated Southeast Asia Regional Centre for the International Network of Food Data Systems (INFOODS), the Institute of Nutrition, Mahidol University (INMU) plays a central role in expanding the food composition knowledge base for the region. Current efforts focus on systematically documenting the nutrient profiles of a broad range of edible species, with particular emphasis on NUS. INMU aims to integrate at least 50 new edible species into the ASEAN Food Composition Database in the near term. Complementing this, the Periodic Table of Food Initiative (PTFI) contributes by analysing the bioactive compound profiles of these species using advanced omics technology. Together, these efforts aim to strengthen evidence-based nutrition policy and support food system sustainability across Southeast Asia.

To support this initiative, INMU and PTFI are collaborating with other ASEAN Member States to facilitate centralised food sample analysis. Parallel efforts include regional capacity building through specialised training in food composition analysis, encompassing analytical methods and quality assurance procedures. The resulting data will improve the quality, relevance, and accessibility of food composition information essential for nutrition science, public health and agricultural policy, research, and food system sustainability across Southeast Asia.

Developing formal seed systems for NUS plants is another strategic priority. Government agencies and non-governmental organisations (NGOs) should establish seed banks, local nurseries and distribution networks for high-quality planting material. Training farmers in seed selection, saving and propagation techniques can build local seed sovereignty and promote sustainable NUS cultivation.

Consumer education and awareness are equally vital. Public campaigns, food festivals, culinary workshops, and social media promotion can introduce these species to broader audiences, increasing familiarity and demand. Local markets, when supported by effective storytelling around the nutritional and cultural value of these plants, can become powerful platforms for market expansion.

Adaptation to ecological niches is another consideration for sustainable cultivation. Research should focus on low-input farming practices, such as agroforestry and intercropping systems, which preserve biodiversity while integrating NUS into existing agricultural landscapes. Conservation of wild habitats is also crucial, given that several NUS thrive in specific ecological zones. For example, star apple, which is sensitive to drought, thrives in humid tropical lowlands, primarily at elevations below 400 m, and favours well-drained, slightly acidic, fertile soils (Subhadrabandhu, 2001).

Coordinated responses to environmental threats such as climate change, land degradation and biodiversity loss are needed. These should include reforestation and habitat restoration efforts, sustainable land-use policies, coupled with financial incentives for farmers to grow NUS. Community-based conservation programs and policy reforms can ensure regulatory support for the preservation and promotion of NUS.

To fully integrate NUS into food and health systems, it is imperative to communicate their contribution to dietary quality and public health. However, their limited geographic distribution presents a challenge to inclusion in national Food-Based Dietary Guidelines (FBDGs). For example, species such as *S. oleosa* (Ceylon oak) and *L. flava* (yellow burrhead) are primarily found in the Northern and Northeastern regions of Thailand, reducing their national availability and scalability.

A more context-sensitive approach would be to include these species in institutional feeding programs, such as school meal initiatives. All five selected species—star apple, bastard oleaster, hogweed, yellow burrhead, and Ceylon oak possess favourable organoleptic properties (vibrant colour, palatable flavour) and exhibit post-harvest stability with no known toxicological concerns. Their fresh fruit form is appealing to children, making them ideal candidates for promoting dietary diversity and improved nutrition.

Moreover, four of the five species are perennial fruit-bearing plants, offering advantages for school-based agroforestry programs. These initiatives provide opportunities for hands-on environmental education, strengthen community engagement, and support long-term biodiversity conservation.

Revitalising traditional knowledge is also essential for preserving cultural heritage and ensuring the intergenerational transmission of plant-use practices. Integrating traditional agricultural knowledge into school curricula, community outreach, and media storytelling can maintain cultural relevance and inspire interest among younger generations.

Finally, transforming NUS into functional foods demands targeted R&D investments, particularly to overcome challenges related to perishability and seasonality. For instance, star apple begins to spoil within days of harvest, limiting its shelf life and transportability (Bello & Henry, 2015). Technologies such as freeze-drying could stabilise the fruit while preserving its nutritional value, while alternative formats such as ready-to-use fruit powders or concentrates could further enhance year-round availability and consumer convenience.

There is also commercial potential in nutraceuticals and health products. For example, the high antioxidant content, vitamin profile, and unique bioactive compounds of bastard oleaster make it suitable for health-focused product development. Consumer-ready formats, such as nutrient-rich snack bars or wellness beverages, could appeal to urban, health-conscious markets (Pasakawee et al., 2021). Similarly, star apple extracts rich in phytochemicals may have therapeutic applications for antimicrobial or wound-care products (Adekanmi & Olowofoyeku, 2020). With further research, such attributes could provide new opportunities for pharmaceutical and cosmeceutical development.

6. Conclusion

Among the numerous planetary challenges facing global food systems, biodiversity loss, particularly agrobiodiversity, is among the most overlooked yet most consequential. The widespread transformation of food systems has contributed significantly to ecosystem degradation, undermined the sustainability of food production, and eroded the cultural heritage of indigenous and local communities (Argumedo et al., 2021; Bélanger & Pilling, 2019; Benton et al., 2021). Particularly in developing regions, including Southeast Asia, the decline of indigenous food cultures has been further accelerated by rapid urbanisation, digital inequality, the encroachment of multinational food corporations, and the global convergence toward monocultural diets (Antonelli, 2023; Lugo-Morin, 2020). Loss of indigenous food cultures is cyclically related to loss of agrobiodiversity, partly due to reduced awareness, production, and consumption of traditional foods. However, the revitalisation and mainstreaming of NUS and other edible agrobiodiversity offer a largely untapped opportunity for restoring agrobiodiversity and creating more resilient, sustainable food systems. These species often possess unique bioactive properties and nutritional benefits that can contribute positively to both human and planetary health.

In this review, we focused on five plant NUS native or naturalised to Thailand: Yellow burrhead, Ceylon oak, bastard oleaster, star apple, and hogweed. Despite their demonstrated nutritional value, medicinal properties and favourable sensory qualities, these species remain largely underexploited due to limited commercial use, low consumer awareness, lack of agronomic research and environmental challenges. Their decline reflects broader structural barriers to the integration of NUS into mainstream food systems. To address these challenges and enhance the sustainable use of these species, the following interlinked strategies are recommended:

- Enhance commercialisation and develop formal seed supply systems for NUS plants, including seed banks and nurseries, to ensure consistent access to high-quality planting materials;
- Foster innovation through R&D collaborations between academic institutions, the private sector, and local communities, to create diverse value-added products;
- Raise consumer awareness, via targeted education, food festivals, and digital platforms;
- Adapt cultivation practices to agroecological niches using sustainable methods;
- Mitigate environmental threats through habitat restoration and policy support;
- Strengthen regulatory frameworks and create economic incentives for farmers to grow and/or sustainably collect NUS;
- Revive intergenerational knowledge through community-based documentation and inclusion in school curricula to preserve traditional agricultural and culinary practices;
- Invest in research, particularly on nutritional composition, functional properties, and post-harvest technologies to extend shelf life and improve year-round market availability.

Adoption of these recommendations can drive the diversification of agriculture, improve dietary diversity and nutritional adequacy, and support climate-resilient and biodiversity-friendly food systems. These five plant NUS from Thailand serve as compelling case studies for how local biodiversity can be leveraged to support both community livelihoods and environmental conservation.

A critical enabling factor in the reintroduction and scaling of NUS is their inclusion in food composition databases. These datasets form the foundation of nutritional surveillance, dietary assessment and evidence-based policy development. Yet, they typically have many limitations, including the inadequate enumeration of foods, especially NUS and other edible agrobiodiversity (Greenfield et al., 2003; Kapsokefalou et al., 2019; Micha et al., 2018; Stumbo & Beecher, 2017; West & van Staveren, 1997). Their omission is often due to the high cost of sample collection and nutrient analysis, especially for bioactive compounds and food functionality, as well as their perceived lower priority relative to staple crops (Nxusani et al., 2023; Onuegbu & Ibeabuchi, 2021; Stadlmayr et al., 2011). This data gap has significant downstream implications. Without robust food composition data, it is difficult to assess nutrient intake, develop accurate dietary assessment tools, or measure the nutritional and functional contribution of NUS at the population level. As a result, these foods are under-represented in dietary guidelines, school feeding programs, and nutrition interventions—thus perpetuating their marginalisation and the erosion of agrobiodiversity.

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Declarations

Competing interests The authors declare no competing interests.

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Supporting Information

Table S1. Classification of NUS according to their awareness and consumption status from the survey

177 food items			Score				
Common Name	**Family**	**Species**	**"Unfamiliar" and "never consumed"**	**"Familiar" but "never consumed"**	**"Familiar" and "consumed"**	**Awareness**	**Rank**
False lime merlimau	*Euphorbiaceae*	*Suregada multiflora* (A.Juss.) Baill	75	2	3	6%	Minimally known and used
Chinese salacia	*Celastraceae*	*Salacia chinensis* L.	75	3	2	6%	
Nomnoi	*Annonaceae*	*Polyalthia evecta* (Pierre) Finet & Gagnep.	74	2	4	8%	
Lambiddong	*Ebenaceae*	*Diospyros filipendula* Pierre ex Lecomte.	74	4	2	8%	
Long-horned beetle	*Cerambycidae*	*Trenetica lacrymans* (Thomson, 1865)	74	6	0	8%	
Kui	*Apocynaceae*	*Willughbeia edulis* Roxb.	73	5	2	9%	
Bastard oleaster	*Elaeagnaceae*	*Elaeagnus latifolia* L.	73	4	3	9%	
Prong kio	*Annonaceae*	*Dasymaschalon lomentaceum* Finet & Gagnep.	73	4	3	9%	
Canthium wild fruit	*Rubiaceae*	*Canthium berberidifolium* E.T. Geddes	73	5	2	9%	
Makmo	*Rubiaceae*	*Rothmannia wittii* (Craib) Bremek.	73	5	2	9%	
Mafan	*Burseraceae*	*Protium serratum* (Wall. ex Colebr.) Engl.	72	6	2	10%	
Phak huanmoo	*Apocynaceae*	*Dregea volubilis* (L.f.) Benth. ex Hook.f.	72	7	1	10%	
Phak huead	*Moraceae*	*Ficus lacor* Buch.-Ham.	72	6	2	10%	
Bitter rattan	*Arecaceae*	*Calamus viminalis* Willd.	71	8	1	11%	
Chulta	*Dilleniaceae*	*Dillenia indica* L.	71	8	1	11%	
Mapok	*Chrysobalanaceae*	*Parinari anamensis* Hance	70	8	2	13%	
Luna nut	*Sapindaceae*	*Lepisanthes fruticosa* (Roxb.) Leenh.	70	10	0	13%	

Table S1 (Cont.). Classification of NUS according to their awareness and consumption status from the survey

177 food items			Score				
Common Name	**Family**	**Species**	**"Unfamiliar" and "never consumed"**	**"Familiar" but "never consumed"**	**"Familiar" and "consumed"**	**Awareness**	**Rank**
Somlom	*Apocynaceae*	*Aganonerion polymorphum* Pierre ex Spire	70	5	5	13%	Minimally known and used
Ma huad	*Sapindaceae*	*Lepisanthes rubiginosa* (Roxb.) Leenh.	69	9	2	14%	
Chaulmoogra	*Achariaceae*	*Hydnocarpus anthelminthicus* Pierre ex Gagnep.	69	11	0	14%	
Water scavenger beetle	*Hydrophilidae*	*Hydrous cavistanum* Bedel	69	9	2	14%	
Kluai-tao	*Annonaceae*	*Polyalthia debilis* (Pierre) Finet & Gagnep.	68	9	3	15%	
Masang	*Rutaceae*	*Feroniella lucida* (Scheff.) Swingle	68	8	4	15%	
Cotton tree	*Malvaceae*	*Bombax ceiba* L.	68	9	3	15%	
Water scorpion beetle	*Nepidae*	*Laccotrephes ruber* (Linnaeus, 1764)	68	10	2	15%	
Yellow burhead	*Limnocharitaceae*	*Limnocharis flava* Buch.	67	8	5	16%	
Back skimmer	*Notonectidae*	*Anisops* Spinola, 1837	66	14	0	18%	
Wild almond	*Irvingiaceae*	*Irvingia malayana* Oliv. ex A.W. Benn.	65	7	8	19%	
Samet chun	*Myrtaceae*	*Syzygium antisepticum* (Blume) Merr. & L.M. Perry	65	12	3	19%	
Star apple	*Sapotaceae*	*Chrysophyllum cainito* L.	65	8	7	19%	
Caesalpinia	*Caesalpiniaceae*	*Caesalpinia mimosoides* Lam.	65	12	3	19%	
Korlan	*Sapindaceae*	*Nephelium hypoleucum* Kurz	64	8	8	20%	
Ceylon oak	*Sapindaceae*	*Schleichera oleosa* (Lour.) Merr.	64	8	8	20%	
Predaceous diving beetle	*Dytiscidae*	*Cybister rugosus* (W.S.MacLeay, 1825)	64	14	2	20%	
Phak phokateemia	*Selaginellaceae*	*Selaginella argentea* (Wall. ex Hook. & Grew.) Spring	63	17	0	21%	
Yellow five-horned beetle	*Scarabaeidae*	*Eupatorus gracilicornis* Arrow, 1908	63	16	1	21%	
Hogweed	*Solanaceae*	*Physalis angulata* var. *angulata* L.	62	11	7	23%	
Ma kha num	*Fabaceae (Leguminosae)*	*Sindora siamensis* Teijsm. ex Miq.	62	15	3	23%	
Kenari	*Burseraceae*	*Canarium subulatum* Guill.	61	14	5	24%	

Table S1 (Cont.). Classification of NUS according to their awareness and consumption status from the survey

177 food items			Score			Awareness	Rank
Common Name	**Family**	**Species**	**"Unfamiliar" and "never consumed"**	**"Familiar" but "never consumed"**	**"Familiar" and "consumed"**		
Ebony	*Ebenaceae*	*Diospyros rhodocalyx* Kurz	61	14	5	24%	Minimally known and used
Wild longan	*Meliaceae*	*Walsura trichostemon* Miq.	61	13	6	24%	
Phak nam	*Araceae*	*Lasia spinosa* (L.) Thwaites	61	15	4	24%	
Long-horned beetle	*Cerambycidae*	*Batocera rubus* (Linnaeus, 1758)	61	18	1	24%	
Nom-kwai	*Annonaceae*	*Uvaria hahnii* (Finet & Gagnep.) J.Sinclair	60	14	6	25%	
Thai chestnut	*Fagaceae*	*Castanopsis* (D.Don) Spach	60	11	9	25%	
Band-wing grasshopper	*Tettigoniidae*	*Ducetia japonica* (Thunberg, 1815)	60	19	1	25%	
Damselflies	*Coenagrionidae*	*Ceriagrion* Selys, 1876	60	20	0	25%	
Monkey jack	*Moraceae*	*Artocarpus lakoocha* Roxb.	59	17	4	26%	Infrequently known and used
Jackal jujube	*Rhamnaceae*	*Ziziphus oenopolia* (L.) Mill.	59	18	3	26%	
Crawling water beetle	*Dytiscidae*	*Eretes sticticus* (Linnaeus, 1767)	59	20	1	26%	
Wild rambutan	*Annonaceae*	*Uvaria hirsuta* Jack	58	18	4	28%	
Pink guava	*Myrtaceae*	*Psidium guajava* L.	58	8	14	28%	
Nommaew	*Annonaceae*	*Rauwenhoffia siamensis* Scheff.	57	16	7	29%	
Wild grape	*Vitaceae*	*Ampelocissus martini* Planch.	57	19	4	29%	
Scarab beetle	*Scarabaeidae*	*Anomala cupripes* (Hope, 1839)	57	22	1	29%	
Chebulic myrobalans	*Combretaceae*	*Terminalia chebula* Retz.	56	19	5	30%	
Makok nam	*Elaeocarpaceae*	*Elaeocarpus hygrophilus* Kurz	56	16	8	30%	
Chameleon plant	*Saururaceae*	*Houttuynia cordata* Thunb.	56	16	8	30%	
Tortoise beetles	*Chrysomelidae*	*Sagra femorata* (Drury, 1773)	56	23	1	30%	
Tummy-wood	*Barringtoniaceae*	*Barringtonia acutangula* (L.) Gaertn.	55	20	5	31%	
Phak-tewkhaow	*Hypericaceae*	*Cratoxylum formosum* (Jack) Benth. & Hook.f. ex Dyer	55	18	7	31%	
Spur-throated grasshopper	*Acrididae*	*Chondracris rosea* subsp. *brunneri* Uvarov, 1924	55	23	2	31%	
Weevil	*Curculionidae*	*Hypomeces squamosus* (Fabricius, 1792)	54	24	2	33%	

Table S1 (Cont.). Classification of NUS according to their awareness and consumption status from the survey

177 food items			Score				
Common Name	Family	Species	"Unfamiliar" and "never consumed"	"Familiar" but "never consumed"	"Familiar" and "consumed"	Awareness	Rank
Plubpla	*Malvaceae*	*Microcos tomentosa* Sm.	53	25	2	34%	Infrequently known and used
River skimmer	*Libellulidae*	*Crocothemis erythraea* (Brullé, 1832)	53	26	1	34%	
Op choei thao	*Apocynaceae*	*Atherolepis pierrei* Costantin	51	23	6	36%	
Ground cricket	*Gryllidae*	*Acheta confirmata* Walker, 1859	51	23	6	36%	
Stink bugs	*Pentatomidae*	*Tessaratoma javanica* (Thunberg, 1783)	51	28	1	36%	
Siamese rough bush	*Moraceae*	*Streblus asper* Lour.	50	22	8	38%	
Gymnema	*Apocynaceae*	*Gymnema inodorum* (Lour.) Decne.	50	16	14	38%	
Broken bones tree	*Bignoniaceae*	*Oroxylum indicum* (L.) Kurz	50	22	8	38%	
Para cress	*Asteraceae*	*Acmella oleracea* (L.) R.K.Jansen	49	21	10	39%	
Ceylon spinach	*Basellaceae*	*Basella rubra* L.	49	11	20	39%	
Vietnamese coriander	*Polygonaceae*	*Polygonum odoratum* Lour.	49	16	15	39%	
Mun pu	*Euphorbiaceae*	*Glochidion wallichianum* Müll.Arg.	49	18	13	39%	
Ebony tree	*Ebenaceae*	*Diospyros mollis* Griff.	48	29	3	40%	
Slant-faced grasshopper	*Acrididae*	*Acrida willemsei* Dirsh, 1954	48	30	2	40%	
Thai blueberry	*Phyllanthaceae*	*Antidesma velutinosum* Blume	47	25	8	41%	
Field cricket	*Gryllidae*	*Gryllus bimaculatus* De Geer, 1773	47	28	5	41%	
Yi	*Fabaceae*	*Dialium cochinchinense* Pierre	46	20	14	43%	
Scarab beetle	*Scarabaeidae*	*Holotrichia sichotana* Brenske, 1896	45	32	3	44%	
Fetid passionflower	*Passifloraceae*	Passiflora foetida L.	44	19	17	45%	
Longhorn grasshopper	*Tettigoniidae*	*Pseudophyllus titan* White, 1846	44	33	3	45%	
Wild spider flower	*Cleomaceae*	*Cleome gynandra* L.	43	18	19	46%	
Chebulic myrobalans	*Combretaceae*	*Terminalia chebula* Retz.	43	27	10	46%	
Short-tailed cricket	*Gryllidae*	*Tarbinskiellus portentosus* (Lichtenstein, 1796)	43	25	12	46%	
Ramontchi	*Salicaceae*	*Flacourtia indica* (Burm.f.) Merr.	42	25	13	48%	

True water beetle	*Dytiscidae*	*Cybister limbatus* (Fabricius, 1775)	42	34	4	48%	

Table S1 (Cont.). Classification of NUS according to their awareness and consumption status from the survey

177 food items			Score				
Common Name	Family	Species	"Unfamiliar" and "never consumed"	"Familiar" but "never consumed"	"Familiar" and "consumed"	Awareness	Rank
Dung beetle	*Scarabaeidae*	*Heliocopris dominus* Bates, 1868	42	37	1	48%	Infrequently known and used
Pigeon pea	*Fabaceae (Leguminosae)*	*Cajanus cajan* (L.) Huth	41	14	25	49%	Moderately known and used
Mole cricket	*Gryllotalpidae*	*Gryllotalpa africana* Palisot de Beauvois, 1805	40	31	9	50%	
Wild mango	*Anacardiaceae*	*Mangifera caloneura* Kurz	39	19	22	51%	
Solanum	*Solanaceae*	*Solanum stramoniifolium* Jacq.	38	29	13	53%	
Elephant beetle	*Scarabaeidae*	*Megasoma elephas* (Fabricius, 1775)	38	38	4	53%	
Oriental radish	*Brassicaceae*	*Raphanus caudatus* L.	37	23	20	54%	
Rice paddy herb	*Plantaginaceae*	*Limnophila aromatica* (Lam.) Merr.	37	21	22	54%	
Giant water bug	*Belostomatidae*	*Diplonychus rusticus* Fabricius, 1871	37	28	15	54%	
House cricket	*Gryllidae*	*Acheta domesticus* (Linnaeus, 1758)	37	32	11	54%	
Long-horned grasshopper	*Tettigoniidae*	*Euconocephalus incertus* (Walker, 1869)	37	38	5	54%	
Scarab beetle	*Scarabaeidae*	*Xylotrupes gideon* (Linnaeus, 1767)	36	42	2	55%	
Gold apple	*Ebenaceae*	*Diospyros decandra* Lour.	35	32	13	56%	
Sweet leaf	*Phyllanthaceae*	*Sauropus androgynus* (L.) Merr.	35	18	27	56%	
White cheesewood	*Annonaceae*	*Melodorum fruticosum* Lour.	34	43	3	58%	
Soap pod	*Fabaceae (Leguminosae)*	*Acacia concinna* (Willd.) DC.	32	34	14	60%	
Water clover	*Marsileaceae*	*Marsilea crenata* C. Presl	31	26	23	61%	
Red pea eggplant	*Solanaceae*	*Solanum trilobatum* L.	31	35	14	61%	
Green okra	*Malvaceae*	*Abelmoschus esculentus* (L.) Moench	30	23	27	63%	
Brihati	*Solanaceae*	*Solanum indicum* L.	30	37	13	63%	
Indian mulberry	*Rubiaceae*	*Morinda citrifolia* L.	30	25	25	63%	

Garcinia cowa	*Clusiaceae*	*Garcinia cowa* Roxb. ex Choisy	29	24	27	64%	
Spider	*Theraphosidae*	*Melophagus ovinus* (Linnaeus, 1758)	29	50	1	64%	
Red palm weevil	*Curculionidae*	*Rhynchophorus ferrugineus* (Olivier, 1790)	29	44	7	64%	
Sweet leaf (wild)	*Opiliaceae*	*Melientha suavis* Pierre	26	24	30	68%	

Table S1 (Cont.). Classification of NUS according to their awareness and consumption status from the survey

177 food items			Score			Awareness	Rank
Common Name	**Family**	**Species**	**"Unfamiliar" and "never consumed"**	**"Familiar" but "never consumed"**	**"Familiar" and "consumed"**		
Sesbania	*Fabaceae (Leguminosae)*	*Sesbania javanica* Miq.	26	28	26	68%	Moderately known and used
Dung beetle	*Scarabaeidae*	*Gymnopleurus aethiops* Sharp, 1875	26	52	2	68%	
Burmese grape	*Phyllanthaceae*	*Baccaurea ramiflora* Lour.	25	27	28	69%	
Gac	*Cucurbitaceae*	*Momordica cochinchinensis* (Lour.) Spreng.	24	30	26	70%	
Giant water bug	*Belostomatidae*	*Lethocerus indicus* (Le Peletier & Serville, 1825)	24	34	22	70%	
Mantid	*Mantidae*	*Hierodula patellifera* Serville, 1839	24	50	6	70%	
Dung beetle	*Scarabaeidae*	*Copris nevinsoni* Waterhouse, 1891	22	55	3	73%	
Jambolan plum	*Myrtaceae*	*Syzygium cumini* (L.) Skeels	20	38	22	75%	
Cowslip creeper	*Apocynaceae*	*Telosma cordata* (Burm.f.) Merr.	20	28	32	75%	
Bombay locust	*Acrididae*	*Patanga succincta* (Johannson, 1763)	20	48	12	75%	
Water silk	*Zygnemataceae*	*Cladophora glomerata* (L.) Kütz.	18	30	32	78%	
Metallic wood-boring beetle	*Buprestidae*	*Sternocera aequisignata* E.Saunders, 1866	18	59	3	78%	
Bamboo caterpillar	*Pyralidae*	*Omphisa fuscidentalis* (Hampson, 1896)	17	36	27	79%	
Madan	*Clusiaceae*	*Garcinia schomburgkiana* Pierre	16	38	26	80%	
Ya-nang	*Menispermaceae*	*Tiliacora triandra* (Colebr.) Diels	16	29	35	80%	
Phak liang	*Gnetaceae*	*Gnetum gnemon* L.	16	11	53	80%	
Horse tamarind	*Fabaceae (Leguminosae)*	*Leucaena leucocephala* (Lam.) de Wit	15	25	40	81%	
Hyacinth bean	*Fabaceae (Leguminosae)*	*Lablab purpureus* (L.) Sweet	14	23	43	83%	

Termite	*Termitidae*	*Termes* sp.	14	62	4	83%	
Moringa	*Moringaceae*	*Moringa oleifera* Lam.	13	37	30	84%	
House cricket	*Gryllidae*	*Acheta* Fabricius, 1775	13	42	25	84%	
Bilimbi	*Oxalidaceae*	*Averrhoa bilimbi* L.	11	20	49	86%	Commonly known and used
Lotus stem	*Nymphaeaceae*	*Nymphaea pubescens* Willd.	11	32	37	86%	

Table S1 (Cont.). Classification of NUS according to their awareness and consumption status from the survey

177 food items			Score				
Common Name	**Family**	**Species**	**"Unfamiliar" and "never consumed"**	**"Familiar" but "never consumed"**	**"Familiar" and "consumed"**	**Awareness**	**Rank**
Bael	*Rutaceae*	*Aegle marmelos* (L.) Corrêa	9	24	47	89%	Commonly known and used
Sesban agasta	*Fabaceae (Papilionaceae)*	*Sesbania grandiflora* (L.) Poir.	8	16	56	90%	
Cluster fig	*Moraceae*	*Ficus racemosa* L.	8	51	21	90%	
Wildbetal leafbush	*Piperaceae*	*Piper sarmentosum* Roxb.	7	21	52	91%	
Paco fern	*Athyriaceae*	*Diplazium esculentum* (Retz.) Sw.	7	22	51	91%	
Cicada	*Cicadidae*	*Meimuna opalifera* (Walker, 1850)	7	66	7	91%	
Indian gooseberry	*Phyllanthaceae*	*Phyllanthus emblica* L.	6	20	54	93%	
Cassod tree	*Fabaceae (Leguminosae)*	*Santalum album* L.	6	23	51	93%	
Neem	*Meliaceae*	*Azadirachta indica* A.Juss	6	39	35	93%	
Bitter bean	*Fabaceae (Leguminosae)*	*Parkia speciosa* Hassk.	6	26	48	93%	
Banana	*Musaceae*	*Musa sapientum* L.	5	1	74	94%	
Galangal	*Zingiberaceae*	*Alpinia galanga* (L.) Willd.	5	6	69	94%	
Jack fruit	*Moraceae*	*Artocarpus heterophyllus* Lam.	4	5	71	95%	
Bitter gourd	*Cucurbitaceae*	*Momordica charantia* L.	3	33	44	96%	
Garlic	*Amaryllidaceae*	*Allium sativum* L.	3	14	63	96%	
Climbing wattle	*Fabaceae*	*Acacia pennata* (L.) Willd.	2	5	73	98%	
Ivy gourd	*Cucurbitaceae*	*Coccinia grandis* (L.) Voigt	2	5	73	98%	
Winged bean	*Fabaceae (Leguminosae)*	*Psophocarpus tetragonolobus* (L.) DC.	2	15	63	98%	

Asiatic pennywort	*Apiaceae (Umbelliferae)*	*Centella asiatica* Urb.	2	22	56	98%	
Wasp	*Vespidae*	*Vespa* sp.	2	73	5	98%	
Hornet	*Vespidae*	*Polistes stigma* (Fabricius, 1793)	2	74	4	98%	
Silk worm pupae	*Bombycidae*	*Bombyx mori* (Linnaeus, 1758)	2	46	32	98%	
Water mimosa	*Fabaceae (Leguminosae)*	*Neptunia oleracea* Lour.	1	16	63	99%	

Table S1 (Cont.). Classification of NUS according to their awareness and consumption status from the survey

177 food items			Score				
Common Name	**Family**	**Species**	**"Unfamiliar" and "never consumed"**	**"Familiar" but "never consumed"**	**"Familiar" and "consumed"**	**Awareness**	**Rank**
Culantro	*Apiaceae*	*Eryngium foetidum* L.	1	8	71	99%	Commonly known and used
Thai water convolvulus	*Convolvulaceae*	*Ipomoea aquatica* Forssk.	1	5	74	99%	
Pumpkin	*Cucurbitaceae*	*Cucurbita moschata* Decne.	1	4	75	99%	
Hog plum	*Anacardiaceae*	*Spondias pinnata* (L.f.) Kurz	1	24	55	99%	
Turkey berry	*Solanaceae*	*Solanum torvum* Sw.	1	19	60	99%	
Red ant	*Formicidae*	*Oecophylla smaragdina* (Fabricius, 1775)	1	61	18	99%	
Honey bee	*Apidae*	*Apis florea* Fabricius, 1787	1	74	5	99%	
Bird pepper	*Solanaceae*	*Capsicum frutescens* L.	0	2	78	100%	
Tamarind	*Fabaceae (Leguminosae)*	*Tamarindus indica* L.	0	7	73	100%	
Mango	*Anacardiaceae*	*Mangifera indica* L.	0	3	77	100%	
Cashew	*Anacardiaceae*	*Anacardium occidentale* L.	0	4	76	100%	
Star gooseberry	*Phyllanthaceae*	*Phyllanthus acidus* (L.) Skeels	0	17	63	100%	
Papaya	*Caricaceae*	*Carica papaya* L.	0	2	78	100%	
Kitchen mint	*Lamiaceae (Labiatae)*	*Mentha × villosa* Huds.	0	15	65	100%	
Bamboo shoots	*Poaceae (Gramineae)*	*Bambusa vulgaris* Nees	0	8	72	100%	
Holy basil	*Lamiaceae*	*Ocimum tenuiflorum* L.	0	1	79	100%	
Lemongrass	*Poaceae*	*Cymbopogon citratus* (DC.) Stapf	0	3	77	100%	
Coriander	*Apiaceae (Umbelliferae)*	*Coriandrum sativum* L.	0	2	78	100%	

Awareness (%) = ("Familiar" but "never consumed" + "Familiar" and "consumed") ÷ Total respondents × 100