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Yoghurt fortification with *Moringa oleifera*: nutritional and production aspects

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Abstract

Yoghurt is a nutrient-dense dairy food product produced by lactic acid bacteria that enhances digestion and nutrient absorption, as well as sustains gut flora. However, it is a low-phenolic food. In addition to being a potential food delivery system, creating unique yoghurts with plant-derived ingredients has become more popular. Increasingly, *Moringa oleifera* remains a popular phytotherapeutic plant known for its antioxidant properties, given the presence of a wide range of phenolic compounds. Adding *M. oleifera* to yoghurt, therefore, would enhance both mineral and phenolic compositions, as well as promote the growth of probiotic bacteria. In this review, the nutritional and production aspects of *M. oleifera* to fortify yoghurt is discussed. The obtained findings on *M. oleifera*'s therapeutic properties consolidate it as a promising ingredient for yoghurt fortification, as demonstrated by its nutritional and functional impact on yoghurt. Given that yoghurt production requires adherence to specific standardized thresholds, the rich polyphenolic content of *M. oleifera*, which adds an astringent taste, requires future studies to overcome this challenge.

Keywords: *Moringa oleifera*; antioxidant; yoghurt; fortification; functional foods

Introduction

Consumers today are aware of their energy intake and its impact on health and are therefore concerned about the products they include into their diets. Besides, considering that the body sometimes produces excess oxidants that cause imbalance and oxidative damage to biomolecules and may eventually be responsible for the occurrence of several diseases, including cancer. Food products that provide psychological or physiological benefits in addition to the classical nutritional function are in demand. As a result, there is growing interest in foods containing functional ingredients and nutraceuticals that can benefit the body. In response to consumer demand, the food industry is attempting to fulfil these requirements by developing functional products with specific health benefits.

Yoghurt is one of the oldest fermented dairy products worldwide and is commonly produced from domesticated milk by lactic acid bacteria (especially *Lactobacillus bulgaricus* and/or *acidophilus*, as well as *Streptococcus thermophilus*) (Das et al., 2019; Ogunyemi et al., 2021). Furthermore, the active microorganisms in yoghurt, called probiotics, help to improve the balance between beneficial and undesirable bacteria in the intestinal tract. This stabilizes the gut microflora, lowers blood cholesterol, and improves immunomodulation, all of which are associated with a lower incidence of chronic diseases, such as gastrointestinal disorders and cancer (Ahmad et al., 2022). Yoghurt is considered a nutritious food that, in addition to its high digestibility and acceptability, improves lactose intolerance and continues to serve as an appropriate food vehicle for functional and nutritional ingredients for human wellness (Gahruie et al., 2015; da Silva et al., 2019). Fortifying food with natural additives is one of the best ways to boost the overall nutrient intake of food while minimizing adverse effects. The addition of additives, such as fruits, cereals, herbs, and plant extracts, to yoghurt can improve its rheological and antioxidant properties (Durmus et al., 2021; Wu et al., 2023; Ibhaze et al., 2022; Kiros et al., 2016; El-Sayed and Youssef, 2019).

Moringa oleifera Lam is one of the most cultivated cruciferous herbs in tropical and subtropical areas of Asia, Africa, and Central America. This crop is well-adapted to tough climatic conditions, allowing it to thrive across different geographical locations (Kou et al., 2018). Furthermore, the plant's vegetative parts have a long history of use as food, medicine, and water clarifier, making practically all plant parts versatile, particularly because of their high levels of dietary fiber, phenolic compounds, and macro- and micronutrients (Xu et al., 2019). *M. oleifera* extracts are used in traditional medicine in India, Malaysia, and Puerto Rico to treat anxiety, anaemia, diarrhoea, diabetes, and obesity (Ma et al., 2018; Luangpiom et al., 2013). Additionally, *M. oleifera* leaves are considered an excellent food source, rich in protein, vitamins, calcium, ascorbic acid, and antioxidant compounds such as flavonoids and phenols. Leaf extracts of *M. oleifera* have been shown to be useful in diabetes treatment, with the ability to lower blood sugar levels and improve antioxidant status (Olurishe et al., 2016; Pontual et al., 2012).

As a less expensive source of nutrients, *M. oleifera* can modulate the microbiota, just as prebiotics can improve cardiovascular health and enhance diets in developing nations (Fernandez and Marette, 2017). Therefore, *M. oleifera* may be more beneficial when paired with yoghurt to help people recover from both nutritional deficits and provide the body with the necessary nutrients (Ahmad et al., 2022). Taking all these factors into consideration, fortifying yoghurt with phenolic-rich additives, such as *M. oleifera*, seems to be an ideal way to maximize the benefits of consuming high phenolic compounds. Howbeit, yoghurt has unique properties that make it acceptable to consumers; therefore, it needs to be clarified whether the addition of *M. oleifera* will positively or negatively impact yoghurt. Given the dearth of understanding regarding the potential use of *M. oleifera* in yoghurt production, it is expected that specific aspects such as fermentation time, rheology, acidification, and physicochemical properties may well be altered (Dimitrellou et al., 2020). There is the need to learn more about the impact of *M. oleifera* in fortifying yoghurt quality towards improving human wellness. To supplement the existing information, this review compiles important information from relevant literature about *M. oleifera* fortifying yoghurt products, specifically the nutritional and production aspects. The therapeutic properties of the *M. oleifera* plant, yoghurt production, and its fortification (with *M. oleifera* powder and extracts) will be discussed, ending with limitations and directions for future studies.

Therapeutic effects of *M. oleifera*

M. oleifera possesses various phytochemicals, some with therapeutic properties, including antioxidant, antidiabetic, anti-inflammatory, and antitumor aspects. The aerial parts of *M. oleifera* plants and their bioactive components (Figure 1) reveal how physiological and environmental factors influence the existence of various compounds, including phenolic acids, flavonoids, tannins, glucosinolates, etc. Therapeutic effects of *M. oleifera* are presented in subsequent sub-sections, specifically antioxidant, antimicrobial, and anticancer aspects.

Antioxidant activity

Biochemical reactions in the human body produce unstable free radicals like reactive oxygen species (ROS) that, in excess, can damage essential macromolecules such as proteins, lipids, carbohydrates, and nucleic acids. Thus, antioxidants would stabilize the free radicals and prevent such damage to macromolecules (Swati et al., 2018). *M. oleifera* contains antioxidant micronutrients such as zinc and selenium, vitamins A, C, and E, and other antioxidant pigments (α and ß-carotene, xanthine, chlorophyll, lutein, and others) (Hodas et al., 2021). *M. oleifera* leaves, pods, and seeds contain such antioxidant compounds as rutin, quercetin, caffeoylquinic acid, and kaempferol. For example, *M. oleifera* leaves were reported to have 89.8 mg/100 g quercetin, 36.3 mg/100 g

Figure 1. *Aerial parts of M. oleifera plants and their bioactive components*

kaempferol, 2.9 mg/100 g isorhamnetin, and 129 mg/100 g total flavonoids, excluding apigenin and luteolin (Yang et al., 2008). Phenolic compounds could also be found in *M. oleifera* leaves, roots, flower, seed, and bark. Myricetin and quercetin (1530±10 µg/g, 985±4 µg/g) in the leaves, as well as gentisic acid and biochanin A (85±2 µg/g, 45±1 µg/g) in the roots, had significantly higher concentrations than others (Prabakaran et al., 2018). Elsewhere, the antioxidant capacity of methanolic extracts from the leaves, root, and stem bark of *M. oleifera* revealed IC_{50} values of 30, 16, and 38 µL, respectively. More so, *in-vitro* evaluation of the methanolic extracts of the leaves, root, and stem bark in the 2-deoxyguanosine assay model showed IC_{50} values of 40, 72, and 58 µL, respectively (Atawodi et al., 2010). To further contextualize this sub-section, Table 1 summarizes some recent reports of the antioxidant potential of *M. oleifera* (Wang et al., 2019; Soliman et al., 2020; Sailaja et al., 2021; Gupta et al., 2012; Amara et al., 2021; Vongsak et al., 2015; Cheraghi et al., 2017; Karthivashan et al., 2015; Edeogu et al., 2019; Khalil et al., 2020; Jaiswal et al., 2013; Abou-Zeid et al., 2021; Alqahtani and Albasher, 2020).

Antimicrobial activity

Practically all *M. oleifera* plant parts, from bark, roots, seeds, flowers, to leaves, would exhibit antimicrobial activities (Arora and Arora, 2021). Isolated from various parts of *M. oleifera*, both pterygospermin and isothiocyanates would exert both antibiotic and antifungal properties (Islam et al., 2021). Ethanolic extract of *M. oleifera* leaves/seeds would show antimycotic activities *in vitro* against *Epidermophyton floccosum*, *Microsporum canis*, *Trichophyton rubrum,* and *Trichophyton mentagrophytes* (Chuang et al., 2007). Antimicrobial activities of *M. oleifera* seed extracts were associative with the presence of moringin (4-(α-L-rhamnosyloxy) benzyl isothiocyanate) (Padla et al., 2012; Wen et al., 2022). Whilst crude chloroform extract of *M. oleifera* bark displayed promising antibacterial/antifungal activity (Nikkon et al., 2003), those of leaf (ethanol, methanol, and chloroform) would be anti-bactericidal, specifically against such gram-negatives as *Pseudomonas aeruginosa* and *Shigella shinga*, and gram-positives as *Escherichia coli*, *Bacillus subtilis*, *Klebsiella aerogenes*, *Salmonella typhi*, *Staphylococcus aureus*, and *Streptococcus B haemolytica* (Masurekar et al., 2015).

Anti-cancer activity

M. oleifera leaves/bark are considered as potential anti-cancer agents, as shown in Table 2. Extracts from *M. oleifera* leaf would inhibit the viability of hepatoma and acute

Table 1. Some reports about the antioxidant potential of M. oleifera

Active components	Duration	Study model	Outcomes	References
Niazirin (5 and 25 μM, 10 and 40 mg/kg/day)	14 days after induction of diabetes	High glucose induced VSMCs and STZ-induced diabetic mice	Niazirin inhibits cell proliferation by inhibiting the expression of Nox4, which results in the deactivation of PKCζ thus, decreasing the production of ROS	Wang et al., 2019
Hydro-alcoholic leaf extract (300 mg/kg)	12 days	Methotrexate-induced oxidative stress in mice	Extract regulates renal oxidative stress by upregulating Nrf2 and HMOX1 genes and downregulating NFκB	Soliman et al., 2020
Moringa isothiocyanate-1 (MIC-1, 80 mg/kg)	3 days	LPS-induced acute inflammation in mice	MIC-1 increases nuclear translocation of Nrf2, leading to increased transcriptional activity of AREs, antioxidant genes and reduced nuclear accumulation of NFκB	Sailaja et al., 2021
Methanolic extract of pods (150 and 300 mg/kg/day)	21 days treatment post-induction of diabetes	STZ-induced diabetes in Wistar rats	*M. oleifera* extract exerted cellular antioxidant defences by protecting ß-cells from ROS-mediated damage and reduced lipid peroxidation with concomitant increase in SOD, CAT, and GSH	Gupta et al., 2012
Sprout extract (100 μg/mL)	24 h	DEHP-induced Human neuroblastoma	*M. oleifera* extract decrease levels of ROS by modulating the expression of antioxidant genes (Nrf2 and HO-1)	Amara et al., 2021
Leaf extract (100 μg/mL); Astragalin (100 μg/mL); crypto-chlorogenic acid (50 μg/mL); Isoquercetin (5 μg/mL)	24 h	H_2O_2-induced ROS in HEK-293 cells	*M. oleifera* leaf extract, isoquercetin, and crypto-chlorogenic acid suppressed the production of ROS by increasing the mRNA expression levels of antioxidant enzymes, SOD, CAT, and HO-1.	Vongsak et al., 2015
N, α-L-rhamnopyranosyl vincosamide (200-2000 μg/mL)	14 days	Doxorubicin -induced cardiac toxicity in rats	N, α-L-rhamnopyranosyl vincosamide mediated cardioprotective effect by blocking lipid peroxidation in cardiac tissue through its antioxidant potential	Cheraghi et al., 2017
Methanolic leaf extract (250 mg/kg)	14 days	Lead-induced neurotoxicity in Wistar rats	Increased activities of SOD, GPx, GR, GSH, and CAT and decreased MDA and NO levels	Alqahtani and Albasher, 2020
Ethanolic leaf extract (400 and 800 mg/kg)	7 days	Tilmicosin-induced renal damage in Sprague Dawley rats	Decreased renal levels of hydrogen peroxide and MDA, and increased SOD and GPx	Abou-Zeid et al., 2021
Aqueous leaf extract (200 mg/kg)	21 days	STZ-induced diabetic in Wistar rats	Increased SOD, GST, and CAT levels and decreased MDA levels in tissues	Jaiswal et al., 2013
Ethanolic leaf extract (400 and 800 mg/kg)	7 days	Tilmicosin-induced cardiac damage in Sprague Dawley rats	*M. oleifera* extract modulate total ROS level by decreasing the levels of MDA, protein carbonyl, and 8-OHdG	Khalil et al., 2020
Seed oil (5 mL/kg)	16 days	Gentamicin-induced oxidative nephrotoxicity in Wistar rats	Increased renal levels of SOD, CAT, GSH, and GPx and decreased levels of MDA, IL-6, IL-1ß, TNF-α, NO, iNOS, and NFκB	Edeogu et al., 2019
Ethanolic leaf extract (100 and 200 mg/kg)	24 h	Acetaminophen-induced hepatotoxicity in male Balb/c mice	Decreased hepatic levels of MDA and increased levels of SOD, CAT, and GPx, by upregulating the expression of NQO1, HO-1, Gsta2, GCLM, and Nrf-2	Karthivashan et al., 2015

lymphoblasts (Khalafalla et al., 2010). Such active ingredients as niazimicin, glucomoringin, glucosinolates, and ß-sitosterol-3-O-ß-D-glucopyranoside makes *M. oleifera* a promising anticancer candidate (Berkovich et al., 2013). Indeed, benzyl isothiocyanate promotes apoptosis by producing intracellular reactive oxygen species that lead to cancer cell death (Wu et al., 2021). Cold-water extract of *M. oleifera* leaf could be an anti-proliferative agent that inhibits cancer cell growth (Jung et al., 2015). Anti-proliferative effect may induce reactive oxygen species in cancer cells, which lead to apoptosis shown by upregulation of apoptotic pathway members, caspase 3 and caspase 9 (Hermawan et al., 2012). Elsewhere and through the activation of the intrinsic/extrinsic pathway, *M. oleifera* extracts would induce cell death in different tumour cells (Do et al., 2020; Madi et al., 2016; Akinlolu et al., 2021; Asaduzzaman et al., 2017; Das et al., 2021).

Table 2. Some reports about the anticancer potential of M. oleifera

Active components	Duration	Study model	Outcomes	References
Water soluble leaf extract (50-200 µg/mL)	48 h	HepG2 cells and HFA in immunodeficient nude mice	Induces apoptosis by overexpressing apoptotic genes such as cleaved caspase-3 and cleaved PARP, and downregulating Bcl-xL genes.	Jung et al., 2015
Moringin (4-(α-L-rhamnosyloxy) benzyl isothiocyanate) (1.64-16.4 µM)	24 - 72 h	SH-SY5Y and WI-38 cells	Moringin induced p53-mediated cell cycle arrest by upregulating p21 and Bax, as the increased transcription of Bax leads to permeabilization of the mitochondrial outer membrane and the activation of caspases 9 and 3, which trigger the intrinsic apoptotic cascade and induce apoptosis by preventing the nuclear translocation of NFκB	Cirmi et al., 2019
Aqueous leaf extract (0.1-2.0 mg/mL)	72 h	Panc-1, p34, and COLO357	Inhibits the NFκB signalling cascade by blocking the translocation of p65 and IκBα, leading to apoptosis and cell death.	Berkovich et al., 2013
Soluble leaf extract (0-400 µg/mL)	24-48 h	A549 cells	*M. oleifera* reduces tumour proliferation and intracellular ROS and induces apoptosis by activating cleaved caspase 3 and JNK and inhibiting NFκB	Jung, 2014
n-hexane fraction of seed (0.25-4.0 mg/mL)	24 h	MCF7 and MDA-MB-231 and normal cell line: MCF 10A	Seed extract upregulates nucleophosmin and hnRNPF levels, thereby inducing apoptosis and cell cycle arrest in cancer cells	Adebayo et al., 2019
Moringin (8-24 µM)	24 h	CCF-STTG1 cells (human grade IV astrocytoma)	Moringin induces oxidative stress-mediated apoptosis by activating p53 and Bax, inhibiting Bcl-2, and modulating the expression of Nrf2 and CK2α	Rajan et al., 2016
Methanolic leaf extract (40-640 µg/mL)	24 h	Normal and carcinogenic prostate cell	Induces cell cycle arrest by increasing Bax/Bcl-2 ratio and decreasing the GLI-1 and SMO mRNA expression in treated cells, hence deregulating the hedgehog signalling pathway.	Khan et al., 2020
Ethanolic flower extract (0.07-100 µg/mL)	24-48 h	PC-3 cells	Induces apoptosis via caspase dependent pathway by upregulating the expression of several apoptosis-related proteins and downregulating p-Akt and Bcl-2	Ju et al., 2018
Seed lectin (1.5-16 µM)	24-48 h	B16-F10 cells and GN cells	Increased ROS levels induce apoptosis by the intrinsic pathway of activating caspase-9 as well as cell death by the extrinsic axis via the activation of caspase 8	De Andrade Luz et al., 2017
Methanolic leaf extract (40-640 µg/mL)	24 h	DU145	Leaf extract downregulates Bcl-2 and upregulates Bax expression, inhibits tumour growth and induces apoptosis by downregulating Notch-1 and Hes-1	Khan et al., 2020
Aqueous leaf extract (0.1-10 mg/mL)	24 h	SNO cells	*M. oleifera* proapoptotic effect - increased caspases 9 and -3/7 activities and decreased ATP - results in the induction of cell death in SNO cells via the intrinsic pathway	Tiloke et al., 2016
Ethanolic fruit extract (50-100 µg/mL)	24-72 h	A2058 and HaCaT cells	Fruit extract induces apoptosis via the mitochondrial signaling pathway by increasing the production of ROS and Bax and decreasing the expression of Bcl-2, which results in the disruption of the mitochondrial membrane followed by activation of cleaved caspases -3 and -9	Goun et al., 2017
Ethyl acetate leaf extract (25-75 µg/mL)	24-48 h	A375 cells	Cell death mechanism involves the activation of caspases -3 and -9 (caspase-dependent pathway) and activation and translocation of apoptosis-inducing factor (AIF) into the nucleus (caspase-independent pathway).	Do et al., 2021
Aqueous leaf extract (1-500 µg/mL)	24 h	$HepG_2$ and PBMC and noncancerous human kidney cells: Hek293	Increased levels of ROS resulted in significant oxidative DNA damage in treated cells, as indicated by increased DNA fragmentation and γH2AX levels. Increased Smac/DIABLO and caspase-9 activity activates caspase-3, which leads to increased cleaved PARP1, which induces apoptosis through the intrinsic pathway	Tiloke et al., 2019

Fortification of yoghurt with *M. oleifera*

Why is yoghurt fortification important?

Food fortification involves the addition of essential nutrients using staple foods as delivery vehicles to a target population especially where nutrients are minute or insufficient (Liyanage and Hettiarachchi, 2011). Notwithstanding the fortification purpose, both vehicle and fortifier must be compatible with the chemical/food matrix and avail nutritionally to achieve healthy food (Oyeyinka and Oyeyinka, 2018). Moreover, fortificants should not influence the taste, texture, colour, or flavour of the overall food product. Indeed, several factors can influence sensory, nutritional, and physicochemical properties of yoghurt, for example, the amount of fat in milk, the type of milk used (buffalo, goat, sheep, etc.), the production technique, additives and functional ingredients, and the starter culture used (Buttriss, 1997). Given the relatively short shelf life compared to other dairy products, such as cheese, the high water activity and rich nutritional composition make yoghurt vulnerable to spoilage microorganisms (Santos et al., 2018). Yoghurt contains free amino acids and bioactive peptides, which arise from the proteolytic activity of lactic acid bacteria during fermentation. Some lactobacilli can create bacteriocins and hydrogen peroxide, which is made proactive by certain bacteria cultures believed to synthesize and boost the presence of vitamin B in yoghurt (LeBlanc et al., 2015). Yoghurt stands out for its nutritional components, alongside prophylactics and therapeutic benefits, despite its slightly low pH that reduces pathogenic infection and gastric juice secretion (O'Connell and Fox, 2001). However, yoghurt remains a low source of phenolic compounds despite its therapeutic effects on casein, whey proteins, and traces of various antioxidant compounds (Niero et al., 2017; Dubrovskii et al., 2019).

Recently, there has emerged an increasing interest to develop unique-flavoured yoghurts, which might be seen as an ideal carrier of nutrients/functional ingredients in the human diet. Besides, the choice of adding different mineral salts (including organic and inorganic salts) to yoghurt, which adds to the complexities of food matrices, remains challenging. For instance, such salt addition tends to change yoghurt's mouthfeel and pH. However, the popularity of functional yoghurts prepared with plant-derived components or additives such as fruits, vegetables, seeds, or even plant extract have risen (Roy et al., 2015; Alenisan et al., 2017; Hamed et al., 2020; Ahmad et al., 2022). Functional foods would possess various phytochemicals that facilitate their bioactivity, which helps to mitigate certain disease conditions/risks. Indeed, the addition of either fruits, herbs or plant extracts to yoghurt remains crucial, either as adaptogens (natural substances that increase the body's resistance to stress) or as functional ingredients with additional functions other than supplying nutrients (Dubrovskii et al., 2019).

Functional impact of M. oleifera in yoghurt

M. oleifera contains several classes of phytochemicals besides minerals and carotenoids that can support the growth of lactic acid bacteria and exert antimicrobial and antioxidant scavenging activities. Antioxidants play an essential role in safeguarding against oxidative stress and maintaining a balance between the generation of active oxygen species and the quantity of endogenous antioxidants. Male albino rats exposed to lead acetate-induced oxidative stress received oral doses of green tea and *M. oleifera* yoghurt (88.2 mg/kg/day) for five weeks. The results showed a significant reduction in liver weight and levels of the liver enzymes aspartate aminotransferase (AST) and alanine aminotransferase (ALT), as well as a superior lowering effect on plasma total cholesterol, triglycerides, and low-density lipoprotein upon consumption of *M. oleifera* yoghurt (El-Ziney et al., 2017). Other groups of authors further elucidated that *M. oleifera*-fortified yoghurt had increased radical-scavenging activity of up to 40 % in a dose-dependent manner during three weeks of cold storage, as well as an increase in the expression of antioxidant proteins in human colon cells (Zhang et al., 2019). Such results might be attributed to the formation and degradation of mineral and phenolic compounds based on the interactions between lactic acid bacteria and compounds present in *M. oleifera*.

Furthermore, a study on the influence of probiotic yoghurt supplemented with *M. oleifera* leaf powder (4.3 g) as a source of micronutrients in the gut, oral, breast milk, and vaginal microbiotas of pregnant women (n = 56) in Tanzania revealed that *M. oleifera*-probiotic yoghurt provided a safe and inexpensive food for pregnant women without adversely changing the gut and oral microbiota, as well as improving the gut microbiota of new-borns (Bisanz et al., 2015). A previous study on the potential use of *M. oleifera* probiotic yoghurt for heavy metal exposure in vulnerable populations, including pregnant women (n = 60) and children (6–10, n = 44), found that probiotic yoghurt consumption had a protective effect against increases in mercury (3.2 nmol/litre; P = 0.035) and arsenic (2.3 nmol/litre; P = 0.01) levels in pregnant women's blood and no significant changes in children's blood (Bisanz et al., 2014).

Chemical composition of *M. oleifera*-fortified yoghurt versus non-fortified yoghurt at different concentrations or extracts is shown in Table 3. Hassan et al. (2016) claimed that after adding 0.5 %, 1 %, 1.5 %, and 2 % *M. oleifera* leaf powder to yoghurt made from buffalo milk, the optimal supplementation ratio was 0.5 %. Compared to plain yoghurt, the authors observed that adding *M. oleifera* to yoghurt increased total solids, fat, total protein, and amino acids, especially alanine, leucine, tyrosine, and glutamic acid. The increase in the amino acid content of fortified yoghurt may be related to the numerous nutrients in the *M. oleifera* plant, as well as the fact that during fermentation and storage, due to the action of lactobacilli, proteolysis increases, leading to the formation of bioactive peptides that enhance the activity of streptococci. On the contrary, Akajiaku et al. (2018) reported that adding different proportions of *M. oleifera* leaf powder

to yoghurt had no significant changes on total solids and ash, while significantly increasing the percentage of total protein (Table 3).

Bikheet and co-authors also observed that the addition of ethanol and water extracts of *M. oleifera* (1, 3, and 5 %) to yoghurt enhanced its vitamin C and mineral contents (Fe, Ca, K, and P), total solids, total flavonoids, total phenols, total proteins, and antioxidant capacity after production and during storage (Bikheet et al., 2021). This result is further corroborated by a different study that found that adding *M. oleifera* to yoghurt increased the antioxidant scavenging activity, total protein, dietary fibre, volatile fatty acids, and acetaldehyde composition of the fortified yoghurt either fresh or during storage (Al-Ahwal et al., 2017). In addition, yoghurt supplementation by *M. oleifera* has been reported to improve its textural and chemical properties (El-Gammal et al., 2017). Elsewhere, a study on low-fat yoghurt reported that the addition of *M. oleifera* powder resulted in an increase in the water holding capacity (WHC) with a significant decrease ($p<0.05$) in the syneresis when compared to the control sample during the first week of storage. The increase in water holding capacity was postulated to be due to the interaction between the particles of the *M. oleifera* powder and the casein matrix in the yoghurt. However, the study showed a significant increase ($p<0.05$) in syneresis during the second week of storage (Adepoju and Selezneva, 2020). Cardines et al. (2018) prepared yoghurt supplemented with different *M. oleifera* seed extracts at concentrations of 0.5 and 1.5 % (v/v). Seed extract enhanced the acidification of yoghurt and led to higher consistency indices than the control yoghurt. The fortified yoghurts were characterized by higher protein content and significantly lower syneresis, which depicted the compacted networks of the three-dimensional network of aggregated casein micelles (Figure 2). Elsewhere, the addition of permeated (5, 10, and 15 mL/L) and concentrated (1, 2, and 3 mL/L) seed extracts of *M. oleifera* to yoghurt revealed that concentrated additives presented viscoelastic behaviour, improved protein and fat compared to plain yoghurt, and significant pH decrease with storage. By adding 2 mL/L, the produced yoghurt had increased firmness, as confirmed by compact/homogenous microstructure and reduced susceptibility to syneresis (Quintanilha et al., 2021).

The antimicrobial effects of 1 and 2 % ethanolic extracts of pomegranate peels and *M. oleifera* leaves on the viability of *E. coli* in yoghurt were investigated. It was found that 2 % ethanolic extracts of pomegranate peels and *M. oleifera* produced peak inhibition against *E. coli* during the storage period (AM et al., 2019). Fortification of yoghurt with 0.05, 1.0, and 2 % Moringa extract improved the growth of *Streptococcus thermophilus*, *Bifidobacterium longum*, and *Lactobacillus acidophilus* during fermentation, decreased syneresis by up to 21 %, increased WHC by 17 %, and increased viscosity (Zhang et al., 2019). Similarly, *M. oleifera* would support the growth of probiotic cultures of *Lactobacillus rhamnosus* GR-1 and *Lactobacillus acidophilus* (Hekmat et al., 2015). Besides, the polyphenols present in *M. oleifera* leaf prevented spoilage by decreasing the pH of yoghurt and inhibiting the microbial (fermentative) spoilage caused by yeasts and moulds (Georgakouli et al., 2016). To further support the above discourse, a summary of the biochemical and functional changes in yoghurt is presented in Table 4.

Advantages of M. oleifera in comparison to other natural antioxidants

Considering the capacity of *M. oleifera* to fortify yoghurt, understanding the advantages associated with it is important. For example, a clinical study on malnourished individuals found that consuming 10 g of powdered *M. oleifera* leaves per day for six months resulted in a quicker recovery rate (36±16.54 days) and an increase in average weight gain of 8.9±4.3 gkg^{-1} per day with no significant increase ($p>0.05$) in haemoglobin level. Thus, it is recommended as an effective alternative for addressing malnutrition in children (Zongo et al., 2013). Another study on the effect of using *M. oleifera* leaves powder (25 g/ day) to improve anaemia in children with iron deficiency anaemia aged 6-24 months for six months revealed a significant decrease in anaemia prevalence in the intervention group by 53.6 % and an increase in mean haemoglobin (10.9 g/dL) versus the control group (13.6 %, Hb 9.4 g/dL) (Shija et al., 2019)

Moreover, several authors have used *M. oleifera* as a fortifier in yoghurt production, with the primary purpose of improving

Table 3. *Chemical composition of M. oleifera-fortified yoghurt versus non-fortified yoghurt at different concentrations or extracts*

Chemical components	(Hassan et al., 2016)		(Akajiaku et al., 2018)		(Al-Ahwal et al., 2017)	
	Plain yoghurt	*M. oleifera* yoghurt (0.5 %)	Plain yoghurt	*M. oleifera* yoghurt (2 %)	Plain yoghurt	*M. oleifera* extract yoghurt (10 %)
Total protein (%)	6.91	7.10	30.68±2.44	56.80±0.71	3.92±0.11	3.98±0.11
Ash (%)	N/R	N/R	0.40±0.00	0.50±0.42	0.83±0.02	0.90±0.03
Fat content (%)	6.00	6.10	1.50±0.71	0.60±0.71	6.6±0.06	6.6±0.06
Total solids (%)	18.46	18.73	21.0±1.41	20.0±2.26	15.60±0.15	15.86±0.10
Dietary fibre (%)	N/R	N/R	N/R	N/R	0.42±0.04	0.62±0.04
TVFA	9.76	11.90	N/R	N/R	0.37±0.06	0.42±0.07
Acetaldehyde	6.60	9.65	N/R	N/R	162.4±13.2	166.33±12.31

N/R means not reported; TVFA means total volatile fatty acids (0.1N NaOH 10 g^{-1} of Yoghurt); Acetaldehyde (mole 100 g^{-1} of yoghurt).

the organoleptic, nutritional, and functional aspects. Most beneficial features of such fortification include increased antioxidant properties, amino acid content, increased textural qualities of the fortified yoghurt, increased total viability count of both lactic acid bacteria and probiotic strain *Lactobacillus rhamnosus*, and increased nutritional quality of the fortified yoghurt. Similar to *M. oleifera*, several fruit pulps, cereals, vegetables, and extracts have been introduced to yoghurt to improve its functional and nutritional qualities, serving as a gelling, water-binding, and thickening agent (Vénica et al., 2020; Nandakumar et al., 2021; Illupapalayam et al., 2014; Barakat and Hassan, 2017). A study on the sensory and chemical properties of yoghurt fortified with pumpkin fiber (0.5, 1.0, and 1.5 %) revealed increased viscosity and lowered syneresis, but protein decreased with an increase in fibre concentration (Bakirci et al., 2017). Another study

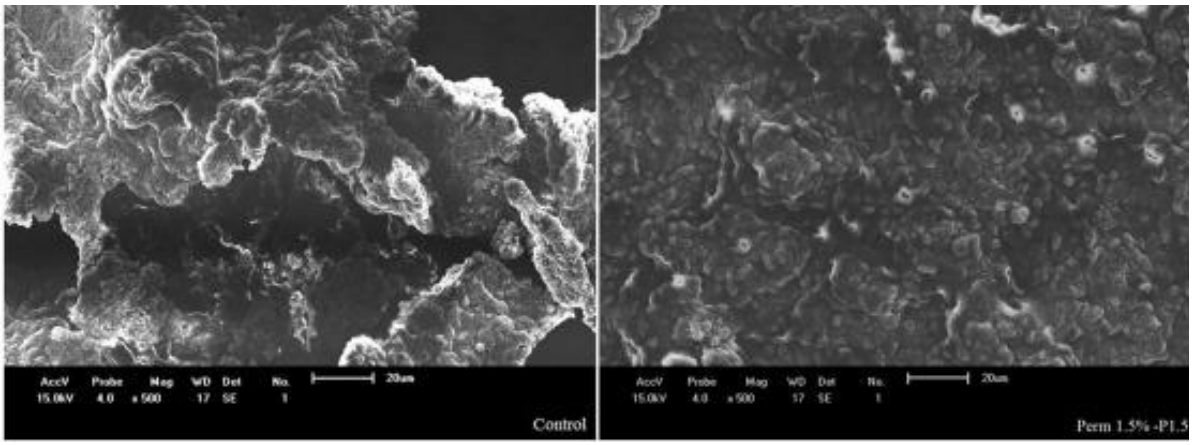

Figure 2. SEM of plain yoghurt (left) with permeated seed extract fortified yoghurt (right) (Source: Cardines et al., 2018)

Table 4. Preparation of functional yoghurt with M. oleifera and its properties

Functional Ingredient	Dairy source	Concentration	Outcomes	References
Leaf powder	Liquid whole milk	0, 0.5, 1, 1.5, and 2 % with mango flavour	Leaf powder increased total solids, protein, and acidity and decreased syneresis and sensory scores during storage. 1% fortified yoghurt scored highest for appearance, aroma, taste, body, and overall acceptability	Saeed et al., 2021
Leaf extract	Yoghurt mix	0 and 0.9 %	The leaf extract increased total phenolic content (18.31 mg/GAE) and DPPH radical scavenging capacity (78 % inhibition), increased syneresis, reduced viscosity and firmness on storage, and lowered the acceptance rate for flavor, smell, and overall acceptability	Shokery et al., 2017
Leaf flour	UHT bovine milk	0, 3, 5, and 7 %	Increased vitamin C content in fortified yoghurt (21.99 and 30.04 mg)	Aznury et al., 2020
Leaf extract	Cow milk (3.2 % milk fat)	0, 1, 3, and 4 %	*M. oleifera* reduced fermentation time, increased mineral elements, total phenolic content, and antioxidant capacity, decreased syneresis and increased water holding capacity on storage, and improved sensory scores compared to control	Lisak Jakopović et al., 2022
Leaf extract	Raw bovine milk	0, 2, 4, and 6 %	Leaf extract improves cohesiveness, decreases firmness and consistency, increases viable counts of *S. thermophilus*, and inhibits *L. bulgaricus*, and improves utilization of iron and manganese by starter cultures during yoghurt fermentation.	Nduti et al., 2018
Root powder	Soy milk, whole cow milk	0 and 0.1 %	Root powder increased copper, manganese, and iron, decreased zinc, calcium, magnesium, potassium, and sodium, lowered pH and titratable acidity, increased ash, crude protein, fiber, and fats, and decreased carbohydrates.	Ponka et al., 2022
Leaf extract	Fresh buffaloes' milk	0, 0.2, 0.4, and 0.8 %	decreased pH and increased protein, total solids, and fat during storage, inhibited the growth of yeast and mold and decreased the viable count of lactobacilli and streptococci during storage.	Saad and Elkhtab, 2019
Seed powder	Full cream powdered milk	0, 0.5, 1, 1.5, 2 and 2.5 %	The addition of seed powder increased shelf stability by inhibiting yeast and mold growth both at refrigerator and ambient temperatures, and the total aerobic count decreased with the advanced storage period for all fortified samples as compared to plain yoghurt.	Obasi et al., 2019
Leaf extract	Fresh cow milk	0, 0.5, 1, 1.5, 2, and 2.5 %	*M. oleifera* extract increases consistency and firmness and reduces pH and fermentation time. The yoghurt with the highest extract concentration had the maximum probiotic viability.	Rupa and Vijay, 2022

on the fortification of yoghurt with fenugreek and *M. oleifera* seed flour (0.1 and 0.2 %, respectively) reported the latter with higher total phenolic content, antioxidant capacity, antibacterial activity, and mineral content (Ca, P, K, and Fe). In contrast, fenugreek seed flour yoghurt obtained significantly higher microbial viability count than plain yoghurt and *M. oleifera* yoghurt (Dhawi et al., 2020). Shokery et al. (2017) prepared yoghurt supplemented with green tea extract and *M. oleifera* leaves extract at 1 and 0.9 %. The workers found increased syneresis with *M. oleifera*, while green tea decreased it. However, both bio yoghurts were characterized by higher contents of phenolic acids and improved antioxidant activities than plain yoghurt, which may offer range of yoghurt products with additional health benefits to consumers. Thus, compared to other widely used plant antioxidants, *M. oleifera* can improve the properties of yoghurt and yield extra nutritious products.

Yoghurt production process using *M. oleifera*

A block diagram of yoghurt production with *M. oleifera* is shown in Figure 3. It can be argued that streptococci possess higher aerotolerance compared to lactobacilli, which, given the well-established growth ratio of 4:1, would suggest a recognized synergistic interaction, especially when fermentation kicks off. Further, *Lactobacillus* avails the needed peptides that enhance the growth of streptococci because of its greater and more significant proteolytic activity. More so, the initial fermentation taken over by the cocci is believed to depress the redox potential, producing formate (methanoate), CO_2, and pyruvic acid as by-products. Methanoate would, therefore, encourage the growth of lactobacillus given by decreased oxygen, which in tandem accelerates the whole fermentation process. Post-fermentation, the yoghurt's temperature is rapidly dropped to about 4-5 °C via chiller/heat exchanger to stop the cultures' fermentative activity, inhibit enzyme activity, and initiate the cold gelatinization of the curd.

M. oleifera can also be added after fermentation, followed by cooling, before serving (Kuikman and O'Connor, 2015). When probiotic yoghurt was refrigerated at 4 °C, the addition of *M. oleifera* had growth-promoting effects on *Lactobacillus rhamnosus* GR-1, a probiotic bacterium (Van Tienen et al., 2011). Moreover, *Lactobacillus rhamnosus* GR-1's growth may be boosted by *M. oleifera*, but potentially only at a greater concentration (*M. oleifera* at 1 %) and when sugar is present (Hekmat et al., 2015). Compared to the control, the supplementation of yoghurt with *M. oleifera* extract would reduce the fermentation period in a dose-dependent manner (Zhang et al., 2019). Besides, increased fermentative activity of bacterial starter cultures may corroborate the flavonoid, phenolic, and organic acid contents of *M. oleifera*-enriched yoghurt (Rodríguez-Pérez et al., 2016). To achieve health benefits, bacterial colony formation must exceed 10^6 CFU mL^{-1}, which makes the potential growth-promoting effects of *M. oleifera* crucial to extending the probiotic yoghurt's shelf-life. Combined with other adjuncts, *M. oleifera* leaf powder would improve yoghurt's nutritional/sensory properties (Kechagia et al., 2013). The effects of adding different adjuncts (banana, avocado, and sweet potatoes) showed improved taste and overall acceptability of *M. oleifera*-enriched yoghurt (Kuikman and O'Connor, 2015).

Despite specific standardized thresholds, such as milk fat content, the overall quality of yoghurt varies globally. Among the very common yoghurt categories, especially those based on fat level, are skimmed, low-fat, and high-fat yoghurt. Yoghurt styling and nutritional qualities are greatly influenced by additives such as sweetening and flavouring agents, preservatives, and functional ingredients. *M. oleifera* and its extracts have served as functional ingredients that enrich yoghurts (Bikheet et al., 2021) and have an added value during yoghurt production. Raw *M. oleifera* leaves can be washed, dried in an oven, and ground to make powder or extract. The extract can then be boiled or macerated in water. The milk base is heated in a homogenizer at 65–70°C and 15–20 MPa pressure to reduce the fat globule diameter and improve the mixing of the extract with milk casein (Adepoju and Selezneva, 2020). Moreover, the milk base is pasteurized to destroy pathogens, denature whey protein, inactivate milk enzymes, reduce redox potential, and eliminate inhibitory substances at 85 °C for 20-30 min or 90-95 °C for 5 min, chilled to 40-45 °C, which is ideal for lactic acid bacteria growth. 2-4 % of the bulk starter or the amount specified on the commercial starter culture for direct vat inoculation or direct vat set at 40-43°C are used to inoculate the milk base (Nagaoka, 2019). Yoghurt fermentation starts with the action of bacterial cultures, which could either be a mixed culture comprising of *Streptococcus thermophilus (S. thermophilus)* and *Lactobacillus delbrueckii* subsp. *bulgaricus (L. bulgaricus)* or other bacteria mixtures, on pasteurized milk. By acting on complex macromolecules in milk, such as proteins, fats, and carbohydrates, *S. thermophilus* and *L. bulgaricus* carry out three key metabolic processes, namely glycolysis, proteolysis, and lipolysis, converting them into simpler and readily absorbable nutrients (Buttriss, 1997). In addition, the fermentation process is carried out in an aseptic vat or containers at the optimum temperature for lactic acid bacteria (40–43 °C) until the pH drops to 4.5-4.7, followed by rapid cooling to stop any further decrease in pH.

Toxicology and safety

There is a need for additional synthesis of relevant information on the safety and toxicity of *M. oleifera* in human studies, especially in relation to effective dose intake. Nevertheless, there are an eclectic number of studies on the therapeutic effects of *M. oleifera* in different preclinical models, and animal studies, when properly conducted, provide useful indicators of safety in humans. Oral administration of *M. oleifera* leaf extract at supra-supplementation levels of

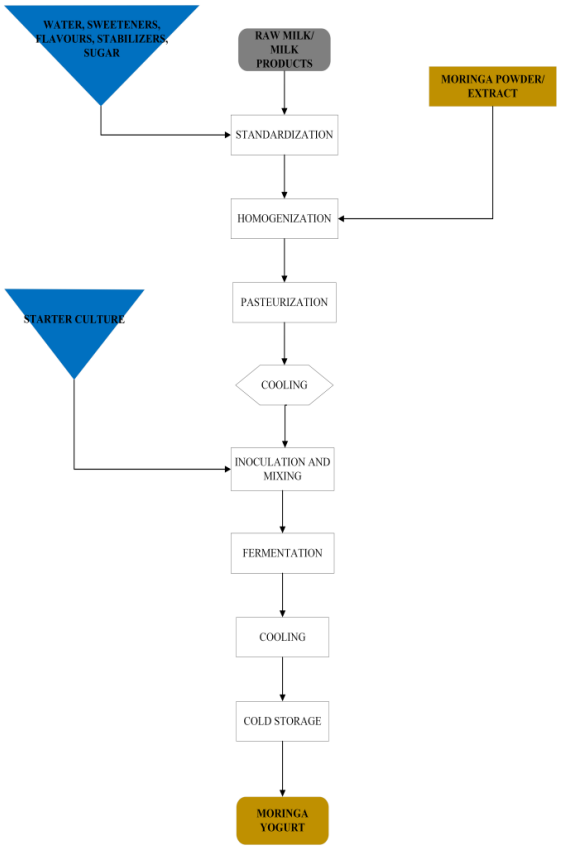

Figure 3. Block diagram of yoghurt production with M. oleifera

3000 mg kg^{-1} to rats did not result in any hepatorenal toxicity or haematological alterations after acute exposure. However, the authors claimed that *M. oleifera* is genotoxic at a dose of 3000 mg kg^{-1} (Asare et al., 2012). Another study on the acute (5000 mg kg^{-1}) and subacute toxicity (40-1000 mg kg^{-1}) of *M. oleifera* extract in rats revealed an increase in liver enzymes ALT and ALP ($p<0.001$) with no adverse histopathological changes, but the consumption of the leaves should not exceed a maximum of 70 g per day to avoid accumulative toxicity of essential elements over extended periods (Asiedu-Gyekye et al., 2014).

A double-blinded, randomized, placebo-controlled trial evaluating the efficacy of feeding *M. oleifera* leaf capsules to early postpartum patients to increase breast milk volume revealed there was no significant difference in breast milk volume on the third day of postpartum between the intervention and the control group (73.5 vs. 50 mL, $p = 0.19$). However, the amount of breast milk in the intervention group was 47 % higher than that in the control group (Fungtammasan and Phupong, 2022). Another randomized crossover study examining the effects of *M. oleifera* leaf extract (500 mg dry extract) on plasma glucose concentrations and antioxidant status in healthy volunteers showed that *M. oleifera* significantly improved antioxidant capacity in humans, without causing hypoglycemia (Ngamukote et al., 2016). Studies on the potential toxicity of *M. oleifera* are currently lacking, and some information in the literature is debatable. Hence, it is necessary to conduct studies on the toxicokinetic, acute, sub-chronic, and chronic toxicity, as well as studies on the allergenicity, immunotoxicity, and neurotoxicity of *M. oleifera*.

Limitations of incorporating *M. oleifera* to yoghurt and future prospects

Although several studies have successfully created one form of *M. oleifera*-enriched yoghurt or another (refer to Table 4), striking a balance on how the bioactive ingredients of *M. oleifera* would be incorporated per serving of yoghurt remains debatable. The main challenge is related to the observed sensory properties when *M. oleifera* extract/leaves are incorporated into yoghurt especially at high concentrations (Trigo et al., 2022). As achieving the recommended dietary allowance of this bioactive ingredient in functional product such as yoghurt without producing an off-taste, not only proves challenging, the rich polyphenolic content of *M. oleifera* may equally be associated with the astringent taste that occurs in milk products (O'Connell and Fox, 2001). Fortification of yoghurt with *M. oleifera* extract, even at a high concentration of 2.5 % w/v yoghurt, showed no adverse effect on lactic acid bacteria; however, the sensory properties of the final product were poorly accepted (Rupa and Vijay, 2022). Potential solutions might include the initial blanching of the leaves before drying, encapsulation of the extracts, as well as introduction of fruit flavours and fruits into yoghurt.

Higher concentrations of *M. oleifera*, which could increase syneresis and reduce firmness/viscosity of fortified yoghurt, could be a minor challenge during storage (Shokery et al., 2017). Achieving a balance between fortification levels using this bioactive ingredient is required, especially within the dietary recommended limits to ensure the sensory property of the final *M. oleifera*-fortified yoghurt becomes acceptable. Thus, the optimum fortification level of *M. oleifera* in yoghurt needs further investigation, with increased focus on sensory, physico-chemical, and antioxidant properties. Furthermore, more chronic toxicity studies using *M. oleifera* on hepatic, renal, hematopoietic, cardiac, and reproductive changes are warranted. This is because there are currently limited human studies on the toxicity levels of *M. oleifera*, especially considering that yoghurt can be appealing to different consumers of different age groups and for different benefits.

Importantly, the *M. oleifera* plant continues to be a rich source of micronutrients, macronutrients, and bioactive compounds that facilitates the growth of lactic acid bacteria with promising effects on antioxidant and rheological properties of yoghurt. Moreover, the low phenolic content of yoghurt not only makes it a potential food vehicle, but also, a target for food fortification with plant ingredients. Owing to

its nutritional, antioxidant, and antimicrobial properties, *M. oleifera* can be positioned as a functional ingredient in dairy technology to help alleviate the situations of malnutrition in low-income countries. Technological challenges such as syneresis and sensory properties involving a *M. oleifera* fortified yoghurt, however, still needs to be addressed.

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Obogaćivanje jogurta biljkom *Moringa oleifera*: prehrambeni i proizvodni aspekti

Sažetak

Jogurt je hranjivi mliječni prehrambeni proizvod proizveden pomoću bakterija mliječne kiseline koji pospješuje probavu i apsorpciju hranjivih tvari, te održava crijevnu floru. Međutim, riječ je o namirnici niskog sadržaja fenola. Budući da se jogurt smatra visokovrijednim prehrambenim proizvodom koji ljudski organizam učinkovito opskrbljuje hranjivim tvarima, razvoj jedinstvenih jogurta obogaćenih sastojcima biljnog podrijetla postaje sve popularniji. *Moringa oleifera* važna je fitoterapeutska biljka poznata po svojim antioksidativnim svojstvima, s obzirom na prisutnost širokog spektra fenolnih spojeva. Obogaćivanje jogurta dodatkom *M. oleifera* stoga bi poboljšalo mineralni i fenolni profil te pospješilo rast probiotičkih bakterija. Ovaj rad daje pregled prehrambenih i proizvodnih mogućnosti biljke *M. oleifera* za obogaćivanje jogurta. Terapeutska svojstva biljke *M. oleifera* ukazuju na visoki potencijal njezine primjene u obogaćivanju jogurta u svrhu poboljšanja nutritivnih i funkcionalnih svojstava. S obzirom da proizvodnja jogurta zahtijeva pridržavanje specifičnih standardiziranih pragova u pogledu okusa, bogat sadržaj polifenola *M. oleifera* koji daju oporost, zahtijeva provedbu istraživanja kojima bi se pronašle mogućnosti za prevladavanje ovog problema.

Ključne riječi: *Moringa oleifera*; antioksidans; jogurt; obogaćivanje; funkcionalna hrana

References

1. Abou-Zeid, S.M., Ahmed, A.I., Awad, A., Mohammed, W.A., Metwally, M.M.M., Almeer, R., Abdel-Daim, M., Khalil, S.R. (2021): *Moringa oleifera* ethanolic extract attenuates tilmicosin-induced renal damage in male rats via suppression of oxidative stress, inflammatory injury, and intermediate filament proteins mRNA expression. *Biomedicine & Pharmacotherapy* 133, 110997. https://doi.org/10.1016/j.biopha.2020.110997
2. Adebayo, I.A., Arsad, H., Kamal, N., Samian, M.R. (2020): The hexane fraction of the *Moringa oleifera* Lam seed extract induces apoptosis, causes cell cycle arrest, and modulates expression of HSP60, NPM, PGK1, RCN1, and PDIA1 in MCF7 cells. *South African Journal of Botany* 129, 379-387. https://doi.org/10.1016/j.sajb.2019.09.001
3. Adepoju, F.O., Selezneva, I.S. (2020): Comparative study of yoghurt enriched with Moringa powder in different concentrations. *AIP Conference Proceedings* 2280 (1), 030001. https://doi.org/10.1063/5.0018035
4. Ahmad, I., Hao, M., Li, Y., Jianyou, Z., Yuting, D., Lyu, F. (2022): Fortification of yoghurt with bioactive functional foods and ingredients and associated challenges-A review. *Trends in Food Science & Technology* 129, 558-580. https://doi.org/10.1016/j.tifs.2022.11.003
5. Akajiaku, L.O., Kabuo, N.O., Omeire, G.C., Odimegwu, E.N., Ogbonna, V.G. (2018): Production and evaluation of *Moringa oleifera* leaves powder enriched yoghurt. *Nutrition and Food Toxicology* 2, 459-466.

6. Akinlolu, A.A., Oyewopo, A.O., Kadir, R.E., Lawal, A., Ademiloye, J., Jubril, A., Ameen, M.O., Ebito, G.E. (2021): *Moringa oleifera* and *Musa sapientum* ameliorated 7, 12-Dimethylbenz [a] anthracene-induced upregulations of Ki67 and multidrug resistance 1 genes in rats. *International Journal of Health Sciences* 15 (3), 26-33.
7. Al-Ahwal, R.I.H., Saleh, A.E., Moussa, M.A.M. (2017): The importance of using *Moringa oleifera* extract on the quality and nutritive value of yoghurt. *Journal of Food and Dairy Sciences* 8 (6), 237-241. https://doi.org/10.21608/jfds.2017.38684
8. Alenisan, M.A., Alqattan, H.H., Tolbah, L.S., Shori, A.B. (2017): Antioxidant properties of dairy products fortified with natural additives: a review. *Journal of the Association of Arab Universities for Basic and Applied Sciences* 24, 101-106. https://doi.org/10.1016/j.jaubas.2017.05.001
9. Alqahtani, WS., Albasher, G. (2021): *Moringa oleifera* Lam. extract rescues lead-induced oxidative stress, inflammation, and apoptosis in the rat cerebral cortex. *Journal of Food Biochemistry* 45 (1), e13579. https://doi.org/10.1111/jfbc.13579
10. Elbagory, A.M., Hussien, H., Homouda, S.N., Fathalla, E.K. (2019): Impact of pomegranate peels and *Moringa oleifera* extract on the viability of *E. coli* O111:H2 (EHEC O111:H2) in yoghurt. *Nutrition and Food Technology* 5, 1-7.
11. Amara, I., Ontario, ML., Scuto, M., Lo Dico, G.M., Sciuto, S., Greco, V., Abid-Essefi, S., Signorile, A., Salinaro, A.T., Calabrese, V. (2021): *Moringa oleifera* protects SH-SY5YCells from DEHP-induced endoplasmic reticulum stress and apoptosis. *Antioxidants* 10 (4), 532. https://doi.org/10.3390/antiox10040532
12. Arora, S., Arora, S. (2021): Nutritional significance and therapeutic potential of *Moringa oleifera*: The wonder plant. *Journal of Food Biochemistry* 45 (10), e13933. https://doi.org/10.1111/jfbc.13933
13. Asaduzzaman, A.K.M., Hasan, I., Chakrabortty, A., Zaman, S., Islam, S. S., Ahmed, FRS., Ahsanul Kabi, K.M., Nurujjaman, Md., Belal Uddin, Md., Alam, M.T., Shaha, R.K., Kabir, S.R. (2018): *Moringa oleifera* seed lectin inhibits Ehrlich ascites carcinoma cell growth by inducing apoptosis through the regulation of Bak and NF-κB gene expression. *International journal of biological macromolecules* 107, 1936-1944. https://doi.org/10.1016/j.ijbiomac.2017.10.070
14. 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 (1), 265-272. https://doi.org/10.1016/j.jep.2011.11.009
15. Asiedu-Gyekye, I.J., Frimpong-Manso, S.A., Awortwe, C., Antwi, D.A., Nyarko, A.K. (2014): Micro-and macroelemental composition and safety evaluation of the nutraceutical *Moringa oleifera* leaves. *Journal of Toxicology* 2014, 1-13. https://doi.org/10.1155/2014/786979
16. Atawodi, S.E., Atawodi, J.C., Idakwo, G.A., Pfundstein, B., Haubner, R., Wurtele, G., Bartsch, H., Owen, R.W. (2010): Evaluation of the polyphenol content and antioxidant properties of methanol extracts of the leaves, stem, and root barks of Moringa oleifera Lam. *Journal of Medicinal Food* 13 (3), 710-716. https://doi.org/10.1089/jmf.2009.0057
17. Aznury, M., Margerty, E., Yuniar, Y., Awwaliyah, S. (2020): Effect of fermentation time and percentage of Moringa (*Moringa oleifera*) flour variations on vitamin C of yoghurt. *Proceeding of the 4th forum in Research, Science and Technology (FIRST-T1-T2-2020)* 376-383. https://doi.org/10.2991/ahe.k.210205.063
18. Bakirci, S., Dagdemir, E., Boran, O.S., Hayaloglu, A.A. (2017): The effect of pumpkin fibre on quality and storage stability of reduced-fat set-type yoghurt. *International Journal of Food Science & Technology* 52 (1), 180-187. https://doi.org/10.1111/ijfs.13264
19. Barakat, H., Hassan, M.F. (2017): Chemical, nutritional, rheological, and organoleptical characterizations of stirred pumpkin-yoghurt. *Food and Nutrition Sciences* 8 (7), 746. https://doi.org/10.4236/fns.2017.87053

20. Berkovich, L., Earon, G., Ron, I., Rimmon, A., Vexler, A., Lev-Ari, S. (2013): *Moringa oleifera* aqueous leaf extract down-regulates nuclear factor-kappaB and increases cytotoxic effect of chemotherapy in pancreatic cancer cells. *BMC complementary and alternative medicine* 13, 1-7. https://doi.org/10.1186/1472-6882-13-212
21. Bikheet, M.M., Yasien, E.E., Galal, S.M. (2021): Preparation of functional yoghurt drink fortified with *Moringa oleifera* leaves. *Journal of Food and Dairy Sciences* 12 (9), 217-223. https://doi.org/10.21608/jfds.2021.201813
22. Bisanz, J.E., Enos, M.K., Mwanga, J.R., Changalucha, J., Burton, J.P., Gloor, G.B., Reid, G. (2014): Randomized open-label pilot study of the influence of probiotics and the gut microbiome on toxic metal levels in Tanzanian pregnant women and school children. *MBio* 5 (5), e01580-14. https://doi.org/10.1128/mbio.01580-14
23. Bisanz, J.E., Enos, M.K., PrayGod, G., Seney, S., Macklaim, J.M., Chilton, S., Willner, D., Knight, R., Fusch, C., Fusch, G., Gloor, G.B., Burton, J.P., Reid, G. (2015): Microbiota at multiple body sites during pregnancy in a rural Tanzanian population and effects of Moringa-supplemented probiotic yoghurt. *Applied and Environmental Microbiology* 81 (15), 4965-4975. https://doi.org/10.1128/AEM.00780-15
24. Buttriss, J. (1997): Nutritional properties of fermented milk products. *International Journal of Dairy Technology* 50 (1), 21-27. https://doi.org/10.1111/j.1471-0307.1997.tb01731.x
25. Cardines, P.H., Baptista, A.T., Gomes, R.G., Bergamasco, R., Vieira, A.M. (2018): *Moringa oleifera* seed extracts as promising natural thickening agents for food industry: Study of the thickening action in yoghurt production. *LWT* 97, 39-44. https://doi.org/10.1016/j.lwt.2018.06.028
26. Cheraghi, M., Namdari, M., Daraee, H., Negahdari, B. (2017): Cardioprotective effect of magnetic hydrogel nanocomposite loaded N, α-L-rhamnopyranosyl vincosamide isolated from *Moringa oleifera* leaves against doxorubicin-induced cardiac toxicity in rats: *in vitro* and *in vivo* studies. *Journal of Microencapsulation* 34 (4), 335-341. https://doi.org/10.1080/02652048.2017.1311955
27. Chuang, P.H., Lee, C.W., Chou, J.Y., Murugan, M., Shieh, B.J., Chen, H.M. (2007): Anti-fungal activity of crude extracts and essential oil of *Moringa oleifera* Lam. *Bioresource Technology* 6 (1), 124-131. https://doi.org/10.1016/j.biortech.2005.11.003
28. Cirmi, S., Ferlazzo, N., Gugliandolo, A., Musumeci, L., Mazzon, E., Bramanti, A., Navarra, M. (2019): Moringin from *Moringa oleifera* seeds inhibits growth, arrests cell-cycle, and induces apoptosis of SH-SY5Y human neuroblastoma cells through the modulation of NF-κB and apoptotic related factors. *International journal of molecular sciences* 20 (8), 1930. https://doi.org/10.3390/ijms20081930
29. Das, K., Choudhary, R., Thompson-Witrick, K.A. (2019): Effects of new technology on the current manufacturing process of yoghurt-to increase the overall marketability of yoghurt. *LWT* 108, 69-80. https://doi.org/10.1016/j.lwt.2019.03.058
30. Das, P.K., Asha, S.Y., Siddika, M.A., Siddika, A., Tareq, A.R.M., Islam, F., Khanam, J.A., Rakib, M.A. (2021): Methanolic extract of *Moringa oleifera* leaves mediates anticancer activities through inhibiting NF-*k*B and enhancing ROS in Ehrlich ascites carcinoma cells in mice. *Journal of Advanced Biotechnology and Experimental Therapeutics* 4, 161-170. https://doi.org/10.5455/jabet.2021.d116
31. da Silva, S.C., Fernandes, I.P., Barros, L., Fernandes, Â., Alves, M.J., Calhelha, R.C., Pereira, C., Barreira, J.C.M., Manrique, Y., Colla, E., Ferreira, I.C.F.R., Barreiro, M.F. (2019): Spray-dried *Spirulina platensis* as an effective ingredient to improve yoghurt formulations: Testing different encapsulating solutions. *Journal of Functional Foods* 60, 103427. https://doi.org/10.1016/j.jff.2019.103427
32. De Andrade Luz, L., Rossato, FA., e Costa, R.A.P., Napoleão, T.H., Paiva, P.M.G., Coelho, L.C.B.B. (2017): Cytotoxicity of the coagulant Moringa oleifera lectin (cMoL) to B16-F10 melanoma cells. *Toxicology in Vitro* 44, 94-99. https://doi.org/10.1016/j.tiv.2017.06.019
33. Dhawi, F., El-Beltagi, HS., Aly, E., Hamed, A.M. (2020): Antioxidant, antibacterial activities and mineral content of buffalo yoghurt fortified with fenugreek and *Moringa oleifera* seed flours. *Foods* 9 (9), 1157. https://doi.org/10.3390/foods9091157

34. Dimitrellou, D., Solomakou, N., Kokkinomagoulos, E., Kandylis, P. (2020): Yoghurts supplemented with juices from grapes and berries. *Foods* 9 (9), 1158. https://doi.org/10.3390/foods9091158
35. Do, B.H., Nguyen, T.P.T., Ho, N.Q.C., Le, T.L., Hoang, N.S., Doan, C.C. (2020): Mitochondria-mediated Caspase-dependent and Caspase-independent apoptosis induced by aqueous extract from *Moringa oleifera* leaves in human melanoma cells. *Molecular Biology Reports* 47 (5), 3675-3689. https://doi.org/10.1007/s11033-020-05462-y
36. Do, B.H., Hoang, N.S., Nguyen, T.P.T., Ho, N.Q.C., Le, T.L., Doan, C.C. (2021): Phenolic extraction of *Moringa oleifera* leaves induces caspase-dependent and caspase-independent apoptosis through the generation of reactive oxygen species and the activation of intrinsic mitochondrial pathway in human melanoma cells. *Nutrition and Cancer* 73 (5), 869-888. https://doi.org/10.1080/01635581.2020.1776885
37. Dubrovskii, I.I., Arseneva, T.P., Evstigneeva, T.N., Gorshkova, S.B., Bazarnova, Y.G., Iakovchenko, N.V. (2019): Development of formulation and technology of yoghurt with prolonged shelf life enriched with biologically active substances from fennel seed extract. *Agronomy Research* 17*,* 1313-1323. https://doi.org/10.15159/AR.19.086
38. Durmus, N., Capanoglu, E., Kilic-Akyilmaz, M. (2021): Activity and bioaccessibility of antioxidants in yoghurt enriched with black mulberry as affected by fermentation and stage of fruit addition. *International Dairy Journal* 117, 105018. https://doi.org/10.1016/j.idairyj.2021.105018
39. Edeogu, C.O., Kalu, M.E., Famurewa, A.C., Asogwa, N.T., Onyeji, G.N., Ikpemo, K.O. (2020): Nephroprotective effect of *Moringa oleifera* seed oil on gentamicin-induced nephrotoxicity in rats: biochemical evaluation of antioxidant, anti-inflammatory, and antiapoptotic pathways. *Journal of the American college of Nutrition* 39 (4), 307-315. https://doi.org/10.1080/07315724.2019.1649218
40. El-Gammal, R.E., Abdel-Aziz, M.E., Darwish, M.S. (2017): Utilization of aqueous extract of *Moringa oleifera* for production of functional yoghurt. *Journal of Food and Dairy Sciences* 8 (1), 45-53. https://dx.doi.org/10.21608/jfds.2017.37114
41. El-Sayed, S.M., Youssef, A.M. (2019): Potential application of herbs and spices and their effects in functional dairy products. *Heliyon* 5 (6), e01989. https://doi.org/10.1016/j.heliyon.2019.e01989
42. El-Ziney, M.G., Shokery, E.S., Youssef, A.H., Mashaly, R.E. (2017): Protective effects of green tea and moringa leave extracts and their bio-yoghurts against oxidative effects of lead acetate in albino rats. *Journal of Nutritional Health & Food Science* 5, 1-11. https://doi.org/10.15226/jnhfs.2017.00196
43. Fernandez, M.A., Marette, A. (2017): Potential health benefits of combining yoghurt and fruits based on their probiotic and prebiotic properties. *Advances in Nutrition* 8 (1), 155S-164S. https://doi.org/10.3945/an.115.011114
44. Fungtammasan, S., Phupong, V. (2022): The effect of *Moringa oleifera* capsule in increasing breast milk volume in early postpartum patients: A double-blind, randomized controlled trial. *European Journal of Obstetrics & Gynecology and Reproductive Biology: X* 16, 100171. https://doi.org/10.1016/j.eurox.2022.100171
45. Gahruie, H.H., Eskandari, M.H., Mesbahi, G., Hanifpour, M.A. (2015): Scientific and technical aspects of yoghurt fortification: A review. *Food Science and Human Wellness* 4 (1), 1-8. https://doi.org/10.1016/j.fshw.2015.03.002
46. Georgakouli, K., Mpesios, A., Kouretas, D., Petrotos, K., Mitsagga, C., Giavasis, I., Jamurtas, AZ. (2016): The effects of an olive fruit polyphenol-enriched yoghurt on body composition, blood redox status, physiological and metabolic parameters, and yoghurt microflora. *Nutrients* 8 (6), 344. https://doi.org/10.3390/nu8060344
47. Guon, T.E., Chung, H.S. (2017): *Moringa oleifera* fruit induce apoptosis via reactive oxygen species dependent activation of mitogen activated protein kinases in human melanoma A2058 cells. *Oncology Letters* 14 (2), 1703-1710. https://doi.org/10.3892/ol.2017.6288

48. Gupta, R., Mathur, M., Bajaj, VK., Katariya, P., Yadav, S., Kamal, R., Gupta, R.S. (2012): Evaluation of antidiabetic and antioxidant activity of *Moringa oleifera* in experimental diabetes. *Journal of Diabetes* 4 (2), 164-171. https://doi.org/10.1111/j.1753-0407.2011.00173.x
49. Hamed, A.M., Taha, S.H., Darwish, A.A., Aly, E. (2020): Antioxidant activity and some quality characteristics of buffalo yoghurt fortified with peanut skin extract powder. *Journal of Food Science and Technology* 58, 2431-2440. https://doi.org/10.1007/s13197-020-04835-2
50. Hassan, F.A.M., Bayoumi, H.M., Abd El-Gawad, M.A.M., Enab, A.K., Youssef, Y.B. (2016): Utilization of *Moringa oleifera* leaves powder in production of yoghurt. *International Journal of Dairy Science* 11 (2), 69-74. https://doi.org/10.3923/ijds.2016.69.74
51. Hekmat, S., Morgan, K., Soltani, M., Gough, R. (2015): Sensory evaluation of locally grown fruit purees and inulin fibre on probiotic yoghurt in Mwanza, Tanzania and the microbial analysis of probiotic yoghurt fortified with *Moringa oleifera*. *Journal of Health, Population and Nutrition* 33 (1), 60-67. https://doi.org/10.3329/jhpn.v33i1.3195
52. Hermawan, A., Nur, K.A., Dewi, D., Putri, P., Meiyanto, E. (2012): Ethanolic extract of *Moringa oleifera* increased cytotoxic effect of doxorubicin on HeLa cancer cells. *Journal of Natural Remedies* 12 (2), 108-114. https://doi.org/10.18311/jnr/2012/263
53. Hodas, F., Zorzenon, M.R.T., Milani, P.G. (2021): *Moringa oleifera* potential as a functional food and a natural food additive: a biochemical approach. *Annals of the Brazilian Academy of Sciences - Anais da Academia Brasileira de Ciências* 93. https://doi.org/10.1590/0001-3765202120210571
54. Ibhaze, G.A., Akinbanjo, D.T., Aro, S.O. (2022): Antioxidant, mineral and hydrophobicity properties of value added yoghurt made from tropical fruits. *Animal Research International* 19 (1), 4297-4307.
55. Illupapalayam, V.V., Smith, S.C., Gamlath, S. (2014): Consumer acceptability and antioxidant potential of probiotic-yoghurt with spices. *LWT-Food science and technology* 55 (1), 255-262. https://doi.org/10.1016/j.lwt.2013.09.025
56. Islam, Z., Islam, SM., Hossen, F., Mahtab-ul-Islam, K., Hasan, M., Karim, R. (2021): *Moringa oleifera* is a prominent source of nutrients with potential health benefits. *International Journal of Food Science* 2021, 1-11. https://doi.org/10.1155/2021/6627265
57. Jaiswal, D., Rai, P.K., Mehta, S., Chatterji, S., Shukla, S., Rai, D.K., Sharma, G., Sharma, B., Khair, S., Watal, G. (2013): Role of *Moringa oleifera* in regulation of diabetes-induced oxidative stress. *Asian Pacific journal of tropical medicine* 6 (6), 426-432. https://doi.org/10.1016/S1995-7645(13)60068-1
58. Lisak Jakopović, K., Repajić, M., Rumora Samarin, I., Božanić, R., Blažić, M., Barukčić Jurina, I. (2022): Fortification of cow milk with *Moringa oleifera* extract: influence on physicochemical characteristics, antioxidant capacity and mineral content of yoghurt. *Fermentation* 8 (10), 545. https://doi.org/10.3390/fermentation8100545
59. Ju, J., Gothai, S., Hasanpourghadi, M., Nasser, A.A., Ibrahim, I.A.A., Shahzad, N., Pandurangan, A.K., Muniandy, K., Kumar, S., Arulselvan, P. (2018): Anticancer potential of *Moringa oleifera* flower extract in human prostate cancer PC-3 cells via induction of apoptosis and downregulation of AKT pathway. *Pharmacognosy Magazine* 14 (58), 477-481. https://doi.org/10.4103/pm.pm_516_17
60. Jung, I.L. (2014): Soluble extract from *Moringa oleifera* leaves with a new anticancer activity. *PLoS ONE* 9 (4), 1-10. https://doi.org/10.1371/journal.pone.0095492
61. Jung, I.L., Lee, J.H. Kang, S.C. (2015): A potential oral anticancer drug candidate, *Moringa oleifera* leaf extract, induces the apoptosis of human hepatocellular carcinoma cells. *Oncology Letters* 10 (3), 1597-1604. https://doi.org/10.3892/ol.2015.3482
62. Karthivashan, G., Arulselvan, P., Tan, S.W., Fakurazi, S. (2015): The molecular mechanism underlying the hepatoprotective potential of *Moringa oleifera* leaves extract against acetaminophen induced hepatotoxicity in mice. *Journal of Functional Foods* 17, 115-126. https://doi.org/10.1016/j.jff.2015.05.007

63. Kechagia, M., Basoulis, D., Konstantopoulou, S., Dimitriadi, D., Gyftopoulou, K., Skarmoutsou, N., Fakiri, E.M. (2013): Health benefits of probiotics: A review. *International Scholarly Research Notices* 2013, 1-7. http://dx.doi.org/10.5402/2013/481651
64. Khalafalla, M.M., Abdellatef, E., Dafalla, H.M., Nassrallah, A.A., Aboul-Enein, K.M., Lightfoot, D.A., El-Deeb, F.E., El-Shemy, H.A. (2010): Active principle from *Moringa oleifera* Lam leaves effective against two leukemias and a hepatocarcinoma. *African Journal of Biotechnology* 9 (49), 8467-8471.
65. Khalil, S.R., Abdel-Motal, S.M., Abd-Elsalam, M., Abd El-Hameed, N.E., Awad, A. (2020): Restoring strategy of ethanolic extract of *Moringa oleifera* leaves against Tilmicosin-induced cardiac injury in rats: Targeting cell apoptosis-mediated pathways. *Gene* 730, 144272. https://doi.org/10.1016/j.gene.2019.144272
66. Khan, F., Pandey, P., Jha, N.K., Jafri, A., Khan, I. (2020): Antiproliferative effect of *Moringa oleifera* methanolic leaf extract by down-regulation of Notch signaling in DU145 prostate cancer cells. *Gene Reports* 19, 100619. https://doi.org/10.1016/j.genrep.2020.100619
67. Khan, F., Pandey, P., Ahmad, V., Upadhyay, TK. (2020): *Moringa oleifera* methanolic leaves extract induces apoptosis and G0/G1 cell cycle arrest via downregulation of Hedgehog Signaling Pathway in human prostate PC-3 cancer cells. *Journal of Food Biochemistry* 44 (8), e13338. https://doi.org/10.1111/jfbc.13338
68. Kiros, E., Seifu, E., Bultosa, G., Solomon, W.K. (2016): Effect of carrot juice and stabilizer on the physicochemical and microbiological properties of yoghurt. *LWT - Food Science and Technology* 69, 191-196. https://doi.org/10.1016/j.lwt.2016.01.026
69. Kou, X., Li, B., Olayanju, JB., Drake, J.M., Chen, N. (2018): Nutraceutical or pharmacological potential of *Moringa oleifera* Lam. *Nutrients* 10 (3), 343. https://doi.org/10.3390/nu10030343
70. Kuikman, M., O'Connor, CP. (2015): Sensory Evaluation of moringa- probiotic yoghurt containing banana, sweet potato or avocado. *Journal of Food Research* 4 (5), 165. https://doi.org/10.5539/jfr.v4n5p165
71. LeBlanc, J.G., Laiño, J.E., del Valle, M.J., de Giori, G.S., Sesma, F., Taranto, M.P. (2015): B-group vitamins production by probiotic lactic acid bacteria. *Biotechnology of lactic acid bacteria: Novel applications* 279-296. https://doi.org/10.1002/9781118868386.ch17
72. Liyanage, C., Hettiarachchi, M. (2011): Food fortification. *The Ceylon Medical Journal* 56 (3), 124-127. https://doi.org/10.4038/cmj.v56i3.3607
73. Luangpiom, A., Kourjampa, W., Junaimaung, T. (2013): Anti-hyperglycemic properties of *Moringa oleifera* Lam. aqueous leaf extract in normal and mildly diabetic mice. *British Journal of Pharmacology and Toxicology* 4 (3), 106-109. https://doi.org/10.19026/bjpt.4.5371
74. Madi, N., Dany, M., Abdoun, S., Usta, J. (2016): *Moringa oleifera*'s nutritious aqueous leaf extract has anticancerous effects by compromising mitochondrial viability in an ROS-dependent manner. *Journal of the American College of Nutrition* 35 (7), 604-613. https://doi.org/10.1080/07315724.2015.1080128
75. Masurekar, T.S., Kadam, V., Jadhav, V. (2015): Roles of *Moringa oleifera* in medicine-a review. *World Journal of Pharmacy and Pharmaceutical Sciences* 5 (1), 375-385.
76. Nagaoka, S. (2019): Yoghurt production. *Methods in Molecular Biology* 1887, 45-54. https://doi.org/10.1007/978-1-4939-8907-2_5
77. Nandakumar, K., Bhavyasree, P.S., Thomas, M.T. (2021): Development of rice based probiotic yoghurt enriched with some fruit pulps and its quality analysis. *Journal of Food Science and Technology* 59, 1024-1029. https://doi.org/10.1007/s13197-021-05106-4
78. Nduti, N.N., Mwangi, A.W., Njeru, P.N. (2018): Experimental analogues of iron, manganese and rheology in yoghurt with moringa extract. *International Journal of Food and Bioscience* 2 (1), 5-10.

79. Ngamukote, S., Khannongpho, T., Siriwatanapaiboon, M., Sirikwanpong, S., Dahlan, W., Adisakwattana, S. (2016): *Moringa oleifera* leaf extract increases plasma antioxidant status associated with reduced plasma malondialdehyde concentration without hypoglycemia in fasting healthy volunteers. *Chinese Journal of Integrative Medicine* 2016. https://doi.org/10.1007/s11655-016-2515-0
80. Niero, G., Penasa, M., Currò, S., Masi, A., Trentin, A.R., Cassandro, M., De Marchi, M. (2017): Development and validation of a near infrared spectrophotometric method to determine total antioxidant activity of milk. *Food Chemistry* 220, 371-376. https://doi.org/10.1016/j.foodchem.2016.10.024
81. Nikkon, F., Saud, ZA., Rahman, M.H., Haque, E. (2003): *In vitro* antimicrobial activity of the compound isolated from chloroform extract of *Moringa oleifera* Lam. *Pakistan Journal of Biological Sciences* 6 (22), 1888-1890. https://doi.org/10.3923/pjbs.2003.1888.1890
82. O'Connell, J.E., Fox, P.F. (2001): Significance and applications of phenolic compounds in the production and quality of milk and dairy products: A review. *International Dairy Journal* 11 (3), 103-120. https://doi.org/10.1016/S0958-6946(01)00033-4
83. Obasi, B.C., Sunday, B.A., Brown, T.C. (2019): Enumeration of microbial quality of yoghurt incorporated with *Moringa oleifera* seed flour during storage. *FUW Trends in Science & Technology Journal* 4 (3), 821-825.
84. Ogunyemi, O., Gyebi, G., Shaibu, R., Fabusiwa, M., Olaiya, C. (2021): Antioxidant, nutritional, and physicochemical quality of yoghurt produced from a milk-based fermentation mix enhanced with food spices. *Croatian Journal of Food Science and Technology* 13 (2), 201-209. https://doi.org/10.17508/CJFST.2021.13.2.10
85. Olurishe, C., Kwanashie, H., Zezi, A., Danjuma, N., Mohammed, B. (2016): Chronic administration of ethanol leaf extract of *Moringa oleifera* Lam. (Moringaceae) may compromise glycaemic efficacy of Sitagliptin with no significant effect in retinopathy in a diabetic rat model. *Journal of Ethnopharmacology* 194, 895-903. https://doi.org/10.1016/j.jep.2016.10.065
86. 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 (2), 127-136. https://doi.org/10.1016/j.jssas.2016.02.002
87. Padla, E., Solis, L., Levida, R., Shen, C., Ragasa, C. (2012): Antimicrobial isothiocyanates from the seeds of *Moringa oleifera* Lam. *A Journal of Biosciences - Zeitschrift für Naturforschung C* 67 (11-12), 557-564. https://doi.org/10.1515/znc-2012-11-1205.
88. Ponka, R., Zhung, P.M., Zomegni, G., Tchouape, C.G., Fokou, E. (2022): Organoleptic and physicochemical properties of soy-milk yoghurt enriched with *Moringa oleifera* root powder. *Global Challenges* 6 (5), 2100097. https://doi.org/10.1002/gch2.202100097
89. Pontual, E.V., Carvalho, B.E., Bezerra, R.S., Coelho, L.C., Napoleao, T.H., Paiva, P.M. (2012): Caseinolytic and milk-clotting activities from *Moringa oleifera* flowers. *Food Chemistry* 135, 1848-1854. https://doi.org/10.1016/j.foodchem.2012.06.087
90. Prabakaran, M., Kim, SH., Sasireka, A., Chandrasekaran, M., Chung, I. M. (2018): Polyphenol composition and antimicrobial activity of various solvent extracts from different plant parts of *Moringa oleifera*. *Food Bioscience* 26, 23-29. https://doi.org/10.1016/j.fbio.2018.09.003
91. Quintanilha, G.E.O., Baptista, A.T.A., Gomes, R.G., Vieira, A.M.S. (2021): Yoghurt production added ultrafiltered seed extract of *Moringa oleifera* Lam. *Biocatalysis and Agricultural Biotechnology* 37, 102159. https://doi.org/10.1016/j.bcab.2021.102159
92. Rajan, T.S., De Nicola, G.R., Iori, R., Rollin, P., Bramanti, P., Mazzon, E. (2016): Anticancer activity of glucomoringin isothiocyanate in human malignant astrocytoma cells. *Fitoterapia* 110, 1-7. https://doi.org/10.1016/j.fitote.2016.02.007

93. Rodríguez-Pérez, C., Mendiola, J.A., Quirantes-Piné, R., Ibáñez, E., Segura-Carretero, A. (2016): Green downstream processing using supercritical carbon dioxide, CO_2-expanded ethanol, and pressurized hot water extractions for recovering bioactive compounds from Moringa oleifera leaves. *The Journal of Supercritical Fluids* 116, 90-100. https://doi.org/10.1016/j.supflu.2016.05.009
94. Roy, D.K.D., Saha, T., Akter, M., Hosain, M., Khatun, H., Roy, M.C. (2015): Quality evaluation of yoghurt supplemented with fruit pulp (banana, papaya, and water melon). *International Journal of Nutrition and Food Sciences* 4 (6), 695-699. https://doi.org/10.11648/j.ijnfs.20150406.25
95. Rupa, R., Vijay, L. (2022): Development and characterization of functional yoghurt prepared with *Moringa oleifera* leaf extract. *The Pharma Innovation Journal* 11 (11), 46-49.
96. Saad, M.A., Elkhtab, E.S. (2019): Antimicrobial activity of *Moringa oleifera* leaves extract and its effect on the shelf life and quality of yoghurt. *Egyptian Journal of Dairy Science* 47, 91-99.
97. Saeed, M., Ali, S.W., Ramzan, S. (2021): Physicochemical analysis of mango flavored yoghurt supplemented with *Moringa oleifera* leaf powder. *Journal of Food Science and Technology* 58 (12), 4805-4814. https://doi.org/10.1007/s13197-021-05146-w
98. Sailaja, B.S., Aita, R., Maledatu, S., Ribnicky, D., Verzi, M.P., Raskin, I. (2021): Moringa isothiocyanate-1 regulates Nrf2 and NF-κB pathway in response to LPS-driven sepsis and inflammation. *Plos One* 16 (4), e0248691. https://doi.org/10.1371/journal.pone.0248691
99. Santos, G., Nogueira, R.I., Rosenthal, A. (2018): Powdered yoghurt produced by spray drying and freeze drying: a review. *Brazilian Journal of Food Technology* 21, e2016127. http://dx.doi.org/10.1590/1981-6723.12716
100. Shija, A.E., Rumisha, SF., Oriyo, N.M., Kilima, S.P., Massaga, J.J. (2019): Effect of *Moringa oleifera* leaf powder supplementation on reducing anemia in children below two years in Kisarawe District, Tanzania. *Food science & nutrition* 7 (8), 2584-2594. https://doi.org/10.1002/fsn3.1110
101. Shokery, E.S., El-Ziney, M.G., Yossef, A.H., Mashaly, R.I. (2017): Effect of green tea and Moringa leave extracts fortification on the physicochemical, rheological, sensory and antioxidant properties of set-type yoghurt. *Advances in Dairy Research* 5 (179), 2. https://doi.org/10.4172/2329-888X.1000179
102. Soliman, M.M., Aldhahrani, A., Alkhedaide, A., Nassan, M.A., Althobaiti, F., Mohamed, W.A. (2020): The ameliorative impacts of *Moringa oleifera* leaf extract against oxidative stress and methotrexate-induced hepato-renal dysfunction. *Biomedicine & Pharmacotherapy* 128, 110259. https://doi.org/10.1016/j.biopha.2020.110259
103. Swati, A.K., Kumari, C., Ali, A., Garg, P., Thakur, P., Attri, C., Kulshrestha, S. (2018): *Moringa oleifera*-a never die tree: An overview. *Asian Journal of Pharmaceutical and Clinical Research* 11 (12), 57-65. https://doi.org/10.22159/ajpcr.2018.v11i12.28049
104. Tiloke, C., Phulukdaree, A., Chuturgoon, A.A. (2016): The antiproliferative effect of *Moringa oleifera* crude aqueous leaf extract on human esophageal cancer cells. *Journal of Medicinal Food* 19 (4), 398-403. https://doi.org/10.1089/jmf.2015.0113
105. Tiloke, C., Phulukdaree, A., Gengan, R.M., Chuturgoon, A.A. (2019): *Moringa oleifera* aqueous leaf extract induces cell-cycle arrest and apoptosis in human liver hepatocellular carcinoma cells. *Nutrition and Cancer* 71 (7), 1165-1174. https://doi.org/10.1080/01635581.2019.1597136
106. Trigo, C., Castelló, M.L., Ortolá, M.D. (2022): Potentiality of *Moringa oleifera* as a Nutritive ingredient in different food matrices. *Plant Foods for Human Nutrition* 78, 25-37. https://doi.org/10.1007/s11130-022-01023-9
107. Van Tienen, A., Hullegie, Y.M., Hummelen, R., Hemsworth, J., Changalucha, J., Reid, G. (2011): Development of a locally sustainable functional food for people living with HIV in Sub-Saharan Africa: Laboratory testing and consumer test. *Beneficial Microbes* 2 (3), 193-198. http://dx.doi.org/10.3920/BM2011.0024

108. Vénica, C.I., Spotti, M.J., Pavón, Y.L., Molli, J.S., Perotti, M.C. (2020): Influence of carrot fibre powder addition on rheological, microstructure and sensory characteristics of stirred-type yoghurt. *International Journal of Food Science & Technology* 55 (5), 1916-1923. https://doi.org/10.1111/ijfs.14415
109. Vongsak, B., Mangmool, S., Gritsanapan, W. (2015): Antioxidant activity and induction of mRNA expressions of antioxidant enzymes in HEK-293 cells of *Moringa oleifera* leaf extract. *Planta Medica* 81 (12/13), 1084-1089. https://doi.org/10.1055/s-0035-1546168
110. Wang, F., Bao, Y., Shen, X., Zengin, G., Lyu, Y., Xiao, J., Weng, Z. (2019): Niazirin from *Moringa oleifera* Lam. attenuates high glucose-induced oxidative stress through PKCζ/Nox4 pathway. *Phytomedicine* 153066. https://doi.org/10.1016/j.phymed.2019.153066
111. Wen, Y., Li, W., Su, R., Yang, M., Zhang, N., Li, X., Li, L., Sheng, J., Tian, Y. (2022): Multi-target antibacterial mechanism of Moringin from *Moringa oleifera* seeds against *listeria monocytogenes*. *Frontiers in Microbiology* 13, 925291. https://doi.org/10.3389/fmicb.2022.925291
112. Wu, T., Deng, C., Luo, S., Liu, C., Hu, X. (2023): Effect of rice bran on properties of yoghurt: Comparison between addition of bran before fermentation and after fermentation. *Food Hydrocolloids* 135, 108122. https://doi.org/10.1016/j.foodhyd.2022.108122
113. Wu, Y.Y., Xu, Y.M., Lau, A.T. (2021): Anti-cancer and medicinal potentials of Moringa isothiocyanate. *Molecules* 26 (24), 7512. https://doi.org/10.3390/molecules26247512
114. Xu, Y.B., Chen, G.L., Guo, M.Q. (2019): Antioxidant and anti-Inflammatory activities of the crude extracts of *Moringa oleifera* from Kenya and their correlations with flavonoids. *Antioxidants* 8, 296-307. https://doi.org/10.3390/antiox8080296
115. Yang, R.Y., Lin, S., Kuo, G. (2008): Content and distribution of flavonoids among 91 edible plant species. *Asia Pacific Journal of Clinical Nutrition* 17 (S1), 275-279. https://doi.org/10.6133/apjcn.2008.17.s1.66
116. Zhang, T., Jeong, C.H., Cheng, W.N., Bae, H., Seo, H.G., Petriello, M.C., Han, S.G. (2019): Moringa extract enhances the fermentative, textural, and bioactive properties of yoghurt. *LWT* 101, 276-284. https://doi.org/10.1016/j.lwt.2018.11.010
117. Zongo, U., Zoungrana, SL., Savadogo, A., Traoré, AS. (2013): Nutritional and clinical rehabilitation of severely malnourished children with *Moringa oleifera* Lam. leaf powder in Ouagadougou (Burkina Faso). *Food and Nutrition Sciences* 04 (09), 991-997. https://doi.org/10.4236/fns.2013.49128