

Moringa *Moringa oleifera*
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MORINGA

Moringa oleifera Lam.
Family: Moringaceae

By Jed W. Fahey, MS, ScD

INTRODUCTION

***Moringa oleifera* is the most widely cultivated of the 13 known species in the monogeneric family Moringaceae.[1] This fast-growing, soft-wooded perennial tree — known by a wide range of common names, including moringa, horseradish tree, drumstick tree, ben oil tree, and kelor — was likely domesticated in India (the name moringa apparently derives from the Tamil word *murungai*, meaning "twisted pod").[2] It is now broadly cultivated throughout the tropics. Moringa is an important food and economic crop in India and the Philippines, with cultivation extending across western, eastern, and southern Africa; Latin America; the Caribbean; Florida; and the Pacific Islands.**

Although its timber is of low quality, all other parts of the tree are edible and have long been consumed by humans, while various parts historically have served medicinal and industrial purposes as well. The leaves are typically harvested once a year, although for casual household use, they are picked continuously. Trees reach 2 m (6.6 ft) in height within the first year of growth; flowers and pods are normally produced in the second year of growth.[3] Various groups have also used extremely dense seed planting to create harvestable vegetable stands in as little as six weeks, with plants cut back to near ground level for leaf harvest (coppicing) and allowed to regrow for multiple leaf production cycles.[4]

Scientific understanding of the genus has been substantially advanced over the last 30 years by Mark E. Olson, PhD, a professor at Universidad Nacional Autónoma de México, a National Geographic Explorer,[5] and one of the foremost authorities on *Moringa* species in the English-speaking world. Olson established the International Moringa Germplasm Collection on the coast of Jalisco, Mexico, which maintains living material of 12 of the 13 *Moringa* species and serves as a primary resource for research into the basic biology, ecology, and phytogeography of the genus and its applied uses — including nutrition, cancer chemoprevention, biofuels, and water clarification.[6-18]

Moringa is notable both nutritionally and phytochemically. Its characteristic isothiocyanates, produced from its glucosinolates after crushing or chewing, are among its key bioactive constituents and are the subject of growing research on moringa's potential health effects. Nutritionally, dried moringa leaves are relatively rich in protein,

often approaching 30% of dry weight, and provide essential amino acids, carotenoid precursors of vitamin A, iron, calcium, and other micronutrients.

Moringa seed oil, commonly called ben oil, constitutes 30%–40% of seed weight and is a sweet, non-sticky, non-drying oil with notable resistance to rancidity. It has a history of use in foods such as salad dressings, as a fine machine lubricant, and in perfumes and hair care products.[19,20] Powdered moringa seeds are used to flocculate (clump together) contaminants and clarify drinking water.[21-23] The seeds are also consumed green or roasted, powdered and steeped as tea, and incorporated into curries.[22] The leaves and dried leaf powder have a characteristically astringent taste that is familiar to populations in moringa's regions of origin, although it tends to be an acquired taste for Western consumers — one that is nevertheless gaining acceptance, as a growing body of market and consumer research attests.[7,10,24] More broadly, moringa has attracted increasing attention as an indigenous source of highly digestible protein, calcium, iron, vitamin C, and carotenoids, particularly in regions where undernutrition remains a significant public health concern.

HISTORY AND CULTURAL SIGNIFICANCE

The human relationship with moringa is among the longest documented for any useful tree. On the Indian subcontinent, where the species is native, the plant appears in ancient Sanskrit literature under the name *shigru* — meaning, roughly, "one of piercing or penetrating qualities" — a reference to the pungent, horseradish-like character of its leaves and roots. The classical Ayurvedic compilations *Charaka Samhita* and *Sushruta Samhita*, which codified Indian medical knowledge dating back more than two millennia, describe moringa as warming, digestive, and detoxifying, with specific preparations recommended for skin diseases, inflammation, pain, and fevers. Ayurvedic practitioners also praise moringa as a Rasayana — a rejuvenative herb — and recommend leaf decoctions to balance the doshas, particularly Vata.

The tree's reach in the ancient world extended well beyond India. Ancient Egyptians used the seed oil of the closely related *M. peregrina* to protect their skin from the harsh desert climate. Early Greeks and Romans valued moringa extracts for both culinary and medicinal purposes, incorporating the oil into perfumes and personal care preparations — a use that, notably, anticipated its primary commercial application in Western cosmetics today. There is even a tantalizing possibility that the tree referenced in Exodus 15:22–25, which Moses cast into the bitter waters of Marah to make them sweet, may have been *M. peregrina*, whose seed proteins have long been used to clarify and purify turbid water.[25]

In the cultures where it has long been cultivated — India, the Philippines, Sudan, Ethiopia, Senegal, and across West and East Africa — moringa has been used as both a food and medicine. In the Philippines, moringa leaves, known locally as *malunggay*, have been a routine ingredient in everyday cooking for generations, added to soups, stews, and rice dishes as a matter of course rather than as a health supplement. In Senegal and across the Sahel (the semi-arid zone south of the Sahara Desert, extending from the Atlantic Ocean eastward to the Red Sea), the leaves and leaf powder have served as a critical nutritional resource, particularly during the dry season when other food sources fail. Lowell Fuglie's oral histories, recorded on video in West Africa and compiled in the landmark *Miracle Tree* publications while he was at Church World Service (1999) and posthumously updated in 2019,[26,27] documented countless instances of moringa being used to reverse acute malnutrition in infants and nursing mothers — a role the tree continues to fill. Traditional healers throughout the tropics have recommended moringa as a general nutrient-dense food source and have prescribed moringa preparations for an extraordinary range of conditions, including skin diseases, respiratory illnesses, ear and dental infections, hypertension, and diabetes.

The story of moringa's encounters with the Western world has been neither linear nor without cautionary episodes. Beginning in the late 1500s, Filipino sailors in the Spanish galleon trade between the Philippines and Spain brought moringa to the New World. Later, during the British colonial period, Indian railway workers and others carried moringa with them, spreading it throughout Britain's colonies (M. Olson email to T. Smith, September 18, 2026). A first flush of modern Western commercial interest in the 1970s and 1980s ended badly: speculators contracted with subsistence farmers in places like Bangladesh to grow moringa for export, luring them with the promise of Western market prices. By the time harvests were ready, demand had already faded, and many farmers who had abandoned traditional subsistence crops were left in serious hardship,[28] a cautionary episode that remains relevant as commercial interest in moringa surges again today.

The more durable pathway into Western awareness came through the humanitarian community. Three nongovernmental organizations in particular — Trees for Life, Church World Service, and Educational Concerns for Hunger Organization — championed moringa as "natural nutrition for the tropics" beginning in the 1990s and disseminated data comparing the nutrient density of moringa leaves with that of more common foods. Although these comparisons can be highly misleading,[29] they have reached millions, establishing the plant's reputation as an exceptional nutritional resource. These advocacy efforts laid the groundwork for the peer-reviewed scientific investigations that followed, as well as numerous reviews that brought the accumulating body of evidence to a wider research audience and helped catalyze the current era of systematic scientific inquiry into moringa's nutritional, chemopreventive, and medicinal potential.[20]

CURRENT AUTHORIZED USES IN COSMETICS, FOODS, AND MEDICINES

Moringa Leaf Powder

The regulatory treatment of moringa leaf powder in the United States varies depending on how a product is positioned — as a food ingredient, dietary supplement, or medicine — and this distinction has practical consequences for manufacturers and formulators.[29]

As a food ingredient, dried moringa leaf powder, when added to conventional foods (e.g., smoothies, protein blends, energy bars, flour fortifications, and similar products), occupies relatively settled regulatory ground. It is used as a whole-plant-derived food ingredient in a form that has not been chemically altered, and its long history of consumption in South Asian and African food traditions is relevant to its standing under US food law.

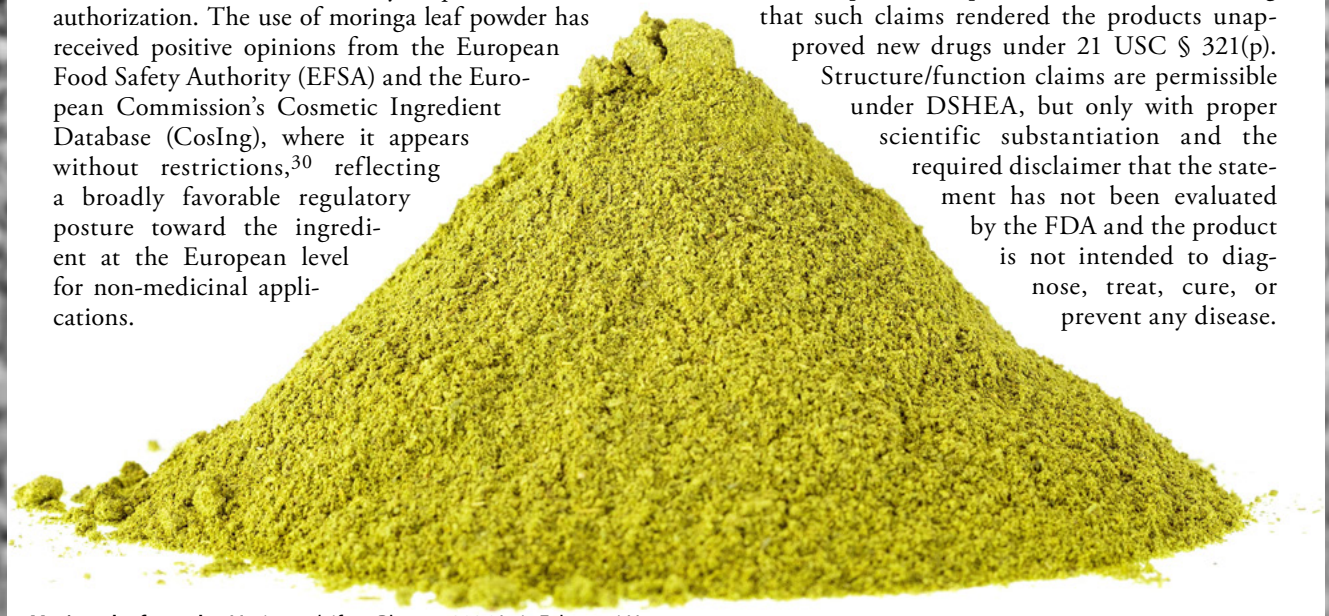
While moringa leaf powder does not have a Generally Recognized as Safe (GRAS) determination from the US Food and Drug Administration (FDA), the absence of GRAS status does not equate to prohibition. Many traditional food ingredients lack formal GRAS filings yet are lawfully used in conventional foods. Manufacturers are responsible for the safety of the ingredients they use, and the growing body of human consumption data without serious documented adverse effects at typical dietary intake levels supports a reasonable basis for moringa's use in food applications at conventional amounts, provided that appropriate labeling and good manufacturing practice (GMP) requirements are met. The FDA's scrutiny of moringa has primarily focused on products that make health claims or are sold as dietary supplements rather than the ingredient itself as used in conventional foods.

In the European Union (EU), moringa leaf and leaf powder are not classified as novel foods under Regulation (EU) 2015/2283, meaning their use in food supplements is permitted without novel food authorization — although certain moringa extracts and moringa seed oil intended for food use may require novel food authorization. The use of moringa leaf powder has received positive opinions from the European Food Safety Authority (EFSA) and the European Commission's Cosmetic Ingredient Database (CosIng), where it appears without restrictions,[30] reflecting a broadly favorable regulatory posture toward the ingredient at the European level for non-medicinal applications.

Interestingly, Food Standards Australia New Zealand (FSANZ) reached a contrary conclusion in 2025, rejecting an application to permit *M. oleifera* as a novel food.[31] In 2026, the Brazilian Health Regulatory Agency (ANVISA) — which, since 2019, has taken a combative stance toward the presence of moringa in food or supplements[29] — ruled that moringa "has not been proven safe for use in food, in any form, such as tea, capsules, tablets, bars, powder, beverage, or others."[32]

For dietary supplements, the US regulatory framework is more complex and is governed by the Dietary Supplement Health and Education Act of 1994 (DSHEA). Under 21 USC § 350b(a), a manufacturer or distributor of a dietary supplement containing a New Dietary Ingredient (NDI) must submit an NDI notification to the FDA unless the ingredient has been present in the US conventional food supply as an article used for food in a form in which the food has not been chemically altered. The notification must be submitted at least 75 days before the ingredient is introduced into interstate commerce. Whether moringa leaf powder qualifies as an NDI — or whether its pre-DSHEA presence in the US food supply exempts it from this requirement — has not been definitively resolved by the agency. In practice, the FDA has, in at least one instance, characterized a moringa dried leaf powder dietary supplement as containing an NDI for which the submitted notification did not provide an adequate basis to conclude the ingredient would reasonably be expected to be safe under the proposed conditions of use,[33] signaling that NDI compliance cannot be assumed.

The more immediate and consistent regulatory risk for supplement marketers in the United States, however, concerns labeling. The FDA has issued warning letters[34-36] to moringa supplement sellers whose product websites made claims that the ingredient could lower blood sugar levels, reduce inflammation, or help control lipids and cholesterol, finding that such claims rendered the products unapproved new drugs under 21 USC § 321(p). Structure/function claims are permissible under DSHEA, but only with proper scientific substantiation and the required disclaimer that the statement has not been evaluated by the FDA and the product is not intended to diagnose, treat, cure, or prevent any disease.



Moringa leaf powder *Moringa oleifera*. Photo ©2026 Luis Echeverri Urrea

As a medicine or pharmaceutical ingredient, moringa leaf powder has no approved drug status in the United States, Canada, or the EU, and no pharmacopeial monograph (United States Pharmacopeia [USP] or otherwise) has been published to standardize it for pharmaceutical use. European legislation explicitly prohibits the use of moringa in herbal medicinal products, drawing a clear distinction between its permitted use as a food supplement and any medicinal application.

From a safety and labeling standpoint, several cautions apply across all categories and are addressed, along with issues of adulteration and contamination, in separate sections to follow. Few clinical studies have formally evaluated herb-drug interactions with moringa, although in vitro evidence suggests moringa extracts may inhibit CYP3A4 and P-glycoprotein,[37,38] making concomitant use with drugs that are CYP3A4 substrates potentially problematic. Animal studies also suggest potential inhibition of the conversion of thyroxine to triiodothyronine,[39] raising concern for those on thyroid medications. Rare case reports of serious adverse events, including Stevens-Johnson syndrome[40] (a rare, serious disorder of the skin and mucous membranes) and cutaneous toxicity with respiratory distress,[41] have been associated with moringa leaf consumption. Use during pregnancy is generally discouraged. Regardless of regulatory category, supplier verification, microbial testing, and robust GMP compliance are essential for any moringa leaf powder product entering commerce.

Moringa Seed Oil and Seeds

The regulatory profile of moringa seed oil is quite different from that of the leaf powder, particularly with respect to its primary authorized use in cosmetics rather than conventional food or supplements.

In the EU, moringa seed oil is a well-established cosmetic ingredient: it carries the International Nomenclature of Cosmetic Ingredients (INCI) name *Moringa Oleifera Seed Oil*, CAS number 93165-54-9, and CosIng reference number 85909, and it is not listed among prohibited or restricted substances under EU Cosmetics Regulation (EC) No 1223/2009. Its use in cosmetic formulations, including skin creams, serums, and hair care products, is therefore permitted without restriction under EU law, subject to standard product safety



Moringa *Moringa oleifera*
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assessment requirements. In contrast, moringa seed oil for use in food supplements is classified as a novel food in the EU, requiring companies to apply for novel food authorization before such products may be sold. No such authorization had been granted at the time of this writing, effectively precluding the use of moringa seed oil as an ingestible supplement in European markets.

In the United States, the moringa seed oil component of NDI notification no. 1069 was similarly characterized by the FDA in the context of a dietary supplement notification, with the agency concluding that the submission did not provide an adequate basis to determine that the ingredient would reasonably be expected to be safe under the proposed conditions of use.[33,42] For topical cosmetic use in the United States, however, it is not subject to premarket approval and can be freely incorporated into personal care products. No pharmacopeial monograph specific to moringa seed oil has been established in major compendia.

Safety considerations for moringa seed oil in cosmetic applications are generally favorable: it is not flagged under any major restricted substance lists and does not appear on Annex II (prohibited) or Annex III (restricted) schedules of the EU Cosmetics Regulation. Whole seeds and seed-derived extracts intended for oral use pose greater concerns. The seeds contain compounds that, at higher doses in animal studies, have demonstrated abortifacient and antifertility effects, although these findings are not directly applicable to the refined, cold-pressed seed oil used in cosmetics at typical concentrations.[43] Labeling for any ingestible seed product should note the absence of established safety data for use in pregnancy and the lack of regulatory authorization in most major markets for food or supplement applications.

MODERN RESEARCH

Main Active Compounds and Nutrients

The phytochemical abundance of moringa has implications with respect to its utility as a nutritional plant and as a source of micronutrients[17] as well as its medicinal effects (the application with which phytochemicals are most often associated).[18,44] The leaves are rich in flavonoids such as quercetin and kaempferol, phenolic acids such as chlorogenic acid, carotenoids such as β-carotene, the plant sterol β-sitosterol, and many others.[45] In particular, this plant family is rich in compounds containing the simple sugar rhamnose and a fairly unique group of phytochemicals called glucosinolates, which are enzymatically converted to isothiocyanates.[46] The isothiocyanates, in general, have notable anti-inflammatory, detoxification, antibiotic, and neuroprotective properties, to name a few. Moringa contains potent glucosinolates that scientists have shown are influenced by both environment and genetics.[8,9,47,48]

In addition to its unique rhamnosylated glucosinolates and isothiocyanates, moringa contains various related carbamates, thiocarbamates, and nitriles. Specific non-glucosinolate components of moringa preparations have been reported to have hypotensive, anticancer, and antibacterial activities.[49-55] Furthermore, compared to other leafy vegetables, moringa leaves are relatively rich in protein (~30% of dry mass), iron, calcium, fiber, potassium, and provitamin A.[8,17,20]

Preclinical Research

In many cases, published in vitro (cultured cells) and in vivo (animal) studies provide a degree of mechanistic support for some of the claims that have sprung from traditional medicine lore. For example, numerous studies now point to elevated levels of various detoxification and antioxidant enzymes and biomarkers, as well as selective and potent antibiotic activity,[56] after treatment with moringa or phytochemicals isolated from moringa.[50,53,57-59] Cellular and animal studies have further demonstrated anti-inflammatory activity through suppression of key cytokines including IL-1β and TNF-α and the enzyme COX-2; anticancer effects via induction of apoptosis and inhibition of NF-κB; blood glucose-lowering activity in hepatic cell models; and reduced motor and inflammatory markers in rodent models of Parkinson's disease, multiple sclerosis, and amyotrophic lateral sclerosis (ALS).[60-67] Taken together, these findings make a compelling case for moringa isothiocyanates as the primary bioactive drivers of these effects. A critical limitation, however, is that many studies conducted with whole-leaf powder or crude extracts do not characterize or quantify the phytochemical constituents responsible for observed outcomes, making it difficult to translate preclinical findings into defined, reproducible human clinical protocols — a gap that ongoing work on standardized moringa preparations is specifically designed to address.

Human Clinical Research

Of the 12,335 papers citing "*Moringa oleifera*" in the Scopus database (accessed July 8, 2026), 112 are coded as "clinical studies" or "trials" that are not reviews, editorials, or commentaries. ClinicalTrials.gov, the registration portal for human clinical trials used worldwide, lists 56 clinical trials using moringa. Despite a dearth of well-designed and executed randomized controlled trials (RCTs) on moringa in the Western medical tradition, many small clinical trials suggest potential benefits for diabetes, hypertension, asthma, exercise performance and fatigue, immune function in people with HIV, pediatric anemia, malnutrition, and lactation, as well as anti-inflammatory, antioxidant, cardioprotective, and chemoprotective effects.

Since the author's previous reviews of this topic (2005, 2019), newly published evidence has not substantially changed the overall assessment of moringa's potential health benefits.[20,30,44] The available evidence also underscores the need for larger, well-designed, and rigorous RCTs to validate the most promising findings in humans.

The following items spotlight just a few of the indications that appear to be most robust currently:

Lactation

One of moringa's oldest traditional uses is as a galactagogue (lactation stimulant). Multiple RCTs have addressed these effects, and a systematic review of eight studies found that moringa increased breast milk production by 135–400 mL per day compared to placebo, increased prolactin levels by more than 50%, and improved milk fat content.[68] A meta-analysis and systematic review published in April 2026, which included 14 studies and 865 lactating women, also found a large, statistically significant beneficial effect of moringa supplementation on breast milk production as a primary outcome, along with various secondary benefits and no significant adverse events.[69]

Malnutrition

Whereas oral histories[26] — and, in fact, much of the traditional lore on moringa — are replete with anecdotes about reversing malnutrition, RCTs on the subject did not appear in the scientific literature until the past decade or so. With the exception of a 2021 trial in Niger that showed no significant improvements in weight or mid-upper-arm circumference (MUAC, a rapid measurement used to assess nutritional status and screen for malnutrition) compared to standard supplementary food,[70] other RCTs in Ghana,[71] Burkina Faso,[72] and India[73] have demonstrated beneficial effects of moringa complementary feeding on hemoglobin levels and severe acute malnutrition.

HIV and Immune Function

Effects of moringa leaf powder on the immune and nutritional status of people living with HIV — both those receiving and those not receiving antiretroviral therapy (ART) — are the subject of numerous anecdotes from physicians and patients in the tropics that have been shared over the years with the author and others in the moringa community. A 2025 meta-analysis examined eight published studies: five from Nigeria and one each from Uganda, Congo, and Kenya.[74] Six of the eight studies were RCTs, and the other two were single-arm pre-post studies. Doses ranged from less than 1 g to 20 g per day, and the interventions lasted 2–12 months. The analysis found highly significant increases in CD4, platelet, and white blood cell counts after moringa consumption. The two studies that reported data on body mass index (BMI) found significant increases.

Exercise Performance and Fatigue

Although moringa's effects on fatigue and energy levels are frequently described in traditional herbal histories, and moringa has been widely touted in Western biohacking circles for these effects, they were not scrutinized quantitatively in the scientific literature until very recently. In a study published in 2024,[75] tablets containing moringa leaf aqueous extract (equivalent to 1 g moringa leaf powder per day) were administered to



Moringa *Moringa oleifera*
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23 young male athletes for 30 days, with a control group receiving placebo tablets. The moringa group had marginally greater upper- and lower-body strength and endurance but showed highly significant improvements in serum glucose, urea, malondialdehyde, and glutathione peroxidase activity.

Type 2 Diabetes and Cardiometabolic Health

Moringa has been identified as one of the most commonly used plants for diabetes and hypertension across much of the tropics according to extensive anecdotal reports from physicians and patients, as well as accounts of its use in traditional medicine systems in those regions. A cross-sectional survey that reported 41 medicinal plants used in Senegal provides supporting evidence from that country.[76]

To date, at least 21 human studies on moringa for type 2 diabetes (T2D) have been reported, including 19 published studies[77-95] and two available only as study records on ClinicalTrials.gov (NCT03189407 in Nigeria and NCT05898750 in Egypt). A substantial majority demonstrated a positive effect of moringa in reducing blood glucose in people with T2D. Unfortunately, several of these studies did not report the use of placebo controls,[88,92,93] thus reducing their potential impact and highlighting the need for higher-quality RCTs. The two studies that enrolled nondiabetic or normoglycemic subjects as the primary population reported no reduction in blood glucose levels after treatment.[89,94] This finding suggests that moringa's glucose-lowering effect may be specific to those with dysregulated glycemia, rather than reflecting a pharmacologically indiscriminate mechanism. A 12-week RCT in which participants with prediabetes consumed 2.4 g of moringa leaf powder per day found substantial improvements in glycemic control markers compared to placebo but found no between-group differences in microbiota, hepatic or renal function markers, or the appetite-controlling hormones ghrelin, peptide YY (PYY), and GLP-1.[81,95]



Moringa *Moringa oleifera*
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A 2025 meta-analysis of RCTs evaluating moringa's impact on cardiometabolic outcomes found a modest but statistically significant reduction in diastolic blood pressure. However, the authors noted substantial heterogeneity in anthropometric and lipid parameters and very low overall certainty for all outcomes evaluated, underscoring the need for large-scale, rigorously designed RCTs.[96] A 2026 systematic review and meta-analysis specifically examining blood pressure and body weight concluded that moringa supplementation significantly reduced systolic and diastolic blood pressure, with greater reductions observed at doses of 5–10 g per day, but had no significant effect on body weight or BMI.[97]

Taken together, the current human clinical literature most reliably supports modest antihypertensive and glucose-regulatory effects in populations with preexisting metabolic dysfunction, while effects on lipid profiles, body composition, and inflammatory markers remain inconsistent across trials and await more definitive investigation (see Table 1).

Dermatology

Finally, although moringa seed oil has long been incorporated into various dermatologic products, moringa leaf extracts have also been examined in skin "revitalization" or "rejuvenation" formulations in both clinical[98] and laboratory studies.[99]

Safety

Formal safety studies on human consumption of moringa leaves or dried leaf powder are limited. Despite the plant's extensive history of use as a food in many tropical regions, clinical trials designed to assess safety are still needed.

Human studies using moringa leaf powder, although generally small and heterogeneous in design, have reported good tolerability at commonly studied intakes in the approximate range of 4–20 g per day (equivalent to roughly 17–84 g fresh leaves, based on ca. 78% moisture content of fresh leaves and 7.4% moisture for dried leaf powder), consistent with its widespread use as a leafy vegetable and traditional food-medicine.

For example, one short-term study in healthy adults tested household-style doses of approximately 2.4, 4.8, and 7.2 g of moringa leaf powder per day. Compliance was high across dose groups, but the highest dose was associated with more self-reported gastrointestinal symptoms, such as bloating, stomach discomfort, and changes in bowel habits, than the lowest dose.[24] Other clinical studies in people with metabolic dysfunction have used approximately 1–10 g per

Table 1. Selected Clinical Studies Evaluating the Antidiabetic Potential of *Moringa oleifera* Leaf Powder

Publication and Year	Study Details	Interventions	Outcome
Rashidmayvan 2026[79]	RCT N = 73 Evaluated the effects of moringa supplementation in participants with metabolic syndrome over 56 days	Treatment: 1 g/day of moringa (n = 37) Control: placebo (n = 36) Study measures: HbA1c, hs-CRP, insulin, and malondialdehyde	↓ HbA1c, hs-CRP, insulin, and malondialdehyde
Irfan 2025[77]	RCT N = 50 Evaluated the effects of adding moringa to metformin therapy in participants with type 2 diabetes (T2D) over 84 days	Treatment: 1 g/day of moringa plus metformin (n = 25) Control: metformin + placebo (n = 25) Study measures: HbA1c, fasting blood glucose (FBG), and blood pressure	↓ HbA1c, FBG, and blood pressure
Leone 2025[78]	Unblinded RCT N = 45 Evaluated the effects of moringa in Sahrawi women with T2D treated with oral glucose-lowering drugs over 84 days	Treatment: 10 g/day of moringa (n = 30) Control: usual treatment without moringa (n = 15) Study measures: body fat and HbA1c	↓ body fat and HbA1c
Díaz-Prieto 2022[81] Gómez-Martinez 2022[95]	RCT N = 65 Evaluated the effects of moringa in participants with prediabetes over 84 days	Treatment: 2.4 g/day of moringa (n = 31) Control: placebo (n = 34) Study measures: HbA1c and TNF-α	TNF-α was a significant predictor of HbA1c response in the moringa group
Leone 2018[82]	Acute controlled study N = 27 Evaluated the acute glycemic effects of moringa in participants with diabetes mellitus (n = 17) and healthy controls (n = 10) over 1 day	Treatment: single 20-g dose of moringa leaf powder with traditional meal Control: same meal without moringa Study measure: glycemia for up to 150 minutes after moringa ingestion	↓ glycemia for up to 150 minutes after moringa ingestion
Ahmad 2018[84]	Randomized, single-blinded, controlled crossover study N = 20 Evaluated the effects of moringa on postprandial blood glucose and hunger in healthy participants during 3 study days separated by washout periods	Treatment: cookie containing moringa leaf powder Control: wheat flour cookie Study measures: postprandial blood glucose and hunger	↓ postprandial blood glucose and less hunger
Taweerutchana 2017[83]	RCT N = 32 Evaluated the effects of moringa supplementation in participants with T2D over 28 days	Treatment: 8 g/day of moringa (n = 16) Control: placebo (n = 16) Study measures: HbA1c, BUN, creatinine, ALT, and AST; insulin was not measured	NSD in HbA1c, BUN, creatinine, ALT, or AST
Mozo 2015[90]	Prospective single-arm study N = 56 Evaluated the effects of moringa in participants with T2D over 84 days	Treatment: 1.5 g/day of moringa No control group Study measures: HbA1c and hs-CRP; insulin was not measured	↓ HbA1c and hs-CRP
Kushwaha 2014[87]	Controlled clinical study N = 90 Evaluated the effects of moringa supplementation in postmenopausal women over 84 days	Group 1: 7 g/day of moringa leaf powder (n = 30) Group 2: 9 g/day of amaranth (*Amaranthus tricolor*, Amaranthaceae) leaf powder (n = 30) Control: no supplement (n = 30) Study measures: serum retinol, ascorbic acid, glutathione peroxidase, SOD, hemoglobin, FBG, and malondialdehyde	↑ serum retinol, ascorbic acid, glutathione peroxidase, SOD, and hemoglobin ↓ FBG and malondialdehyde
Kumari 2010[93]	Controlled clinical study N = 55 Evaluated the effects of moringa supplementation on blood glucose and LDL in participants with T2D over 40 days	Treatment: 8 g/day of moringa leaf powder used regularly with food (n = 46) Control: no treatment (n = 9) Study measures: BG, LDL, and blood lipids (it is unclear how BG was measured and whether the measurements were fasting or postprandial)	↓ BG, LDL, ST, and TC

ALT: alanine aminotransferase, **AST**: aspartate aminotransferase, **BG**: blood glucose, **BUN**: blood urea nitrogen, **FBG**: fasting blood glucose, **HbA1c**: hemoglobin A1c, **hs-CRP**: high-sensitivity C-reactive protein, **LDL**: low-density lipoprotein, **NSD**: no significant difference, **RCT**: randomized controlled trial, **SOD**: superoxide dismutase, **ST**: serum triglycerides, **TC**: total cholesterol, **TNF-α**: tumor necrosis factor alpha

day for several weeks to months, and acute studies have administered larger single doses, including 20 g in postprandial glucose experiments, without consistent reports of serious adverse effects.[82] These observations are reassuring, but they should not be overinterpreted: most trials were not designed primarily as either safety studies or dose-escalation studies, adverse event reporting has been uneven, and as such, long-term exposure data are sparse.

Several concrete safety cautions deserve mention. First, gastrointestinal intolerance is probably the most common practical limitation of dried moringa leaf powder use, particularly as doses rise above ordinary culinary amounts. This may reflect the powder's fiber content, pungent phytochemistry, or simply the difficulty of incorporating gram quantities of a bitter, astringent leaf powder into the diet.

Second, rare but clinically significant hypersensitivity-type reactions have been reported, including a case of generalized cutaneous toxicity with mild respiratory distress and tongue edema after two weeks of moringa powder use,[41] and a separate case report of Stevens-Johnson syndrome after consumption of moringa leaves.[40] Such reports do not establish population-level risk, but they argue against dismissing moringa as categorically benign merely because it is a food plant.

Third, additive pharmacological effects remain plausible. Because moringa preparations have been associated in preclinical and small human studies with lower blood glucose and blood pressure, people taking insulin, sulfonylureas, metformin, antihypertensive drugs, or other cardiometabolic medications could theoretically experience exaggerated effects unless monitored. In vitro evidence suggests effects on CYP3A4 and P-glycoprotein,[100] which also raises the possibility of interactions with certain drugs, although clinically meaningful interactions have not yet been established in controlled studies. Thyroid-related cautions are likewise prudent because animal data suggest possible interference with peripheral thyroid hormone metabolism.

Finally, pregnancy deserves special caution: Moringa leaves are eaten as food in many cultures and have been used traditionally during lactation as a galactagogue. However, concentrated preparations, roots, bark, flowers, and poorly characterized extracts should be avoided in pregnancy because some plant parts (not leaves) and extracts have shown uterotonic, abortifacient, or antifertility activity in experimental systems.

Overall, available evidence suggests that moringa leaf powder is safe as a dietary ingredient at customary intake levels, provided that products are accurately identified, free of microbial and heavy metal contamination, and used with caution by pregnant individuals and people taking medications for diabetes, hypertension, thyroid disease, or other conditions in which additive or interactive effects could be clinically relevant. Moringa's more ambitious medicinal applications require better-controlled human studies before firm conclusions can be drawn.

ADULTERATION AND SUBSTITUTION

Moringa leaf powder is not among the most commonly adulterated botanical ingredients, and deliberate species substitution is relatively rare given the plant's wide availability and low cost. Nevertheless, the commercial powder market is not without quality concerns. Henna (*Lawsonia inermis*, Lythraceae) has been identified as a specific adulterant: recent analytical work using attenuated total reflectance-Fourier transform infrared (ATR-FTIR) spectroscopy combined with chemometric modeling has demonstrated high discriminatory power in distinguishing pure moringa powder from samples adulterated with henna at concentrations as low as 2–4%,[101] suggesting that this form of adulteration is sufficiently common to have attracted dedicated detection methodology.

Within the genus, *Moringa stenopetala* (African moringa) is the species most likely to be confused with or substituted for *M. oleifera*, although it is botanically and phytochemically distinct. The EFSA raised unresolved safety objections specific to *M. stenopetala* in 2019, underscoring that species-level authentication matters from both quality and regulatory standpoints.

Color is also a practical quality indicator: high-quality leaf powder should be a vivid, bright green, whereas a dull, brownish, or grayish appearance can indicate excessive heat during drying, prolonged oxidation, or adulteration with fillers.[101]

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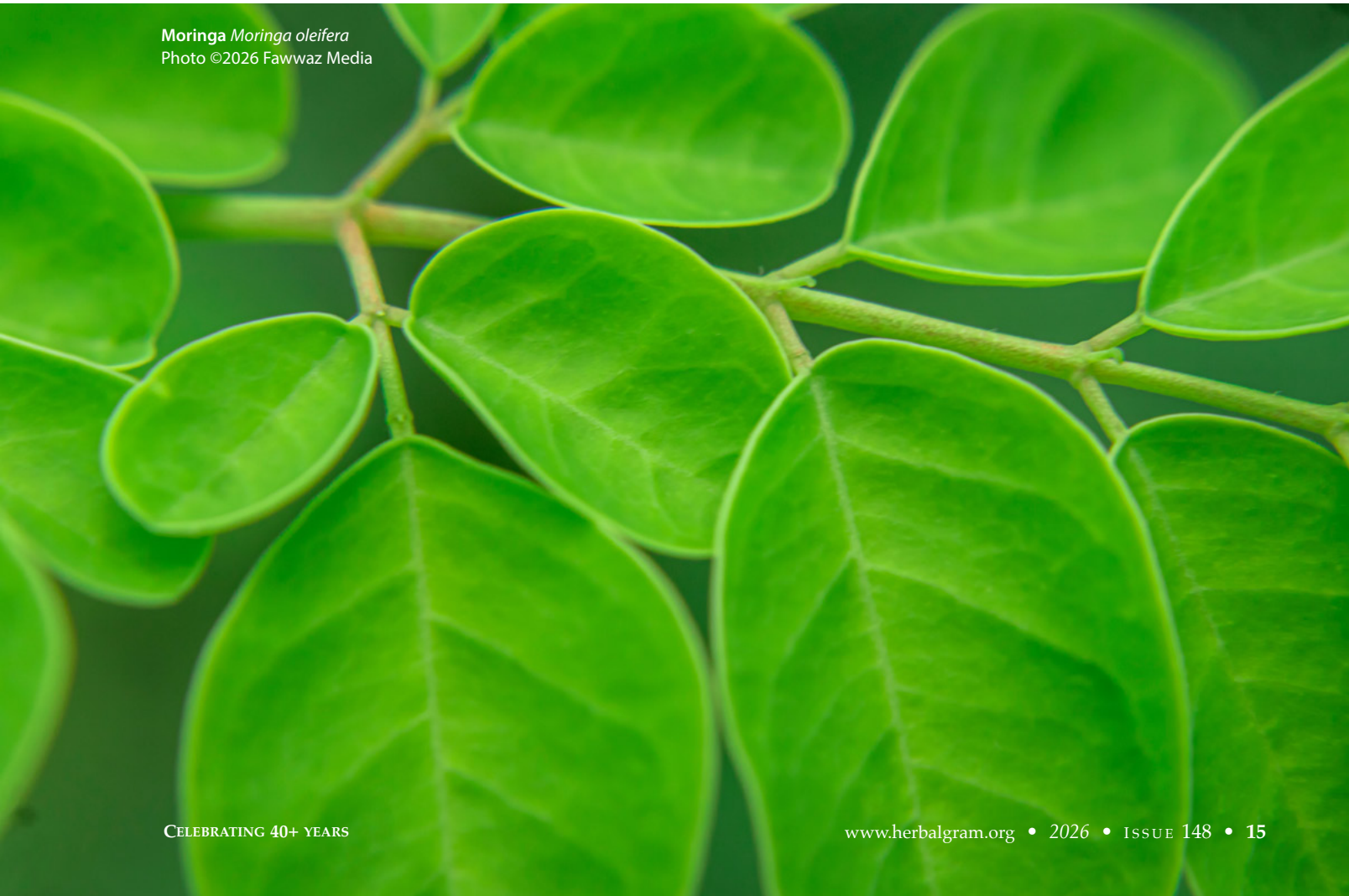
The more pervasive quality-control concern is environmental contamination rather than intentional adulteration. Because moringa has documented phytoremediation potential and can hyperaccumulate metals from contaminated soils, individual commercial samples have exceeded permissible thresholds for lead and cadmium, with one survey of moringa powders sold in Benin finding that 58% of tested products contained lead above EU limits for leafy vegetables,[102] although overall consumer risk was characterized as low given typical consumption levels.

Microbial contamination, including *Salmonella*, *E. coli*, and various fungi, poses the most immediately actionable quality risk, as underscored by the 2025–2026 multistate *Salmonella* outbreak traced to imported Indian-origin moringa leaf powder.[103] Pesticide residues are an additional concern for products that are not certified organic and are sourced from regions with less stringent agricultural oversight. Taken together, these issues point to the importance of robust supplier qualification programs, third-party testing (heavy metals, microbials, pesticide screens), and country-of-origin transparency as baseline requirements for any responsible formulator working with this ingredient.[104]

SUSTAINABILITY AND FUTURE OUTLOOK

From an agronomic standpoint, moringa is among the more inherently sustainable crops in commerce. Its exceptional drought resistance, rapid biomass accumulation and maturation to harvestable size within roughly 12 months, low input requirements, and ability to thrive in marginal tropical soils make it an economically viable option for smallholder farmers across sub-Saharan Africa and South and Southeast Asia. The tree can be coppiced and harvested several times per year, regenerates quickly, and has demonstrated value in agroforestry systems that improve soil health alongside food production. These traits give moringa a genuinely favorable environmental profile relative to many other botanical supplement crops, and its cultivation has been identified as a meaningful livelihood opportunity in regions vulnerable to food insecurity and climate stress. However, in some places (e.g., South Africa and Australia), *M. oleifera* has been flagged as an invasive species, which could complicate future adoption or integration into food production in those areas.[105,106]

Global production of moringa is overwhelmingly concentrated in India, which the Agricultural and Processed Food Products Export Development Authority (APEDA), the statutory export authority of the Government of India, identifies as the leading producer, with an estimated 2.2 million metric tons of tender pods generated annually and consumed almost entirely within the domestic market.[107] This cultivation, however, is directed primarily toward pods for use as a fresh vegetable; dedicated leaf biomass plantations of the kind required



Moringa *Moringa oleifera*
Photo ©2026 Fawwaz Media

to supply a standardized leaf powder industry remain comparatively uncommon — a distinction consequential for the commodity of interest here.

Precise figures for the leaf powder trade are difficult to obtain, as published valuations derive largely from proprietary commercial reports rather than government statistics. Nonetheless, one recent peer-reviewed synthesis places the total global moringa ingredient market (seed oil, tea, and leaf powder) at approximately 2.4 million metric tons, valued at roughly €8.7 billion (approximately $9.4 billion) in 2023 and projected to reach €16.4 billion (approximately $17.7 billion) by 2032, a compound annual growth rate of 8.9%. Within this total, leaf powder accounts for more than half the volume — some 1.5 million metric tons — and is the fastest-expanding major category, growing at an estimated 9.2% annually.[107] These values should be read as indicative rather than definitive, given their commercial provenance and the wide dispersion of estimates across sources; they consistently identify leaf powder, however, as the dominant moringa product by volume and a principal driver of sector growth.

The smallholder-dominated structure of moringa cultivation, while socially beneficial, creates challenges for consistency, traceability, and certification. Moringa lifecycle sustainability analyses point to improved market access, the organization of cultivators into farmer-based groups, and optimized farm-gate collection as key levers for strengthening supply chain reliability.

The public health stakes of these gaps are not hypothetical: a *Salmonella* outbreak traced to an Indian moringa processor in 2025–2026 illustrated how deficiencies in post-harvest handling, sanitation, and export oversight at the point of origin can translate directly into downstream health and commercial risks.[103] The central near-term task for the industry, then, is to close the gap between moringa's nutritional, medicinal, and ecological promise and the quality and traceability standards that mature global markets increasingly demand — a challenge as much about supply chain investment and regulatory engagement as about cultivation itself. If that gap can be closed, moringa is well positioned to consolidate its standing as a versatile, sustainable ingredient across the dietary supplement, cosmetic, and functional-food sectors. HG

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