A Scientific Guide for Moringa-based Leaf Products

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Abstract

As the increase in sale and consumption of moringa (*Moringa oleifera*) leaf-based products continues to grow, there is a need to review current scientific research, increase understanding of moringa's potential health benefits, share current knowledge on processing that effects beneficial components, and caution against unwarranted health claims. We examine the three main uses of moringa leaves in human diets including vitamin and mineral content, high-quality dietary protein, and glucosinolate (isothiocyanate) content and potential benefits. For each use we provide background information and scientific research supporting the potential benefits, recommend types of processing to provide maximal concentrations of interested components, and discuss moringa products and claims that may or may not align with current scientific knowledge or realistic dosages for the desired benefits.

Introduction

Commercialization of products for human consumption containing leaves of the moringa (*Moringa oleifera* Lam.) tree is growing globally. Despite a long history of use of the plant as a nutritious food and as a medicine, robust scientific research must be a follow-on to traditional knowledge in order to assure modern consumers and regulators of the health and safety of moringa use in human diets. Clinical trials in humans to verify safety and specific dosage guidelines are a particularly important lacuna.

However, currently available scientific data can provide best-practice guidelines for moringa products that maximize desired benefits and ensure safety. There is already a general scientific understanding of the mechanism by which moringa's components have their effects. We aim to increase awareness and knowledge of current and needed research on the nutritional and health benefits of moringa.

We and many other scientists agree that a lengthy history of consumption well supports its safety in human diets, this evidence cannot also serve as scientific validation of the nutrition and health benefits about which claims are being ceaselessly made.

Because most moringa products being marketed for dietary consumption are based on the leaves of the plant, our review focuses on leaves and does not discuss the use of seeds, flowers or roots. In what follows, **we examine the three main uses of moringa leaves in human diets, which are those derived from its**:

- **Vitamin and mineral content;**
- **High-quality dietary protein (including all essential amino acids);**
- **Glucosinolate (isothiocyanate) content with attending putative health benefits (cancer chemoprotective, anti-inflammatory, antibiotic, glucose regulatory, etc.)**

In each section, **we briefly review:**

- **Background information and scientific research supporting the benefits provided by fresh and/or dried and powdered moringa leaves;**
- **Types of processing recommended to provide maximal concentrations of interested components and desired health benefit; and conclude with**
- **A discussion of moringa products and claims that may or may not align with current scientific knowledge or realistic dosages for the desired benefits.**

We conclude by noting that there is great potential for moringa leaves to be used to address nutritional and health needs in diverse populations and markets. We suggest that further research, including robust clinical studies, are needed to fully support and validate nutritional and health uses of moringa. We advise strongly against purveyors of moringa products making unvalidated health claims such as: "moringa cures 300 diseases"; "moringa contains over 45 antioxidants"; "moringa treats diabetes"; and "moringa can help you lose weight".

Moringa as a low-cost vitamin and mineral source

Moringa leaves are dense, with low water content compared to most vegetables (fresh moringa leaves contain ~78% water, while most vegetables are ~90-95% water). Moringa, similar to many Brassica species, is a bio-accumulator, meaning it takes up and retains nutrients and minerals from the soil at higher rates than most plants(Khan *et al.*, 2015). **Moringa is considered a nutrient dense plant, which can be explained by low water content and the accumulation of nutrients and minerals.** These nutrients can be further concentrated by drying and removal of water. Nutritional content can vary by a number of factors including genetic/geographic origins, production, cultivation techniques, and processing. **Table 1** lists the estimated and averaged nutritional content of fresh and dried moringa leaves:

Table 1. Estimated nutrient content of fresh and dried moringa leaves (Witt, 2014; USDA 2019)

Nutrient (per 100 g)	Fresh Leaves	Dried Leaf Powder
Water (g)	78.7	7.4
Energy (kcal)	64	304
Protein (g)	9.4	29.1
Fat (g)	1.4	6
Carbohydrate (g)	8.3	38.2
Fiber (g)	2	19.2
Calcium, Ca (mg)	185	2003
Magnesium, Mg (mg)	42	368
Phosphorus, P (mg)	112	204
Potassium, K (mg)	337	1324
Copper, Cu mg)	0.11	0.57
Iron, Fe (mg)	4	28.2

Zinc, Zn (mg)	0.6	2.4
Sodium, Na (mg)	9	220
Vitamin C (mg)	51.7	172
Thiamin (mg)	0.26	2.6
Niacin (mg)	2.22	8.2
Vitamin B-6 (mg)	1.2	2.4
Folate (µg)	40	540
Vitamin A, RAE (µg)	378	3639

However, and in contrast to some of the marketing materials being widely disseminated, the nutritional density of moringa leaf powder must be put into the perspective of what a reasonable and recommended serving size would deliver. Thus, **Table 2** denotes the estimated amount of nutrients delivered by a 10 g serving of moringa powder, and the percent of recommended intake it fulfills in children and women. Men and other adult age groups are fairly similar, and values of course range a bit more for different aged and gender infants, children, and teens.

Table 2. Estimated and averaged nutritional content in a 10 g serving of dried moringa powder and % or daily recommended value for women and young children (Witt, 2014; Food and Nutrition Board; Institute of Medicine; National Academies, 2011)

Nutrient	Amount in 10 g dried moringa powder	% of daily recommended value provided by 10 g of moringa	
		19-30 yr old women	1-3 yr old children
Protein (g)	2.91	6%	22%
Fiber (g)	4	16%	21%
Calcium, Ca (mg)	160.47	20%	32%
Magnesium, Mg (mg)	28.34	11%	44%
Potassium, K (mg)	174.5	4%	6%
Iron, Fe (mg)	2.82	35%	94%
Zinc, Zn (mg)	0.29	4%	12%
Vitamin C (mg)	17.2	29%	132%
Thiamin (mg)	0.26	29%	65%
Niacin (mg)	0.82	7%	16%
Vitamin B-6	0.24	22%	60%
Folate (µg)	54	17%	45%
Vitamin A, RAE (µg)	363.9	73%	173%
Riboflavin (mg)	0.53	35%	84%

The significant fraction of protein, iron, and beta-carotene (precursor to Vitamin A) requirements provided by a 10 g serving are reasonable justifications for the complementary use of moringa to address food insecurity and micronutrient deficiencies. Despite ongoing projects from a range of organizations little has been published in reputable scientific journals on the effectiveness of such interventions. To date, although anecdotal stories abound, only a few published human studies have adequately addressed nutritional outcomes of moringa consumption. For example:

- Severely malnourished children (aged 6 months–5 years) given 10 g daily of moringa powder, in addition to the regular nutrition intervention, gained more weight and recovered faster compared to the control group (Zongo *et al.*, 2013).
- School children consuming moringa-enriched snack foods with 3 g of moringa powder exhibited increased hemoglobin (an indicator for reducing iron-deficiency anemia), Vitamin A, and folic acid levels (Serafico *et al.*, 2017).

While the mineral content of moringa leaves is probably reasonably robust to variation in drying techniques, other molecules, such as vitamin A, are probably more fragile. Calcium and iron in moringa, for example, are present in compounds that, even if degraded by heat, will not significantly lower the contents of these elements. In contrast, the vitamin A molecule is very fragile and susceptible to damage both by heat and by ultraviolet radiation (Allwood and Plane 1984). For maximizing vitamin A content (Seshadri et al. 1997, Nambiar and Seshadri 2001, Serafico et al. 2017), as for programs that use moringa to combat childhood blindness, it is probably best to avoid both excessive heat and exposure to sunlight during drying and especially after the leaves have dried. Once the leaves have dried, the living cell mechanisms that repair or prevent damage are inactivated and delicate compounds such as vitamin likely begin to break down.

Significantly more research and robust clinical studies are needed to better understand the potential of moringa to address malnutrition, protein requirements, and micronutrient deficiencies including:

- Appropriate doses;
- Appeal of fortified foods;
- Bioavailability and digestibility of nutrients;
- Effects of cooking and/or combining in foods;
- Comparison to current and recommended malnutrition interventions; and
- Long-term benefits/risks

Regarding the potential of moringa products as a practical nutritional source we conclude:

- **Nutrient values of fresh leaves and dried moringa powders vary considerably.**
- **Moringa products should have their nutritional content determined on an individual product basis, with quality control maintained throughout the supply chain.**
- **Processes, particularly involving higher temperature such as drying, sterilization, and probably light exposure, will likely reduce vitamin and mineral content.**
- **Consumers should be aware of the recommended serving size to achieve the desired nutritional benefits—**most moringa capsules usually contain 400-500 mg of moringa powder, so **20 capsules (500 mg each) would need to be taken per day to reach a 10 g per day dose.** Gastrointestinal sequelae may well follow consumption of this quantity in at least some people. Usual capsule products recommend consuming 2-4 capsules per day.
- **Organizations already utilizing moringa to address nutritional need are strongly encouraged to monitor, evaluate and report on their effectiveness to provide transparent follow-up.**

Moringa as a low-cost, high-quality protein source

Large proportions of people living in the tropics suffer from protein malnutrition (de Onis *et al.*, 1993; Olson *et al.*, 2016; Semba, 2016). Protein is an essential part of a healthy diet and a basic requirement for proper growth, development, maintenance, and tissue repair. Protein malnutrition is particularly critical for children (UNICEF, 2019), because minimum threshold dietary protein levels are required for proper brain development, with protein intakes below these thresholds leading to permanent cognitive impairment (Ranade *et al.*, 2012). Additionally, there is a global growing need for additional sustainable sources of plant-based protein (Sabaté and Soret, 2014; Nadathur, Wanasundara and Scanlin, 2016). For several reasons, moringa is a useful tool in areas where other sources of protein, such as legumes and meats, are limited by time needed till harvest, cost, seasonality, and climatic pressures. With leaves present except during severe drought, and harvestable soon after germination, moringa provides a rapidly available and potentially year-round protein source. Fresh moringa leaves are approximately 9% protein while moringa dried leaf powder contains about 30% protein (Olson *et al.*, 2016; Chodur *et al.*, 2018). These levels can range slightly depending on cultivation and processing, although protein levels are not as variable as levels of vitamins, minerals, or phytochemicals. The cost of moringa as a protein source in temperate countries rivals or exceeds protein sources such as legumes, eggs, dairy, and even meat. **Further studies are needed and warranted to understand how the use of moringa can address protein malnutrition and meet the global need for novel plant-based protein sources.**

Moringa is also used as a protein source by individuals looking to supplement a healthy diet. The sale of moringa powders for use as a protein has been growing in US and international markets. However, to date, we are aware of no studies performed in humans to measure protein bioavailability and absorption, or to examine changes in metrics of muscle growth, exercise recovery, or performance.

Amino acids are the building blocks of proteins, and essential amino acids are those that our bodies cannot manufacture and that we need to obtain from the diet. What is special about moringa is that it contains these amino acids all in relatively high quantities (**Table 3**), making it a complete protein source. Claims regarding moringa's amino acid profile should therefore say "Moringa contains an exceptionally well-balanced profile of the essential amino acids."

Table 3. Required levels of essential amino acids for adults and children and reported levels of amino acids in dried leaf powder

Essential Amino Acid (mg/g of protein)	**Adult requirements** (WHO, 2007)	**Aged 2-5 requirements** (WHO, 2007)	**Reported values (± standard deviation) for dried leaf powder** (Witt, 2014)
Tryptophan	6	11	22 (±16)
Threonine	23	34	41 (±6)
Isoleucine	30	28	59 (±35)
Leucine	59	66	84 (±14)
Lysine	45	58	59 (±15)
Methionine+ Cystine	22	25	33 (±4)
Phenylalanine+ Tyrosine	38	63	95 (±13)
Valine	39	35	63 (±15)
Histidine	15	19	26 (±8)

During processing or cooking, it is possible that high temperatures could damage the protein in moringa leaves and potentially alter the structure of some amino acids (Finot, 1983; Kirk, 1984).

Thus, it is recommended to dry moringa leaves at moderate temperatures (<55°C). With regard to cooking, short cooking times are the safest bet. For fresh leaves, we find that very short times in boiling water—30-60 seconds-- are sufficient for achieving high palatability. In one study that compared the nutritional content of cooked versus raw or dried leaves, boiling did lower protein content (Abuye *et al.*, 2003). Thus, dried leaf powder can be added for a few minutes of cooking, such that the powder hydrates and becomes more palatable but, not to the detriment of protein quality.

In addition to temperature, some proteins are highly soluble in water. In cases in which moringa is boiled in water and the cooking water then discarded, some of the protein will inevitably be lost. However, if moringa is simply added to soups, sauces, or other preparations in which the cooking water is kept, then proteins entering solution will be preserved.

An important consideration for the use of moringa as a protein supplement is that for products purporting to provide dietary protein, dosage recommendations need to explicitly address the percentage of required protein that it aims to deliver. Simply sprinkling moringa powder in a sauce, putting it in chocolate, or a juice won't deliver a significant amount of protein to those seeking it for protein supplementation or augmentation purposes. The recommended dosage of a 10 g serving of moringa, noted in the nutrition section, would supply approximately 3 grams of protein. Recommendations for protein intake range from 0.8-1.5 g /kg body weight/day (with high-endurance trainers requiring up to 1.8 g/kg/day), depending of age, gender, health status and recommending authorities. According to the World Health Organization WHO, 2007), an average adult needs approximately 1 g of protein /kg body weight /day. Thus, using the WHO guidelines, a 70 kg adult needs some 70 g protein/day. **A 10 g serving would provide approximately 3 g of protein, or ~4.3% of the daily requirement for protein for a 70 kg person. A typical moringa leaf capsule, containing 500 mg of dried moringa leaf powder would provide approximately only 0.2% of the protein needed every day.** Furthermore, more studies are needed to understand the digestibility and bioavailability of protein from moringa. To date, no human studies, and few animal studies (Afuang, Siddhuraju and Becker, 2003; Reyes Sánchez, Spörndly and Ledin, 2006) have been conducted to determine protein bioavailability—limited and varied results from in vitro enzymatic studies reported a digestibility range for moringa protein from 56-89% (Ndong *et al.*, 2007; Elkhalifa, Ahmed and Adam, 2007). Thus, moringa protein is likely not fully available to the body, slightly reducing the amount of protein the body can use from recommended dosages.

Regarding the potential of moringa products as a practical protein source we conclude:

- **Moringa leaves and leaf powder may be a useful source of protein and essential amino acids.**
- **Care and high temperatures during processing or cooking may change the amount of protein in the final product. Treatments that minimize exposure to high temperatures and avoid discarding cooking water have the greatest likelihood of maximizing protein content.**
- **Consumers and policy experts should be aware of the dosage of moringa and how it may meet their personal protein needs.**
- **Further research is needed and warranted to better understand digestibility and benefits of moringa proteins in humans**
- **10 g of moringa powder provides ~4% of an average adult's daily protein requirements.**

Phytochemistry: Moringa's unique glucosinolates (GSs)/isothiocyanates (ITCs) and their potential health benefits

Moringa is, and should be, valued for its high protein, mineral, and vitamin content, but what makes moringa phytochemically and pharmacologically unique are compounds known as isothiocyanates (ITCs). ITCs are almost exclusively present in plants as their glucosinolate (GS) precursors. They are found primarily in the plant order Brassicales, the large alliance of plant families that includes the mustard (Brassicaceae), caper (Capparidaceae), and papaya (Caricaceae) families, as well as Moringaceae, the moringa family. ITCs in Moringaceae have unique structural, and therefore functional, characteristics not found in other families. Moringa ITCs rank among the most potent of phytochemicals, based on their cytoprotective and indirect antioxidant capacity, a property associated with stimulation of well-known antioxidant and detoxication pathways not just in the liver as commonly assumed, but throughout the human body (Fahey, 2017).

The level of ITCs in moringa leaves and/or moringa products can vary greatly, depending on how the leaves are dried and processed. As a result, producers of moringa products need to understand what ITCs are, how moringa produces them, and thereby create the conditions required for maximal ITC content in products to be able to obtain the maximum health benefits that moringa offers.

ITCs are formed after the cleavage of compounds known as GSs by an enzyme called myrosinase when plant cells are broken. ITCs are plant-defense compounds released as a chemical attack against herbivores. The GS to ITC conversion and its protective functions have been well described for broccoli (Fahey, Zhang and Talalay, 1997; Fahey and Talalay, 1999), and the biochemical pathway is the same in moringa (**Figure 1**, highlighting the conserved bioactive pharmacophore (active portion of the molecule; R–N=C=S). This plant defense system (dubbed the mustard oil bomb) is conserved across more than 120 GSs in plants, with about a half dozen GSs being found in moringa (Fahey, Zalcmann and Talalay, 2001; Fahey *et al.*, 2018).

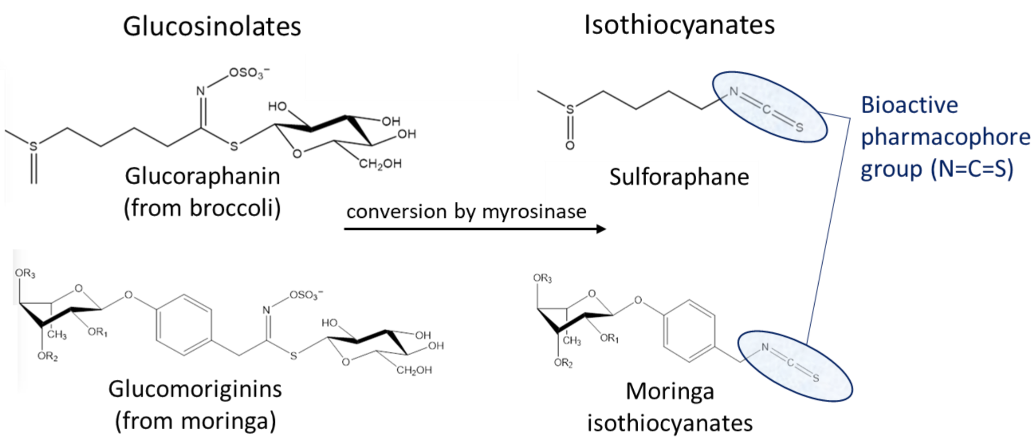

Figure 1. Glucosinolates (GSs) from broccoli and moringa converted to isothiocyanates (ITCs) in the presence of myrosinase.

ITCs give cabbage, radishes, mustard, horseradish, and moringa leaves their piquancy and sometimes sulfurous odors. Thus far, scientific research in cellular and animal studies have demonstrated a range of bioactivity from many of the 120 or so ITCs. Modes of action of the ITCs specifically, and in some cases exclusively found in moringa are highlighted in **Table 4**.

Table 4. Cellular and animal studies on activity of moringa ITCs.

Activity	Description	Reference
Anti-inflammatory	Reduced expression of inflammatory cytokines IL-1β, iNOS, TNFα and COX-2 and nitric oxide (NO) production	(Park *et al.*, 2011; Waterman *et al.*, 2014;

		Giacoppo, Rajan, Iori, *et al.*, 2017; Jaja-Chimedza *et al.*, 2017)
Blood sugar regulation	Reduced production of glucose and GP6 expression in liver cells	(Waterman *et al.*, 2015)
Indirect antioxidant	Stimulate the Nrf-2 Keap pathway involved in detoxification and cellular protection	(Tumer *et al.*, 2015; Fahey *et al.*, 2018)
Anti-cancer	Reduced NF-κB expression and myeloma growth in mice. Induction of apoptosis and Inhibition of prostate cell (PC-3) growth	(Brunelli *et al.*, 2010; Jaafaru *et al.*, 2018)
Cognitive health	Reduced motor deficits in mice with subacute Parkinson's disease	(Giacoppo, Rajan, de Nicola, *et al.*, 2017)
Digestive health	Alleviated ulcerative colitis symptoms and inflammation in mice	(Kim *et al.*, 2017)
Neurological and immune health	Reduced inflammatory and biomarkers of multiple sclerosis, amyotrophic lateral sclerosis (ALS), and decreased secondary damage in a model of spinal cord injury	(Galuppo *et al.*, 2014, Galuppo *et al.*, 2015; Giacoppo *et al.*, 2015)

While numerous additional studies conducted with moringa leaf powder and leaf extracts offer further support for moringa's anti-inflammatory, anti-cancer, and anti-diabetic properties, most have also been conducted in cellular or animal studies and often lack a description of the compounds present in the powder or extract. In addition to ITCs, moringa does contain a wide range of polyphenolic compounds, that may also have biological effects. However, without identifying and quantifying the potential bioactive compounds, it is difficult to translate such research to human applications. **Further studies are needed to validate traditional uses and pre-clinical support for the use of moringa as an agent with valuable medical properties.** A brief summary in **Table 5** demonstrates benefits, with particular focus on anti-diabetic properties proven through a few small clinical studies on moringa powder.
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Table 5. Summary of clinical studies and outcomes using moringa leaf powder

Study design	MO Treatment	Outcomes	Reference
Postmenopausal women (Randomized controlled trial); 30 females; age range 45–55 years	Leaf powder 7 g daily for 3 months	Significant increase in hemoglobin and circulating antioxidant agents.	(Kushwaha, Chawla and Kochhar, 2014)
Type 2 DM (Prospective randomized placebo-controlled study) 9 females, 7 males; age range 20–70 years	Leaf powder capsules 4 g daily before breakfast and dinner for 1 month.	Insulin not measured. No significant difference in HbA1C. No changes in BUN, creatinine, ALT or AST.	(Taweerutchana *et al.*, 2017)
DM (Prospective quasi experimental study) 48 females, 12 males; age range 19–65 years	Leaf powder capsules 500 mg capsule (3	significant reduction in HbA1c in MO-treated patients. Insulin not measured. Significant reduction in high specificity C-	(Mozo and Caole-Ang, 2015)

	times/day) for 12 weeks	Reactive Protein, in MO-treated patients.	
Type 2 DM and healthy subjects (Randomized controlled trial) 17 DM (9 females, 8 males); 10 healthy (6 females, 4 males)	Leaf powder 20 g once	Significant reduction in glycaemia up to 150 min after intake of 20 g of moringa leaf powder (268±18 mg/dL) compared with Con (296±17 mg/dL, $p < 0.001$).	(Leone *et al.*, 2018)
Type 2 DM controlled trial (36 men and 19 women); age range 30-60 years	Leaf powder 8g daily for 40 days	Significant reduction in fasting blood glucose and post prandial blood glucose levels, total cholesterol and low-density lipoprotein (LDL) compared to control group.	(Kumari, 2010)
Patients with serum total cholesterol > 180 mg/dl and/ or serum triglycerides > 140 mg/dl (27 men and 9 women); age range 41-60	Leaf powder 4.6 gr daily for 50 days	Significant decrease in total cholesterol and increase in high density lipoprotein. (HDL).	(Nambiar *et al.*, 2010)
Systematic analysis of 6 randomized controlled studies concluded moringa consumption and breastmilk supply; pooled 73 patients from all studies	Range of dosage and study duration	Increased breast milk supply in nursing mothers by day 7 and increased weight gain of moringa-breastfeed infants compared to controls.	(Raguindin, Dans and King, 2014)

Safety studies on moringa have not been conducted in humans, but from the above listed clinical trials, no serious adverse effects were reported. Thus far, safety has only been evaluated in animal studies, which suggests that **nutritional and therapeutic consumption of moringa leaves at doses below 2g/kg body weight** [would be below 140g for a 70 kg (154lb) person] appear to be safe (Vargas-Sánchez, Garay-Jaramillo and González-Reyes, 2019; Stohs and Hartman, 2015).

The aforementioned clinical studies are often limited in their descriptions of the phytochemicals and other compounds in the moringa powders being used. With most of them, it is unclear what the levels of ITCs and other bioactive compounds are, and what their contributions are to the outcomes observed (Fahey, 2017)**.**

While further studies are needed, at this time it can be suggested that moringa may have beneficial health effects due to a multitude of factors including high protein, fiber, nutrient and phytochemical content, primarily ITC content, but also potentially polyphenols content. **We recommend that for moringa products to have maximal health benefits ITCs should be considered a major and primary bioactive constituent.**

To maintain capacity to produce beneficial quantities of ITCs from GSs during processing of leaves, the myrosinase reaction needs to occur, and this can only happen under certain circumstances. Treatments that allow the myrosinase reaction to occur, in an aqueous medium and at moderate temperatures, will maximize ITC content. There are two primary ways that these have been implemented. The most common is to make an infusion of dried moringa leaf powder in water at room temperature (Waterman *et al.*, 2014; Chodur *et al.*, 2018; Attah *et al.*, 2019; Fahey *et al.*, 2018). These room-temperature infusions or "cold teas" are likely the easiest way of providing maximal doses of moringa ITCs. Some processing researchers have also explored crushing (by hand or blender) the leaves before consuming fresh or drying and grinding them to a powder; this allows the conversion to ITCs to occur; however caution on higher temperatures during drying of the crushed leaves should also be monitored as ITCs, while relatively stable, will begin to breakdown at temperatures >35°C (Waterman *et al.*, 2014). Thus, cold tea or maceration of fresh leaves are the preparation modes most likely to provide the highest yields of moringa dietary ITCs. Exposure of fresh moringa leaves to boiling water or drying at high temperatures will likely destroy the myrosinase enzyme and prevent the conversion of GLS to ITCs (Fahey *et al.*, 2019; Tetteh *et al.*, 2019).

Most commercialized moringa leaf products on the market have very low- to non-detectable levels of ITCs. This is because moringa leaflets are dried intact, and ground only after drying. This means that there is little opportunity for the myrosinase catalyzed conversion of GS into ITC to occur. However, given what is known from studies of other GS-bearing plants (Getahun and Chung, 1999; Fahey *et al.*, 2012), some conversion of GS into ITC will occur in the gut upon ingesting dried moringa leaves. Moreover, the proportion of GSs converted to ITCs is variable from person-to-person (Fahey *et al.*, 2012). Among other reasons, this is because it is the gut bacteria that are responsible for conversion of GSs to ITCs and preponderance of the myrosinase-producing bacteria varies greatly between individuals. However, given what is known currently, it seems best to assume that cold infusions are preferable to ingestion of dried moringa leaf powder as a source of dietary ITCs.

Regarding the potential of moringa and moringa ITCs to have beneficial effects in terms of disease prevention and treatment:

- **Current research on moringa ITCs has shown promising results in cellular and animal studies, but clinical studies are needed to further support their use in disease management or prevention.**
- **Clinical studies that have been conducted with moringa leaf powders have demonstrated promising potential for the use of moringa in disease management; however, limited information on the phytochemical profiles or ITC content has been conducted on powders used in such research.**
- **Thus far, all clinical studies have reported generally safe use (no adverse effects) of the products at the dosages delivered (~4-20 g powder/day). Safety studies in humans are yet to be conducted, but the urgency for doing them is not at all obvious, due to the long term and intensive use of this plant as a food.**
- **Consumers should be aware that while moringa leaves do have long-standing and wide-spread traditional use as a medicine, and while preliminary research supports many of these uses, more research is needed to confirm such medical uses. In the meantime, it is likely safe to add moringa into one's diet as a potential anti-inflammatory and preventative health agent.**
- **Moringa producers wishing to maximize the ITC content of their products should avoid temperatures >35°C, and make sure that there is opportunity for the myrosinase reaction to occur, for example by making cold infusions of (gently dried) moringa leaf powder for ~30 minutes.**

Conclusion: preparation techniques and appropriate statements about moringa benefits
In general, gentle drying, out of direct sunlight and at temperatures <35°C, should conserve all of the health benefits of moringa. **Table 6** summarizes examples of processing techniques that should result in high to low ITC and protein concentrations, to serve as a guide for moringa products that maximize the health benefits desired. **Table 7** provides statements that are factually correct given current knowledge that represent moringa's health benefits without exaggeration. These statements can be confidently used in promoting moringa's benefits. So, while much research remains to be carried out, even based on what is now known it is clear that moringa has much to offer in terms of nutrition and other health benefits. The present guide is intended to assist moringa producers in using the available information to maximize the benefits of moringa products and to promote moringa in a way that is aligned with what the plant truly offers.

Table 6. Preparation techniques and isothiocyanate (ITC) and protein concentrations

Benefit	Preparation technique	Concentration
Isothiocyanate (ITC) content	crushed fresh leaves	highest
	cold tea made from leaves dried <35°C	highest
	direct ingestion of leaves dried <40ºC, including moringa leaf capsules and any other product containing dry leaf powder	moderate
	any product with leaves dried >40ºC, including cold infusions	low
	hot tea made with leaves dried <40ºC	low
	cooked fresh leaves	low
Protein content	fresh, raw leaves	highest
	dried leaves, probably <55°C	highest
	fresh leaves, boiled <60 seconds	moderate
	any product cooked for a long time and at high temperature	low

Table 7. Statements regarding moringa's benefits and characteristics that are accurate given current knowledge

Benefit	Statement
Isothiocyanate (ITC) content	Moringa's mustard oils, compounds known as ITCs, are likely some of the most potent indirect antioxidants known. Indirect antioxidants are compounds that increase the body's ability to deal with offensive substances. In studies in the laboratory, moringa ITCs have been found to reduce inflammation, help regulate blood sugar levels, maintain moderate blood pressure, and to help prevent cancer
	In lab studies, moringa ITCs have been shown to be potent inducers of the phase 2 detoxification response, an essential part of the body's system for eliminating cancer-causing and other harmful compounds.
	Current evidence makes it seem likely that moringa's ITCs are among the most potent cancer-preventing natural compounds know. As a

	result, consuming properly prepared moringa promises benefits to people living anywhere in the world.
Protein content	Moringa leaves are high in protein, often around 30% by dry weight, which is comparable to powdered milk but at a fraction of the cost
Protein quality/ essential amino acid profile	Moringa contains an exceptionally well-balanced profile of the essential amino acids, the building blocks of proteins that our bodies cannot manufacture and that we need to obtain from the diet
Vitamin and mineral content	Carefully dried moringa can serve as a useful dietary source of vitamin A and iron.
Where moringa is from	Moringa is native to India, was domesticated thousands of years ago, and is now cultivated in all tropical countries.
The scientific name	The correct way to write the scientific name of moringa is *Moringa oleifera*
Potential social benefits of moringa	Moringa is fast growing and drought resistant, meaning that it can provide nutrition and powerful antioxidants to underserved dry tropical communities.

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