https://doi.org/10.17221/221/2022-CJFS

Potential of moringa (*Moringa oleifera*) leaf powder for functional food ingredients: A review

Lina Novi Ariani[1], Teti Estiasih[2], Wenny Bekti Sunarharum[2], Alfi Khatib[3]*

[1]Department of Food Science – doctoral program, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia
[2]Department of Food Science and Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia
[3]Kuliyyah of Pharmacy, International Islamic University of Malaysia, Kuantan, Malaysia

**Corresponding author: teties@ub.ac.id*

Citation: Ariani L.N., Estiasih T., Sunarharum W.B., Khatib A. (2023): Potential of moringa (*Moringa oleifera*) leaf powder for functional food ingredients: A review. Czech J. Food Sci., 41: 8–20.

Abstract: One of the efforts to produce functional foods is using ingredients containing health-beneficial bioactive compounds. Another way to produce functional foods is fermentation generating bioactive compounds or fortification with the bioactive compound extract. An ingredient historically believed to have benefits on health is moringa (*Moringa oleifera*) leaf powder. Moringa leaf powder is a valuable source of functional ingredients, including protein, vitamins, minerals, and phytonutrients such as carotenoids, tocopherols, polyphenols, flavonoids, alkaloids, and tannins. However, moringa is a plant that is distributed in various tropical countries in the world. Its quality depends on geographical differences, cultivars, environmental conditions, seasons, genotypes, and varieties. This article reviews the bioactive compounds of moringa leaf powder and the characteristics of moringa leaf powder extract. The effect of moringa leaf powder fortification on food product characteristics is also discussed. Moringa leaf powder possesses many pharmacological properties, such as anticancer, anti-inflammatory, hepatoprotective, cardioprotective, and antioxidant ones. The bioactivity of leaf extract is extracting solvent dependent. Therefore, fortification results in nutritional improvement and increasing health benefits of food products. However, the adverse effect is found in sensory. Thus properties, thus the moringa leaf powder fortification level usually is less than 10%. Changes in the functional properties of foods due to moringa leaf powder fortification have been studied to a limited extent. A low level of fortification might not affect the properties of food products. Therefore, moringa leaf powder is potentially used as a functional food ingredient. Some studies reported the toxicological effects of moringa leaf powder and the use of this ingredient, should be below the harmful doses.

Keywords: bioactive compounds; fortification; leaf extract; phytochemicals

Moringa oleifera is a miracle tree because of its numerous uses and adaptability; it contains nutrients, as well as secondary metabolites that have health benefits (Biswas et al. 2020; Zainab et al. 2020). In many developing countries, moringa is used as an ingredient in traditional medicine (Magaji et al. 2020). Moringa is a tropical plant that is rich in bioactive compounds. Moringa has pharmacological activities such as anticancer, antidiabetic (Chigurupati et al. 2021), anti-inflammatory (Cuellar-Nunez et al. 2021), and antioxidant

Supported by the Universitas Brawijaya, Project No. 975.9/UN10.C10/PN/2021.

https://doi.org/10.17221/221/2022-CJFS

(Mahmoud et al. 2022). The pharmacological properties of moringa are adequately related to the presence of its bioactive compounds (Ma et al. 2020). Moringa leaves are effective as an antidiabetic (Chigurupati et al. 2021). *In vitro* and *in vivo* studies confirmed various biological activities such as antioxidant (Mahmoud et al. 2022), anti-inflammatory (Cuellar-Nunez et al. 2021), antidiabetic (Mahmoud et al. 2022), anticancer (Kumar et al. 2023), cardioprotective (Aju et al. 2020), hypocholesterolemic (Chen et al. 2020), hepatoprotective (Asgari-Kafrani et al. 2020; Fotio et al. 2020), antihypertensive (Acuram 2019), and antibacterial (van den Berg and Kuipers 2022).

M. oleifera leaves were also found to contain substantial amounts of total phenol, protein, calcium, potassium, magnesium, iron, manganese and copper (Owon et al. 2021). *M. oleifera* leaves are also a good source of phytonutrients such as carotenoids, tocopherols and ascorbic acid (Mahato et al. 2021). These nutrients are known to scavenge free radicals when combined with a balanced diet and may have immunosuppressive effects. In addition to leaves, flowers and fruits, *M. oleifera* and significant amounts of carotenoids (Oyeyinka and Oyeyinka 2018).

Moringa leaf metabolite profiles are determined by genotype, cultivation method (Managa et al. 2021), agroclimatic (Rébufa et al. 2021), geographic, variety, environmental conditions, and season (Ma et al. 2020). The moringa leaf metabolite profile is influenced by cultivation method, harvest time and genotype (Managa et al. 2021). Moringa trees have high genetic diversity between genotypes (Ravi et al. 2022). There are three types of moringa based on the stem's colour, namely white, green, and red. Cholesterol reduction of hypercholesterolaemic rats fed red and white moringa leaf powder was different (Asrifah et al. 2017).

The food industry tends to develop high-fibre products to fulfil the demand for dietary fibre consumption, one of which is a fortification with moringa leaf powder. This powder is rich in fibre and has the potential to decrease postprandial glucose and insulin responses, maintain or reduce cholesterol and lipid levels, improve gastrointestinal function, immunomodulatory and antitumour effects, and prevent type 2 diabetes and cardiovascular diseases (Ortiz et al. 2020).

Fortifying bread dough with *M. oleifera* leaf powder has been reported to increase bread nutrition (Abu et al. 2013; Ogunsina et al. 2014; Azeez et al. 2022). Substitution of moringa leaf powder for flour in bread is probable to produce healthy functional bread to prevent hypercholesterolaemia. For example, the protein and crude fibre content of wheat flour enriched with 5% moringa leaf powder was confirmed to increase by about 54 and 56%, respectively (Abu et al. 2013). Another study on bread enriched with moringa leaf powder reported an increase in protein and crude fibre content by around 17 and 88% (Azeez et al. 2022). This fortification increases micro and macro nutrients (Bolarinwa et al. 2019).

This article aims to review the bioactive compounds of moringa leaf powder, their extraction, moringa leaf powder characteristics, and its potential as a functional food ingredient.

Moringa oleifera. *M. oleifera*, also known as a miracle tree, is a tree belonging to the family *Moringaceae* in the order *Brassicales*. The family *Moringaceae* has 13 species which are the most widely cultivated and studied (Singh et al. 2020). *M. oleifera* is native to the sub-Himalayan tract of Northern India, where it was first described as a medicinal plant. Later, it was distributed to Africa and Ethiopia. Today, because the tree can grow in a variety of conditions, it is also found in places as far away as Latin America and the Pacific Islands, among other countries (Avilés-Gaxiola et al. 2021). In Africa, *M. oleifera* has also been used to combat child malnutrition (Avilés-Gaxiola et al. 2021).

A moringa is a plant that proliferates, has a long life, flowers throughout the year, and can endure extreme heat conditions. This plant is native to tropical and subtropical regions of South Asia. This plant is commonly used for food and medicine in several parts of the world, mainly Asia and Africa. Most parts of the moringa tree have been exploited and used for food, including seeds, fruit, and leaves.

Some of the other benefits of the moringa plant include the bark of the moringa tree as a medicine for colon inflammation and its leaves as an anti-anaemic agent (White 2015). Moringa leaves and stems can be used as a lowering agent for high blood pressure and to treat diabetes (Hassan et al. 2021). In several developing countries, *M. oleifera* has been used to prevent protein energy malnutrition, especially among children at an initial age and pregnant females (Alain et al. 2016; Mune et al. 2016).

The moringa tree is declared a miracle tree or tree of life because it has beneficial effects on health, nutrition, water sanitation, and the environment. Moringa is characterised by diversity, is a valued tree in numerous places in the tropics and is used in numerous traditional medicines. Moringa is a versatile traditional medicinal plant due to the content of various bioactive compounds (Duranti et al. 2021). Moringa is a source of various nu-

https://doi.org/10.17221/221/2022-CJFS

Table 1. Physical characteristics of *Moringa oleifera* leaves based on colour

Characteristics	Stem colour		
	white	green	red
Leaf shape	imperfect fins	imperfect fins	imperfect fins
Size	small oval	small oval	small oval
Stem colour	white	green	red
Leaf blade colour	green	green	red
Leaf base	rounded	rounded	rounded
Leaf tip	blunt	blunt	blunt

trients such as protein, vitamins, minerals, and phytonutrients such as carotenoids, polyphenols, flavonoids, alkaloids, and tannins. This plant is used in certain areas experiencing nutritional problems as a nutritional supplement for infants and children (Mahato et al. 2022). The nutritional and bioactive content of moringa leaves is influenced by agroclimatic conditions, plant age, and harvest time (Rébufa et al. 2021). The moringa plant genotype also affects the bioactive content of moringa leaves (Managa et al. 2021). The physical characteristics of moringa leaves are shown in Table 1. Figure 1 shows the genotype of MO based on the colour of its stem.

***Moringa oleifera* leaf phytochemicals.** Phytochemicals are secondary metabolites present in plants, which accumulate in high concentrations but play a small role in plant growth and development. Humans have used phytochemicals as medicine to cure and protect against various diseases. About 80% of the population in developing countries use phytochemicals as traditional medicines for health. Based on their chemical structure, vegetable phytochemicals are divided into five classes, namely polyphenols, carotenoids, alkaloids, terpenoids, and compounds containing sulphur (Ma et al. 2020). The majority of these phytochemicals are also present in the moringa tree. The diverse biological activities and disease prevention potential of moringa are largely believed to be due to the presence of these phytochemicals (Ma et al. 2020).

Moringa is rich in polyphenols, including flavonoids, tannins and phenolic acids (Owon et al. 2021). Of the various parts of the moringa plant, the leaves contain the highest number of polyphenols. Moringa phenol content is strongly influenced by geography and environmental conditions of growth. Quercetin and kaempferol glycosides (glucoside, rutinoside and malonyl glucoside) are the most common flavonoids in various parts of the moringa tree except the roots and seeds. Other flavonols are e.g. myricetin, rutin, and epicatechin. Geographical variations in the concentration of flavonoids have also been observed among the different varieties. Phenolic acids are present in various parts of moringa including gallic acid, caffeic acid, chlorogen-

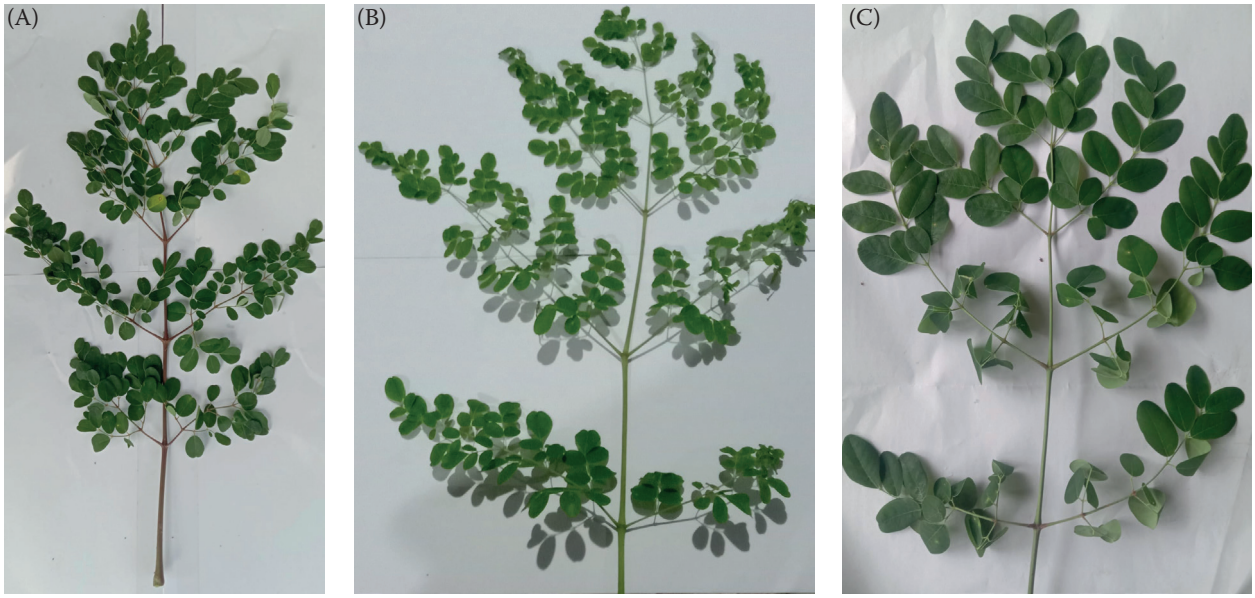

Figure 1. Moringa leaves with different stem colour: (A) red, (B) green, (C) white

https://doi.org/10.17221/221/2022-CJFS

ic acid, coumaric acid and ellagic acid. Moringa leaves also contain a significant number of tannins which are complex polyphenols that can bind to proteins. Tannin concentrations vary in different parts of the moringa tree, with the highest concentrations in the leaves (Ma et al. 2020).

By using UPLC-Q-TOF-MS (ultra-high performance liquid chromatography with quadrupole time-of-flight mass spectrometry), phenolic acid derivatives were identified, which included glucomoringin, 3-caffeoyl quinic acid, 3-p-coumaroylquinic acid, 4-caffeoyl quinic acid, acetyl 4-(a-L-rhamnopyranosyloxy) benzyl glucosinolate, apigenin C-diglycoside, 4-p-coumaroylquinic acid, 4-feruloylquinic acid, quercetin-3-O-rutinoside, apigenin-C-hexose, quercetin-7-hexose, quercetin-3-hexose, quercetin-3-acetyl-hexose, kaempferol-3-O-rutinoside, luteolin-7-O-glucoside, kaempferol-3-hexose, cyanidin hexose isorhamnetin-hexose, kaempferol acetyl hexose (Teclegeorgish et al. 2021), rutin, kaempferol acetyl glycoside, quercetin-3-glucoside, quercetin-3-acetyl-glucoside and kaempferol 3-glucoside were identified by LC-ESI-MS (liquid chromatography electrospray ionization tandem mass spectrometry) as reported by Hamed et al. (2019). The results of the identification of phytochemical compounds from the ethanol extract of moringa leaves with GC MS (gas chromatography–mass spectrometry) showed the presence of 9, 12, 15-octadecatrienoic acid (39.66%), hexadecenoic acid (16.71%), palmitic acid, ethyl ester (14.70%), and phytol (9.81%) as the largest component (Adeyemi et al. 2021). Their phenolic compounds in *M. oleifera* leaves and their health benefits are shown in Table 2.

***Moringa oleifera* leaf extract.** Hassan et al. (2021) described that phenolic compounds from moringa leaves could be extracted using a combination of water and organic solvents (methanol, ethanol, ethyl

Table 2. Phenolic compounds in *Moringa oleifera* leaves and their health benefits

Constituents	Postulated function	Model used	Disease protection	Reference
Polyphenols	increases antioxidant enzymes and inhibit the expression of inflammatory mediators of tumour necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6)	Wistar rats	diabetes/ nephrotoxic	Omodanisi et al. 2017
	increases antioxidant enzymes and decreases nitric oxide levels	rats	liver disorders	El-Hadary and Ramadan 2019
	decreases oxidative stress damage and brain infarct volume	Wistar rats	cerebral ischemia	Kirisattayakul et al. 2013
	represses pancreatic α-amylase, α-glucosidase, and cholesterol esterase	*in vitro*	diabetes disease	Adisakwattana and Chanathong 2011
Polyphenols: catechin, epicatechin, ferulic acid, ellagic acid, and myricetin	increases antioxidant enzymes, suppresses ROS (reactive oxygen species) formation and scavenges free radicals	rats	kidney protection	Mansour et al. 2014
Polyphenols: gallic acid, caffeic acid, and quercetin	scavenges free radicals, promotes antioxidant activity and reduces the expression of liver disease markers	Wistar rats	non-alcoholic fatty liver disease	Asgari-Kafrani et al. 2020
Phenolic acid: chlorogenic acid	reduces the expression of differentiation-68 and sterol regulatory element binding protein-1c	guinea pigs	non-alcoholic fatty liver disease	Vergara-Jimenez et al. 2017
Flavonoids	prevents the increased level of interleukin 17 (IL-17) via the NFκB (nuclear factor kappa-light-chain-enhancer) pathway, supports a decrease of the level of soluble vascular endothelial growth factor receptor 1 (sFlt-1), and angiogenesis	Wistar rats	antihypertensive	Batmomolin et al. 2020

https://doi.org/10.17221/221/2022-CJFS

Table 2. To be continued

Constituents	Postulated function	Model used	Disease protection	Reference
Flavonoids	scavenges free radicals inhibits the GABAergic system	rats	Alzheimer's disease	Ganguly et al. 2010
	inhibits the GABAergic system	mice	epilepsy and anxiety	Ingale and Gandhi 2016
	influences noradrenergic-serotonergic agents through the neurotransmission pathway	mice	depressant	Aggarwal et al. 2020
	decreases oxidative stress and improves cholinergic function by suppressing acetylcholinesterase (AChE) activity	rats	dementia	Sutalangka et al. 2013
	alter the brain's monoamine level and electrical activity	rats	Alzheimer's disease	Ganguly and Guha 2008
	suppress the activity of the crucial enzymes associated with hypertension, including angiotensin-1 converting enzyme (ACE), acetylcholinesterase (AChE), arginase, and phosphodiesterase-5 (PDE5)	rats	antihypertensive	Adefegha et al. 2019
Flavonoids: quercetin	stimulates endogenous antioxidant enzymes and scavenges free radicals	Wistar rats	cerebellar disorders	Omotoso et al. 2018
Quercetin	prevents fat accumulation and increases lipolysis by stimulating the AMPK (5' adenosine monophosphate-activated protein kinase) signalling pathway	*in vitro* and mice	antiobesity	Xie et al. 2018
	modulates the expression of gene glycogen synthase and stimulates insulin release	rats	antidiabetes	Abd Eldaim et al. 2017
Flavonoids: isoquercetin	reduces the blood glucose level by inhibiting α-amylase and α-glucosidase activities	Wistar rats	antidiabetes	Jimoh 2018
Kaempferol	regulates activities of major enzymes causing obesity, including HMG-CoA (3-hydroxy-3-methylglutaryl coenzyme A), FAS (fatty acid synthase), and increasing the mRNA expression of PPARα, MC4R, enhancing fatty acid β-oxidation and reducing fat accumulation	rats	antiobesity	Ezzat et al. 2020
Flavonoids: kaempferol, apigenin quercetin	decreases pro-inflammatory cytokines such as TNF-α, IL-1β, and IL-6, and increases anti-inflammatory (IL-10) and antioxidant enzymes, such as SOD (superoxide dismutase), CAT (catalase), and GSH-Px (glutathione sulfhydril peroxidase)	mice	kidney protection	Karthivashan et al. 2016

https://doi.org/10.17221/221/2022-CJFS

acetate, and acetone). Their profile of the bioactive compounds of moringa leaf extract is shown in Table 3.

The health benefits of moringa leaves have been widely studied and have an extended history as traditional medicine in many countries (Biswas et al. 2020). Moringa has a wide range of pharmacological activities, antimicrobial, hypotensive, hypoglycaemic, immunomodulatory and anti-inflammatory. Moringa leaves have the potential as a source of natural antioxidants such as flavonoids, quercetin, β-sitosterol and zeatin. Moringa roots and leaves have antispasmodic activity. Hot water infusion of leaves, seeds, flowers, roots, and bark exhibits anti-inflammatory activity. Various parts of the tree, such as leaves, roots, seeds, pods, fruits, and flowers are used to treat common illnesses such as skin infections, anaemia, asthma, coughs, diarrhoea, swelling, headaches, hysteria, cholera, respiratory disorders, scurvy, diabetes, sickness, throat and chest tightness (Padayachee and Baijnath 2020). The moringa tree trunk methanol extract showed the ability to repair glycerol-induced rat kidney damage (Apedapo et al. 2020). The ethanol extract of moringa leaves shows the ability to inhibit neurotoxins from venom so that it acts as an antivenom and prevents bleeding (Adeyemi et al. 2021). Moringa leaf bioactive compounds improve physical and metabolic functioning related to muscles, they act as antitumor and cytotoxic (García-Beltrán et al. 2020), antiasthma, anticancer, anti-inflammatory, hepatoprotective, and cardioprotective agents (Hassan et al. 2021). The bioactive compounds of moringa leaves, and their potential as antioxidants, anticancer, antiasthma, antidiabetic,

Table 3. Bioactive compounds in *Moringa oleifera* leaf extract

Extract	Bioactive compounds	Reference
Infusion	alkaloids, terpenoids, saponins, plobatin, and cardiac glycosides, but no flavonoids, steroids, and anthraquinones were detected	Akpor et al. 2021
	phytosterol, steroids, and flavonoids	Barodia et al. 2022
Ethanol	14 types of phenolic compounds were identified in ethanol extract of moringa leaves	Chigurupati et al. 2021
Methanol	phenolic compounds decrease atherogenic index, cholesterol, LDL (low density lipoprotein), triglyceride, and VLDL (very low density lipoprotein) blood serum levels and increase LDL in hyperlipidaemic rats	Jain and Patel 2010
	polyphenol compounds and flavonoids	Duranti et al. 2021
Ether	gallic tannins, catechol tannins, saponins, alkaloids and anthraquinones were detected in low concentrations, steroids and triterpenoids were detected in high concentrations, coumarins were not detected	Kasolo et al. 2010
Ethanol	*i*) gallic tannins and saponins were detected in low concentrations *ii*) steroids, triterpenoids, flavonoids and anthraquinones were detected in moderate concentrations *iii*) catechol, coumarin and alkaloid were not detected	Kasolo et al. 2010
Water	*i*) gallic tannins, catechol tannins, steroids and triterpenoids, flavonoids, saponins and alkaloids were detected in moderate concentrations *ii*) anthraquinone was detected in high concentration, coumarin was not detected	Kasolo et al. 2010
Ethanol and water	*i*) contains phenolic compounds, flavonoids, saponins, condensed tannins, and cyanogenic glycosides *ii*) phenol from moringa leaves can be extracted using a combination of water and organic solvents (methanol, ethanol, ethyl acetate, and acetone)	García-Beltrán et al. 2020
	the same phenolic and flavonoid compounds but different concentrations	Kerdsomboon et al. 2021

https://doi.org/10.17221/221/2022-CJFS

anti-inflammatory, hepatoprotective, and cardioprotective agents are shown in Table 4.

***Moringa oleifera* leaf powder as a food ingredient.** *M. oleifera* has great potential to use in biscuits, cakes, brownies, meats, juices and sandwiches. These uses are interesting, as the product's nutritional value and health function increase. Still, the concentration should not be high because of the harmful effect on the organoleptic properties (Milla et al. 2021). Cattan et al. (2022) described that moringa leaf powder has a protein content of 27.4%, oil of 5.6%, and dietary fibre of 23.7% so moringa leaf powder has the potential to be used as a food ingredient. Moringa leaf protein extract has good emulsification and solubility ability. Giuberti et al. (2021) reviewed various studies showing that moringa leaves have the potential to be added to numerous products and cause improvements in protein, lipid/fat, minerals, fibre, and antioxidant activity. The effect of adding moringa leaf powder on the anticholesterol activity of the bread has been reported (Aly et al. 2022). Food products that are said to have been fortified are biscuits that can prevent anaemia in pregnant women with an indicator of an increase in haemoglobin due to iron and zinc intake with biscuits containing moringa leaf powder (Páramo-Calderón et al. 2019; Manggul et al. 2021), tortillas, so it has a higher antioxidant activity (Páramo-Calderón et al. 2019). Adding moringa flour to tortillas increases the total phenolic content, oleic acid, palmitic acid, protein, lipids significantly, and snacks with better nutritional quality are produced (Zungu et al. 2020).

The study by Bolarinwa et al. (2019) showed that bread fortification with moringa leaf powder increased protein (8.55–13.46%), ash (0.63–1.76%), fat (7.31–15.75%) and fibre (0.08–0.62%) with a decrease in water and carbohydrate content of 22.90–20.01% and mineral content (P, K, Ca, Fe) increased through 46.73–57.68% compared to the bread without Moringa leaf powder fortification. Sensory analysis revealed that adding 5% moringa leaf powder did not show any differences from the unfortified bread. Moringa is a fortificant for amala, ogi, bread, biscuits, yoghurt, cheese, and soups (Oyeyinka and Oyeyinka 2018). The fortification of bread with moringa dried leaves increased protein, ash, fat, and fibre but moisture content decreased (Aly et al. 2022). Bread fortification with moringa leaf powder showed the same physical properties of volume and skin colour as the control at a 5% fortification level. Colour is an important sensory attribute. The moringa leaf protein concentrate is a potential ingredient for bakery products and is one of the ways to remove the adverse effect of chlorophyll on fortified foods. Lower sensory properties due to moringa leaf powder fortification are related to different breadcrumbs and crust colour and lower volume than unfortified bread (Oyeyinka and Oyeyinka 2018). The fortified bread revealed improvement in the blood lipid profile and, as well as liver and kidney functions.

Table 4. *Moringa oleifera* leaf bioactive compounds and their potential

Bioactive compounds	Application	Reference
Moringa leaf phenolic compounds	potential as an antioxidant and antidiabetic agent	Chigurupati et al. 2021
Phenolic compounds	antiasthma, anticancer, anti-inflammatory, hepatoprotective and cardioprotective effects	Hassan et al. 2021
Moringa leaf phenolic compounds	moringa leaf bioactive compounds improve physical and metabolic performance related to muscle, antitumor and cytotoxic effects	García-Beltrán et al. 2020
Moringa leaf ethanol extract	the ability to inhibit neurotoxin from venom so that it acts as an antivenom, besides also playing a role in preventing bleeding	Adeyemi et al. 2021
Moringa leaf water extract	protects mice from hepatotoxicity because it acts as an antioxidant and anti-inflammatory agent to treat liver disease	Fotio et al. 2020
	potential as an immunostimulant, cytotoxic, antitumor, antibacterial and antioxidant effects	García-Beltran et al. 2020
	potential to repair damaged brain tissue	García-Beltran et al. 2020
	antioxidant and anti-inflammatory potential to treat liver disease	Fotio et al. 2020

https://doi.org/10.17221/221/2022-CJFS

The use of moringa leaf powder in bakery products and its effect on product quality are shown in Table 5.

Oyeyinka and Oyeyinka (2018) studied the sweet potato flour-based amala fortification with moringa leaf powder at numerous concentrations of 2.5, 5, 7.5, and 10%. The addition of 10% moringa leaf powder was found to increase the protein content by about 48%. Similarly, fortified amala's calcium, magnesium, potassium, sodium, and iron content increased after fortification. However, the sensory perception of amala colour enriched with 10% moringa leaf powder decreased.

Moringa leaves are high in fibre and low in fat. It is very important to use in the formulation of low-calorie food products. The combination of moringa leaf powder will increase the nutritional value and the contribution of macro and micronutrients, including protein, fibre, vitamins, and minerals (Milla et al. 2021). In addition, besides having nutritional purposes, fortification with moringa leaf powder also provides other benefits such as increased digestibility, dough stability, antioxidant capacity, and preservation (Oyeyinka and Oyeyinka 2018). Therefore, it can be said that moringa leaf powder can be used as a functional ingredient in bakery products.

The safety profile of *Moringa oleifera* leaf extract and powder. Toxicity studies on *M. oleifera* are scarce (Asare et al. 2012). The international regulation of human health-related products requires that the toxicity of nutraceutical products should be tested to ensure their safety. The key to ensuring safety is toxicity testing on both *in vitro* and *in vivo* models (Robinson et al. 2008). Asare et al. (2012) evaluated the possible acute toxicity of an aqueous extract of moringa leaf powder. That study showed that levels ≥ 20 mg·mL^{-1} of *M. oleifera* aqueous extract were cytotoxic. The LD50 (LD – lethal dose) of *M. oleifera* water extract was previously determined to be ≥ 3 000 mg·kg^{-1} b.wt. (body weight). The study of Monera et al. (2008) indicated that the lower concentration (6 mg·mL^{-1}) of aqueous leaf extract was cytotoxic to HepG2 (human hepatocellular carcinoma cells). Another study by Pavathy and Umamaheshwari (2007) showed much lower cytotoxicity at a concentration of 0.6 mg·mL^{-1} of aqueous leaf extract. The differences in toxicity levels might be af-

Table 5. Moringa leaf powder effects on bakery products

Food products	Fortification level (%)	Result	Reference
Cookies	2.5, 5, 7.5	wheat flour bread fortified with moringa leaf powder showed an increase in nutritional values (protein, fibre, and minerals)	Olson and Fahey 2011
	10, 20, 30, 50	bread with 10% and cake with 20% of moringa leaf powder had higher protein, iron and calcium	Timilsena et al. 2017
	5, 10	the best formula was fortification with moringa leaf powder level of 10%	Martín et al. 2013
	0, 10, 20, 30, 50	the best formula was fortification with moringa leaf powder level of 10%	Nwakalor 2014
Brownies (cake)	0, 5, 10	improved physicochemical characteristics and increased ash content, and lowered lipid content compared to the control	Castro-López et al. 2017
Bread	5, 10, 15, 20	Fortification of bread increased the nutrition of protein, ash and minerals but the carbohydrate content decreased. Acceptability decreased by increasing fortification. The best acceptability was 5% and 10% fortification level.	Shah et al. 2015
Rice crackers	1, 2, 5	fortification with 1% and 2% resulted in higher carotene, vitamin C and calcium compared to the control; the sensory score was comparable with the power even at the end of the storage test	Manaois and Hashmi 2013
Bread	1, 2, 3, 4, 5	nutritional composition of protein, ash, fibre, minerals, and carotene was enhanced; acceptability decreased when the fortification level increased; fortification affected bread's physical and sensory attributes	Abu et al. 2013

https://doi.org/10.17221/221/2022-CJFS

fected by the method of extraction and purification, toxicity assays, types of cells used, and different characteristics of the leaves due to the geographical locations and soil constituents (Asare et al. 2012). The most important finding of the study of Asare et al. (2012) was that *M. oleifera* leaves were genotoxic at a high dose (3 000 mg·kg^{-1} b.wt.), and the intake is safe at levels of ≤ 1 000 mg·kg^{-1} b.wt.

Sagrera et al. (2021) presented a case of a rarely described adverse action of moringa that was cutaneous toxicity in a patient who consumed moringa powder. A biopsy showed necrotic keratinocytes with inflammatory infiltrate. The harmful effect of moringa powder might be caused by its components, interaction with drugs, or contaminants. The exact mechanism of this cutaneous toxicity was still unknown because most studies reveal anti-inflammatory properties.

The acute toxicity assay study of de Barros et al. (2022) used mice and oral administration in a single dose in 2 000 and 5 000 mg·kg^{-1} of infusion or powder, and for 28 days, the assay with oral administration of infusion or powder at the doses of 250, 500 and 1 000 mg·kg^{-1}. That study showed that alterations in behaviour were observed in the first 2 h after 5 000 mg·kg^{-1} dose administration in both treatments. No toxicity was observed in the infusion treatment during 28-day administration. However, 500 and 1 000 mg·kg^{-1} powder dose promoted kidney and liver damage. At a dose of 2 000 mg·kg^{-1}, no genotoxicity and mutagenicity were observed (de Barros et al. 2022). Previously, the study of Awodele et al. (2012) showed that the aqueous moringa leaf extract had the estimation of LD50 to be 1 585 mg·kg^{-1}. The extract did not exhibit a significant difference from the control in biochemical and haematological parameters, and sperm quality as well.

So far, there have been no studies that reported the mutagenicity and carcinogenicity of moringa leaf powder since this ingredient is claimed scientifically as anticancer in many studies (Chigurupati et al. 2021; Hassan et al. 2021; Kumar et al. 2023). The beneficial effect of moringa leaf powder and its use as an ingredient for functional foods should consider the toxicological effects, and the uses should be below the reported harmful doses.

CONCLUSION

Moringa leaf powder is a valuable source of functional ingredients for the food industry and contains a large amount of protein, vitamins, minerals, and phytonutrients that are efficacious for health. The nutritional and bioactive content of moringa leaves is influenced by agro-climate, plant age, harvest time and genotype. Moringa leaf powder contributes significantly to the intake of some essential nutrients and health-promoting human phytochemicals. It possesses many pharmacological properties such as anticancer, anti-inflammatory, hepatoprotective, cardioprotective and antioxidant ones. The use of moringa leaf powder as a functional food ingredient is widely popular and enhances the improvements in nutritional quality aspects, its health-promoting phytochemicals in humans could be used as a useful additive in food products.

Acknowledgement. The authors would like to thank Universitas Brawijaya for funding the *Moringa oleifera* leaf powder research about the *M. oleifera* leaf powder for functional food ingredients through Hibah Penelitian Unggulan 2022.

REFERENCES

Abd Eldaim M.A., Shaban Abd Elrasoul A., Abd Elaziz S.A. (2017): An aqueous extract from *Moringa oleifera* leaves ameliorates hepatotoxicity in alloxan-induced diabetic rats. Biochemistry and Cell Biology, 95: 524–530.

Abu O., J., Gernah D.I., Sengev A.I., Abu J.O., Gernah D.I. (2013): Effect of *Moringa oleifera* leaf powder supplementation on some quality characteristics of wheat bread. Food and Nutrition Sciences, 4: 270–275.

Acuram L.K., Christine L., Hernandez C. (2019): Antihypertensive effect of *Moringa oleifera* Lam. Cogent Biology, 5: 1.

Adefegha S.A., Oboh G., Iyoha A.E., Oyagbemi A.A. (2019): Comparative effects of horseradish (*Moringa oleifera*) leaves and seeds on blood pressure and crucial enzymes relevant to hypertension in rat. PharmaNutrition, 9: 100152.

Adedapo A.A., Etim U., Falayi O.O., Ogunpolu B.S., Omobowale T.O., Oyagbemi A.A., Oguntibeju O.O. (2020): Methanol stem extract of *Moringa oleifera* mitigates glycerol-induced acute kidney damage in rats through modulation of KIM-1 and NF-kB signaling pathways. Scientific African, 9: e00493.

Adeyemi S., Larayetan R., Onoja A.D., Ajayi A., Yahaya A., Ogunmola O.O., Adeyi A.O., Chijioke O. (2021): Antihemorrhagic activity of ethanol extract of *Moringa oleifera* leaf on envenomed albino rats. Scientific African, 12: e00742.

Aggarwal V., Tuli H.S., Tania M., Srivastava S., Ritzer E.E., Pandey A., Aggarwal D., Barwal T.S., Jain A., Kaur G., Sak K., Varol M., Bishayee A. (2020): Molecular mechanisms of action of epigallocatechin gallate in cancer: Recent trends and advancement. Seminars in Cancer Biology, 80: 256–275.

https://doi.org/10.17221/221/2022-CJFS

Aju B.Y., Rajalakshmi R., Mini S. (2020): Protective role of *Moringa oleifera* leaf extract on cardiac antioxidant status and lipid peroxidation in streptozotocin induced diabetic rats. Heliyon, 6: e02935.

Akpor O.B., Ndakotsu J., Evbuomwan I.O., Olaolu T.D., Osemwegie O.O. (2021): Bacterial growth inhibition and antioxidant potentials of leaves infusions of (*Moringa oleifera)*, locust beans (Parkia biglobosa) and bitter leaves (*Vernonia amygladina*). Scientific African, 14: e01001.

Alain M., Mune M., Bernard C., Bassogog B., Nyobe C., René S., Minka R., Mune Mune M.A., Bakwo Bassogog C.B., Nyobe E.C., Minka S.R. (2016): Physicochemical and functional properties of *Moringa oleifera* seed and leaf flour. Cogent Food & Agriculture, 2: 1220352.

Aly A.A., Zaky E.A., Khatab N.R., Hameed A.M., Kadasah S. (2022): The Biological and chemical ameliorative effects of bread substituted with dried moringa leaves. Arabian Journal of Chemistry, 15: 103875.

Asare G.A., Gyan B., Bugyei K., Adjei S Mahama R., Addo P., Otu-Nyarko L., Wiredu E.K., Nyarko A. (2012): Toxicity potentials of the nutraceutical *Moringa oleifera* at supra-supplementation levels. Journal of Ethnopharmacology, 139: 265–272.

Asgari-Kafrani A., Fazilati M., Nazem H. (2020): Hepatoprotective and antioxidant activity of aerial parts of *Moringa oleifera* in prevention of non-alcoholic fatty liver disease in Wistar rats. South African Journal of Botany, 129: 82–90.

Asrifah I., Estiasih T., Sujuti H. (2017): Potential hypocholesterolemic activity of flour from leaves of Moringa (*Moringa oleifera* L.). Malaysian Journal of Nutrition, 23: 449–460.

Avilés-Gaxiola S., León-Félix J., Jiménez-Nevárez Y.B., Angulo-Escalante M.A., Ramos-Payán R., Colado-Velázquez J., Heredia J.B. (2021): Antioxidant and antiinflammatory properties of novel peptides from *Moringa oleifer*a Lam. leaves. South African Journal of Botany, 141: 466–473.

Awodele O., Oreagbaa I.A., Odoma S., Da Silva J.A.T., Osunkalu V.O. (2012): Toxicological evaluation of the aqueous leaf extract of *Moringa oleifera* Lam. (*Moringaceae).* Journal of Ethnopharmacology, 139: 330–336.

Azeez S.O., Chinma C.E., Bassey S.O., Eze U.R., Makinde A.F., Sakariyah A.A., Okubanjo S.S., Danbaba N., Adebo O.A. (2022): Impact of germination alone or in combination with solid-state fermentation on the physicochemical, antioxidant, *in vitro* digestibility, functional and thermal properties of brown finger millet flours. Lebensmittel-Wissenschaft + Technologie, 154: 112734.

Barodia K., Cheruku S.P., Kanwal A., Menon A., Rajeevan R., Rukade A., Kumar Shenoy R.U., Prabhu C., Sharma V., Divya K.P., Sumalatha S., Nayak Y., Kumar N. (2022): Effect of *Moringa oleifera* leaves extract on exercise and dexamethasone-induced functional impairment in skeletal muscles. Journal of Ayurveda and Integrative Medicine, 13: 100503.

Batmomolin A., Ahsan A., Wayan I., Wiyasa A., Santoso S. (2020): Ethanolic extract of *Moringa oleifera* leaves improve inflammation, angiogenesis, and blood pressure in rat model of preeclampsia. Journal of Applied Pharmaceutical Science, 10: 52–057.

Biswas D., Nandy S., Mukherjee A., Pandey D.K., Dey A. (2020): Moringa oleifera Lam. and derived phytochemicals as promising antiviral agents: A review. *S*outh African Journal of Botany, 129: 272–282.

Bolarinwa I.F., Aruna T.E., Raji A.O. (2019): Nutritive value and acceptability of bread fortified with moringa seed powder. Journal of the Saudi Society of Agricultural Sciences, 18: 195–200.

Castro-López C., Ventura-Sobrevilla J.M., González-Hernández M.D., Rojas R., Ascacio-Valdés J.A., Aguilar C.N., Martínez-Ávila G.C.G. (2017): Impact of extraction techniques on antioxidant capacities and phytochemical composition of polyphenol-rich extracts. Food Chemistry, 237: 1139–1148.

Cattan Y., Patil D., Vaknin Y., Rytwo G., Lakemond C., Benjamin O. (2022): Characterization of *Moringa oleifera* leaves and seed protein extract functionality in emulsion model system. Innovative Food Science & Emerging Technologies, 75: 102903.

Chen G.L., Yong-Bing Xu Y.B., Wu J.L., Li N., Guo M.G. (2020): Hypoglycemic and hypolipidemic effects of *Moringa oleifera* leaves and their functional chemical constituents. Food Chemistry, 333: 127478.

Chigurupati S., Al-Murikhy A., Almahmoud S.A., Almoshari Y., Saber Ahmed A., Vijayabalan S., Das S., Raj Palanimuthu V. (2021): Molecular docking of phenolic compounds and screening of antioxidant and antidiabetic potential of *Moringa oleifera* ethanolic leaves extract from Qassim region, Saudi Arabia. Saudi Journal of Biological Sciences, 29: 854–859.

Cuellar-Nunez M.L., de Mejia E.G., Pina G.L. (2021): *Moringa oleifera* leaves alleviated inflammation through down-regulation of IL-2, IL-6, and TNF-α in a colitis-associated colorectal cancer model. Food Research International, 144: 110318.

De Barros M.C., Silva A.G.B., Souza T.G.D.S., Chagas C.A., Machado J.C.B., Ferreira M.R.A., Soares L.A.L., Xavier V.L., De Araújo L.C.C., Borba E.F.O., Da Silva T.G., Alves R.R.V., Coelho L.C.B.B., De Oliveira A.M., Napoleão T.H., Paiva P.M.G. (2022): Evaluation of acute toxicity, 28-day repeated dose toxicity, and genotoxicity of *Moringa oleifera* leaves infusion and powder. Journal of Ethnopharmacology, 296: 115504.

https://doi.org/10.17221/221/2022-CJFS

Duranti G., Maldini M., Crognale D., Sabatini S., Corana F., Horner K., Ceci R. (2021): *Moringa oleifera* leaves extract influences oxidative metabolism in C2C12 myotubes through SIRT1-PPARα pathway. Phytomedicine Plus, 1: 100014.

El-Hadary A.E., Ramadan M.F. (2019): Phenolic profiles, antihyperglycemic, antihyperlipidemic, and antioxidant properties of pomegranate (*Punica granatum*) peel extract. Journal of Food Biochemistry, 43: e12803.

Ezzat S.M., El Bishbishy M.H., Aborehab N.M., Salama M.M., Hasheesh A., Motaal A.A., Rashad H., Metwally F.M. (2020): Upregulation of MC4R and PPAR-α expression mediates the antiobesity activity of *Moringa oleifera* Lam. in high-fat diet-induced obesity in rats. Journal of Ethnopharmacology, 251: 112541.

Fotio A.L., Nguepi M.S.D., Tonfack L.B., Temdie R.J.G., Nguelefack T.B. (2020): Acetaminophen induces liver injury and depletes glutathione in mice brain: Prevention by *Moringa oleifera* extract. South African Journal of Botany, 129: 317–323.

Ganguly R., Guha D. (2008): Alteration of brain monoamines & EEG wave pattern in rat model of Alzheimer's disease & protection by *Moringa oleifera*. Indian Journal of Medical Research, 128: 744–751.

García-Beltrán J.M., Mansour A.T., Alsaqufi A.S., Ali H.M., Esteban M.Á. (2020): Effects of aqueous and ethanolic leaves extracts from drumstick tree (*Moringa oleifera*) on gilthead seabream (*Sparus aurata* L.) leucocytes, and their cytotoxic, antitumor, bactericidal and antioxidant activities. Fish and Shellfish Immunology, 106: 44–55.

Giuberti G., Rocchetti G., Montesano D., Lucini L. (2021): The potential of *Moringa oleifera* in food formulation: a promising source of functional compounds with health-promoting properties. Current Opinion in Food Science, 42: 257–269.

Hamed Y.S., Abdin M., Akhtar H.M.S., Chen D., Wan P., Chen G., Zheng X. (2019): Extraction, purification by macrospores resin and *in vitro* antioxidant activity of flavonoids from *Moringa oliefera* leaves. South African Journal of Botany, 124: 270–279.

Hassan M.A., Xu T., Tian Y., Zhong Y., Ali F.A.Z., Yang X., Lu B. (2021): Health benefits and phenolic compounds of *Moringa oleifera* leaves: A comprehensive review. Phytomedicine, 93: 153771.

Ingale S.P., Gandhi F.P. (2016): Effect of aqueous extract of *Moringa oleifera* leaves on pharmacological models of epilepsy and anxiety in mice. International Journal of Epilepsy, 3: 12–19.

Jain P.G., Patil S., Haswani N., Girase M., Surana S. (2010): Hypolipidemic activity of *Moringa oleifer*a Lam., Moringaceae, on high fat diet induced hyperlipidemia in albino rats, Revista Brasileira de Farmacognosia, 20: 969–973.

Jimoh T.O. (2018): Enzymes inhibitory and radical scavenging potentials of two selected tropical vegetable (*Moringa oleifera* and *Telfairia occidentalis*) leaves relevant to type 2 diabetes mellitus. Revista Brasileira de Farmacognosia, 28: 73–79.

Karthivashan G., Masarudin M.J., Kura A.U., Abas F., Fakurazi S. (2016): Optimization, formulation, and characterization of multiflavonoids-loaded flavanosome by bulk or sequential technique. International Journal of Nanomedicine, 11: 3417–3434.

Kasolo J.N., Bimenya G.S., Ojok L., Ochieng J., Ogwal-Okeng J.W. (2010): Phytochemicals and uses of *Moringa oleifera* leaves in Ugandan rural communities. Journal of Medicinal Plants Research, 4: 753–757.

Kerdsomboon K., Chumsawat W., Auesukaree C. (2021): Effects of *Moringa oleifera* leaves extracts and its bioactive compound gallic acid on reducing toxicities of heavy metals and metalloid in *Saccharomyces cerevisiae*. Chemosphere, 270: 128659.

Kirisattayakul W., Wattanathorn J., Tong-Un T., Muchimapura S., Wannanon P., Jittiwat J. (2013): Cerebroprotective effect of *Moringa oleifera* against focal ischemic stroke induced by middle cerebral artery occlusion. Oxidative Medicine and Cellular Longevity: 951415.

Kumar S., Verma P.K., Shukla A., Singh R.K., Patel A.K., Yadav L., Kumar S., Kumar N., Kaushalendra Acharya A. (2023): *Moringa oleifera* L. leaf extract induces cell cycle arrest and mitochondrial apoptosis in Dalton's Lymphoma: An *in vitro* and *in vivo* study. Journal of Ethnopharmacology, 302: 115849.

Ma Z.F., Ahmad J., Zhang H., Khan I., Muhammad S. (2020): Evaluation of phytochemical and medicinal properties of Moringa (*Moringa oleifera*) as a potential functional food. South African Journal of Botany, 129: 40–46.

Magaji U.F., Sacan O., Yanardag R. (2020): Alpha amylase, alpha glucosidase and glycation inhibitory activity of *Moringa oleifera* extracts. *S*outh African Journal of Botany, 128: 225–230.

Mahato D.K., Kargwal R., Kamle M., Sharma B., Pandhi S., Mishra S., Gupta A., Mahmud M.M.C., Gupta M.K., Singha L.B., Kumar P. (2022b): Ethnopharmacological properties and Nutraceutical potential of *Moringa oleifera*. Phytomedicine Plus, 2: 100168.

Mahmoud K.B., Wasli H., Mansour R.B., Jemai N., Selmi S., Jemmali A., Ksouri R. (2021): Antidiabetic, antioxidant and chemical functionalities of Ziziphus jujuba (Mill.) and *Moringa oleifera* (Lam.) plants using multivariate data treatment. South African Journal of Botany, 144L: 219–228.

Managa L.R., Du Toit E.S., Prinsloo G. (2021): Variations in the leaves metabolite profile between hydroponic and

https://doi.org/10.17221/221/2022-CJFS

field grown *Moringa oleifera* Lam. genotypes. Biochemical Systematics and Ecology, 97: 104302.

Manaois R.V., Morales A.V., Abilgos-Ramos R.G. (2013): Acceptability, shelf life and nutritional quality of moringa-supplemented rice crackers. Philippine Journal of Crop Science, 2: 1–8.

Manggul M.S., Hidayanty H., Arifuddin S., Ahmad M., Hadju V., Usman A.N. (2021): Biscuits containing M*oringa oleifera* leaf powder improve conditions of anemia in pregnant women. Gaceta Sanitaria, 35: S191–S195.

Mansour A.R., Farmer M.A., Baliki M.N., Apkarian A.V. (2014): Chronic pain: The role of learning and brain plasticity. Restorative Neurology and Neuroscience, 32: 129–139.

Martín Medina C., Martín G., García A., Fernández T., Hernández E., Puls J. (2013): Potential applications of *Moringa oleifera*. A critical review. Pastos y Forrajes, 36: 137–149.

Milla P.G., Peñalver R., Nieto G. (2021): Health benefits of uses and applications of *Moringa oleifera* in bakery products. Plants, 10: 318.

Monera T.G., Alan R., Maponga C.C., Leslie Z.B., Guglielmo J. (2008): *Moringa oleifera* leaf extracts inhibit 6-hydroxylation of testosterone by CYP3A4. The Journal of Infection in Developing Countries, 2: 379–383.

Mune M.M.A., Bakwo Bassogog C.B., Nyobe E.C., René Minka S.R. (2016): Physicochemical and functional properties of *Moringa oleifera* seed and leaf powder. Cogent Food and Agriculture, 2: 1220352.

Nwakalor C.N. (2014): Sensory evaluation of cookies produced from different blends of wheat and *Moringa oleifera* leaf powder. International Journal of Nutrition and Food Sciences, 3: 307–310.

Ogunsina B.S., Indira T.N., Bhatnagar A.S., Radha C., Debnath S., Gopala Krishna A.G. (2014): Quality characteristics and stability of *Moringa oleifer*a seed oil of Indian origin. Journal of Food Science and Technology, 51: 503–510.

Olson M.E., Fahey J.W. (2011): *Moringa oleifera*: A multipurpose tree for the dry tropics. Un Revista Mexicana de Biodiversidad, 82: 1071–1082.

Omodanisi E.I., Aboua Y.G., Oguntibeju O.O., Lamuela-Raventós R.M. (2017): Assessment of the antihyperglycaemic, anti-inflammatory and antioxidant activities of the methanol extract of *Moringa oleifera* in diabetes-induced nephrotoxic male Wistar rats. Molecules, 22: 439.

Omotoso G.O., Gbadamosi I.T., Olajide O.J., Dada-Habeeb S.O., Arogundade T.T., Yawson E.O. (2018): *Moringa oleifera* phytochemicals protect the brain against experimental nicotine-induced neurobehavioral disturbances and cerebellar degeneration. Pathophysiology, 25: 57–62.

Owon M., Osman M., Ibrahim A., Salama M.A., Matthaus B. (2021): Characterisation of different parts from *Moringa oleifera* regarding protein, lipid composition and extractable phenolic compounds. Oilseeds & fats, Crops and Lipids, 28: 45.

Oyeyinka A.T., Oyeyinka S.A. (2018): *Moringa oleifera* as a food fortificant: Recent trends and prospects. Journal of the Saudi Society of Agricultural Sciences, 17: 127–136.

Padayachee B., Baijnath, H. (2020): An updated comprehensive review of the medicinal, phytochemical and pharmacological properties of *Moringa oleifera.* South African Journal of Botany, 129: 304–316.

Páramo-Calderón D.E., Aparicio-Saguilán A., Aguirre-Cruz A., Carrillo-Ahumada J., Hernández-Uribe J.P., Acevedo-Tello S., Torruco-Uco J.G. (2019): Tortilla added with *Moringa oleífer*a flour: Physicochemical, texture properties and antioxidant capacity. Lebensmittel-Wissenschaft + Technologie, 100: 409–415.

Pavathy M.V.S., Umamaheshwari A. (2007): Cytotoxic effect on *Moringa oleifera* leaf extracts on human multiple myloma cell lines. Trends in Medical Research, 2: 44–50.

Rébufa C., Dupuy N., Bombarda I. (2021): AComDim, a multivariate tool to highlighting impact of agroclimatic factors on *Moringa oleifera* Lam. leaves' composition from their FTIR-ATR profiles. Vibrational Spectroscopy, 116: 103297.

Ravi D.R.S., Nair B.R., Siril E.A. (2022): Fingerprinting and genetic variability in drumstick (*Moringa oleifera* Lam.) elite trees using RAPD markers – An underutilized and wild edible future crop. South African Journal of Botany, 145: 370–377.

Robinson S., Delongeas J.L., Donald E., Dreher D., Festag M. (2008): European pharmaceutical company initiative challenging the regulatory requirement for acute toxicity studies in pharmaceutical drug development. Regulatory Toxicology and Pharmacology, 50: 345–352.

Sagrera A., Montenegro T., Borrego L. (2021): Cutaneous toxicity due to *Moringa oleifera* ACTAS Dermo-Sifiliográficas, 112: 928–965.

Shah M.A., Bosco S.J.D., Mir S.A. (2015): Effect of *Moringa oleifera* leaves extract on the physicochemical properties of modified atmosphere packaged raw beef. Food Packaging and Shelf Life, 3: 31–38.

Singh A.K., Rana H.K., Tshabalala T., Kumar R., Gupta A., Ndhlala A.R., Pandey A.K. (2020): Phytochemical, nutraceutical and pharmacological attributes of a functional crop *Moringa oleifera* Lam: An overview. South African Journal of Botany, 129: 209–220.

Sutalangka C., Wattanathorn J., Muchimapura S., Thukham-Mee W. (2013): *Moringa oleifera* mitigates memory impairment and neurodegeneration in animal model of age-related dementia. Oxidative Medicine and Cellular Longevity, 2013: 695936.

https://doi.org/10.17221/221/2022-CJFS

Teclegeorgish Z.W., Aphane Y.M., Mokgalaka N.S., Steenkamp P., Tembu V.J. (2021): Nutrients, secondary metabolites and antioxidant activity of *Moringa oleifera* leaves and Moringa-based commercial products. South African Journal of Botany, 142: 409–420.

Timilsena Y.P., Vongsvivut J., Adhikari R., Adhikari B. (2017): Physicochemical and thermal characteristics of Australian chia seed oil. Food Chemistry, 228: 394–402.

Van den Berg J., Kuipers S. (2022): The antibacterial action of *Moringa oleifera*: A systematic review. South African Journal of Botany, 151: 224–233.

Vergara-Jimenez M., Almatrafi M.M., Fernandez M.L. (2017): Bioactive components in *Moringa oleifera* leaves protect against chronic disease. Antioxidant, 6: 94.

White P. (2015): The concept of diseases and health care in African traditional religion in Ghana. HTS Teologiese Studies/Theological Studies, 71: a2762.

Zainab B., Ayaz Z., Alwahibi M.S., Khan S., Rizwana H., Soliman D.W., Alawaad A., Mehmood Abbasi A. (2020): In-silico elucidation of *Moringa oleifer*a phytochemicals against diabetes mellitus. Saudi Journal of Biological Sciences, 27: 2299–2307.

Zungu N., Van Onselen A., Kolanisi U., Siwela M. (2020): Assessing the nutritional composition and consumer acceptability of *Moringa oleifera* leaf powder (MOLP)-based snacks for improving food and nutrition security of children. South African Journal of Botany, 129: 283–290.

Received: November 20, 2022
Accepted: January 16, 2023
Published online: February 9, 2023