https://chemclassjournal.com/
ChemClass Journal Vol. 9 Issue 4 (2025); 194 - 213
e-ISSN:3092-8214 p-ISSN:3092-8206
doi.org/10.33003/chemclass-2025-0904/14

Gum Arabic and Its Potential as Medicine in Kidney Diseases, a Mini Review

Ahmad Alin Baffa [1, 2, a)] and Maimuna Waziri [1, b)]

[1]*Department of Chemistry, Federal University Gashua, 631101, Yobe State, Nigeria.*
[2]*School of Chemical Sciences, Universiti Sains Malysia, 11800, Pulau Pinang, Malaysia.*

***Corresponding author:** Email: a) ahmadalinbaffa@yahoo.com, aabaffa@student.usm.my, b) maimunakadai@gmail.com.

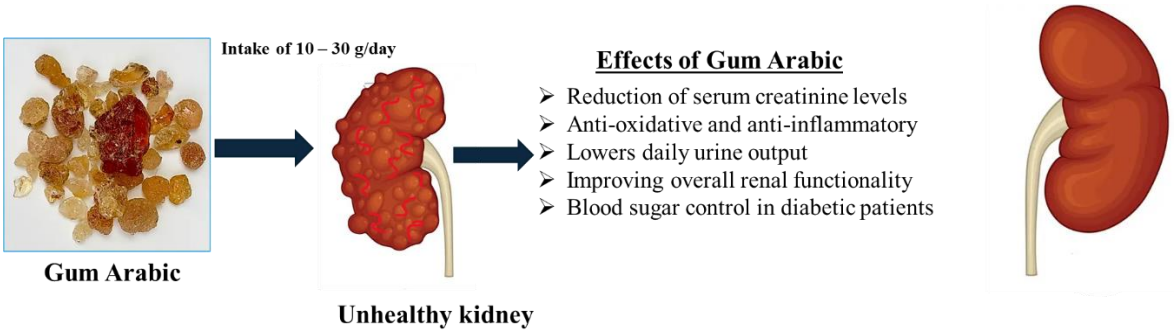
Abstract

The physicochemical characteristics and emerging therapeutic uses of Gum Arabic (GA), a natural hydrocolloid—formally described as a complex polysaccharide derived from the exudates of *Vachellia seyal* (formerly Acacia seyal) and *Senegalia senegal* (formerly Acacia senegal)—are methodically examined in this mini-review. Because of its useful functions as an emulsifier, stabiliser, and viscosity modifier, it is widely used in the food, pharmaceutical, and cosmetic industries. With a 'Generally Recognised as Safe' (GRAS) designation from the U.S. Food and Drug Administration (FDA), its safety profile is well-known around the world. With the Republic of Sudan accounting for around 70% of global trade, the global supply chain is still very concentrated. Other producing countries, such as Chad, Nigeria, Mali, Niger, and Senegal, provide the remaining supply, with Nigeria being a key West African contributor. Due to its high biochemical content and complex amino acid profile, recent clinical literature posits GA as a significant nephroprotective agent. This review, thus, synthesises findings demonstrating GA's efficacy in managing chronic kidney disease (CKD). Mechanistically, GA's observed benefits—including the reduction of elevated serum creatinine levels and the clinical downregulation of CKD staging—are attributed to its potent anti-inflammatory and anti-oxidative properties. Furthermore, this paper briefly summarises the established role of GA in glycaemic control. Based on current evidence, the maximum daily intake is established not to exceed 30 g/day. We critically conclude that thorough consideration of potential drug-excipient interactions is essential, particularly for patients undergoing chronic pharmacotherapy. Therefore, while moderation is key for this food additive and dietary supplement, we strongly advocate that individuals with pre-existing health conditions must seek consultation with a qualified healthcare professional before initiating GA supplementation to ensure clinical suitability and appropriate dosing.

Keywords: *Acacia senegalese*, *Acacia seyal*, Chronic Kidney, Gum Arabic, *Senegalia senegal*, *Vachellia seyal*

© CSN Zaria Chapter

Graphical abstract



Introduction

1.1 The origin and properties of gum Arabic:

Gum Arabic (GA) is a plant-based natural substance derived from acacia trees (*Acacia seyal* and *Acacia Senegal)* from the Leguminosae family. GA is usually found in Nigeria, Tchad, Sudan (Al-Jubori et al., 2023), Senegal, Ethiopia, and some parts of the Indian peninsula (Patel & Goyal, 2015). GA is rich in dietary fibre, with a good percentage of carbohydrates and low protein content (Jaafar, 2019). GA is obtained as a dried sap from a cut from the bark or branches of its trees which will later be cleaned and processed according to the desired exporting condition, mainly to the western countries.

GA was reportedly a branched heteropolysaccharide that was reported to be neutral but sometimes slightly acidic. It is composed of 1, 3-linked β-d-galactopyranosyl units. L-rhamnose, L-arabinose, as well as D-glucuronic acid have also been detected as constituents of GA (Shirwaikar et al., 2008). It was also reported that GA is a matrix of magnesium, calcium and potassium salts of polysaccharide acids that can dissolve in water. GA's chemistry, structure, and properties gave it the advantages of biocompatibility as well as biodegradability with a wide range of applications as an emulsifier, thickener, stabiliser, antioxidant etc (Prasad et al., 2022).



Figure 1: A Picture of amber-coloured Gum Arabic (Adapted from Dashtdar & Kardi, 2018).

GA trees mature within 4-5 years, after which the process of collecting latex from a rubber tree is applied in collecting it by piercing or cutting method with a sharp object, such as a cutlass or a knife. Slowly, whitish, sticky, sparkling substances appear, which are then collected, dried and processed according to the desired use.

1.2 Common uses of GA in Food and Industry

1.2.1 Food industry: GA has gained interest in many fields ranging from food industries as emulsifiers, stabilisers, and thickening agents (Shao et al., 2020). It can be best described as a non-starchy polysaccharide that can ferment inside the colon to remove short chain fatty acids and resist intestinal enzymes (Shirwaikar et al., 2008). GA has been applied in extending the shelf lives of some fruits and vegetables courtesy of its emulsifying, stabilising, and binding properties. When GA is applied as an edible coating, an improvement in the postharvest shelf-life and preservation of fruit and vegetable quality was observed. It affects both the physicochemical and phytochemical properties of the fruits and vegetables as well as their physiological disorders, and sensory qualities (Tiamiyu et al., 2023).

GA was also found to be used in reducing the salt content by minimising the effects of Na^+ (Li et al., 2020). It was also reported that adding some high amounts of GA enables a 30% reduction in the salt content of liquid and semi-solid foods in yoghurt drinks and mayonnaise, without affecting the saltiness perception (Li et al., 2019). GA was also found to improve the stability of curcumin when used as a scaffolding material for loading curcumin. The digestive properties and characteristics of the curcumin-loaded nanoparticle showed an enhanced stability under high saline dosage. The stability of the curcumin loaded in the nanoparticles was found to be significantly higher than that of free curcumin under ultraviolet irradiation. The GA-curcumin-nanoparticle was found to be a good nanocarrier for improving curcumin stability that can be applied in food systems that include salt addition (Ai et al., 2023). GA was also found to be used as a thickener in the food industry by increasing the viscosity of sauces, syrups etc. It also encapsulates the flavours of beverages and foods. The United States Food and Drug Administration (FDA) has accepted GA as a generally safe material as food or as a food additive. It has also been accepted by the European Union (EU) as a safe food additive material for its numerous benefits (Obaid, 2020).

1.2.2 As anticorrosive material: Due to GA's polymeric nature and solubility in water, it is used widely as an anticorrosive material, especially in aqueous electrolytes. GA was found to have contained various electron-rich polar sites that easily enable it get adsorbed on metallic surfaces and behave as effective anticorrosive materials. Because of its natural and biological origin, GA

is regarded as one of the environmentally sustainable and edible alternatives to traditional toxic corrosion inhibitors (Verma & Quraishi, 2021).

1.2.3 In the pharmaceutical industry: GA has been widely used. Thanks to its very complex molecular structure that contains 39%–42% galactose, 15%–16% glucuronic acid, 24%–27% arabinose, 12%–16% rhamnose, 12.5%–16% moisture, 1.5%–2.6% protein, and 0.22%–0.39% nitrogen. It has been widely used in the pharmaceutical industries during the past few years. GA has been widely exploited as a useful and effective excipient in accomplishing various nano scaffolds for drug delivery and biomedical applications (De et al., 2021). Other uses of GA in the pharmaceutical industries include tablet binding (holding ingredients of the tablet together in pill form), emulsification (creating stable mixtures of oil and water-based components), and as a suspending agent **(**keeping solid particles suspended in liquid medications).

1.2.4 As a source of antimicrobial and anticancer compounds: GA probiotics catalyse the growth of beneficial bacteria that live in the large intestine of the human being since birth and are useful to the digestive system, immunity system and also, protect the body against cancer, diabetes, pathogens, and obesity. Thanks to its rich fibre content, GA in the gut, is good at enhancing probiotic bacteria, enhancing satiety after meals, regulating hormone secretion, and decreasing gastric emptying, thus improving human health. The research suggested that GA are anti-cancer (Akram Ahmed Aloqbi, 2020).

1.2.5 Other uses of GA: GA is used as a thickener, emulsifier, suspender, binder, stabiliser and encapsulating material in paint production. (Sulieman, 2018; Prasad Niranjan, 2025). It also aids in various industrial applications, such as viscosity control in textile factories and inks (Hassabo et al., 2023). Ali et al. (2020) reported GA as the most commonly used type of adhesive for rolling papers that are used in cigarettes industries (Ali et al., 2020). GA was also reported to be widely used in ceramics, photography, and printing (Üretim et al., 2023).

1.3 Gum Arabic in Nigeria.

Nigeria is among the largest producers of GA in West Africa and the third largest producer cum exporter of GA, following Sudan and Chad (Pretorius & Dayoub, 2025). Some of the already identified major producing areas include, but are not limited to Borno, Yobe, Kebbi, Taraba, Jigawa, Katsina, Plateau, Zamfara, Nasarawa, Adamawa, Niger, Bauchi, and Sokoto states (Finelib, 2017). Sudan produces about 70% of the world's GA, leaving about 30% for Nigeria and other countries, including Chad, Mali, Niger Republic, and Senegal (ELA FOODS, 2017).

2.0 Chemical Composition of Gum Arabic.

GA exhibits an interesting chemical composition that has been of interest for many studies. GA is

composed of complex acidic or neutral polysaccharides that are formed from mixed constituents such as calcium, magnesium, and potassium salt derivatives of the polysaccharide acid (Atgié et al., 2019). While the units 1,3-β-d-galactopyranosyl forms the main chain of the polysaccharide acid, the 2–5 units of 1,3-β-d-galactopyranosyl form the adjacent side chains or side chains that are joined to the main chain by 1,6-linkages (Mariod, 2018). Subsequently, the units of β-d-glucopyranosyl and 4-O-methyl-β-d-glucopyranosyl form the ends of the side and main chains of the polysaccharide acid, respectively (Dave & Bamaniya, 2025; (Shakeel and Hussain, 2018). According to Musa (2019), both chains contain the units of α-L-rhamnopyranosyl, α-L-arabinofuranos, β-D-glucopyranosyl, and 4-O-methyl-β-D-glucopyranosyl, with the last two frequently present as end units (Musa et al., 2019).

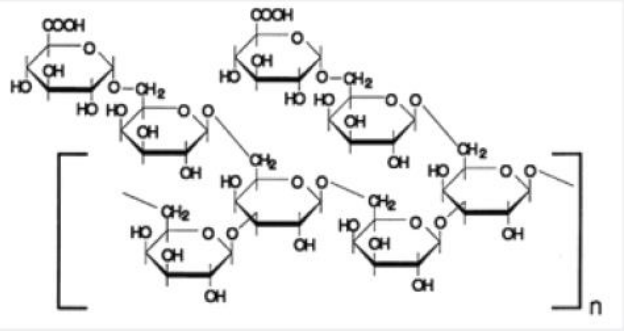


Figure 2: Chemical structure of GA ((Ezera et al., 2019).

GA shows a variety of chemical compositions depending on the species and ages of the trees, climate of the harvested areas, as well as the soil composition of the farms and their structure (Masbernat et al., 2018). Moisture content plays a vital role in the determination of the hardness of GA. Recommended moisture content should be within the international specifications range of 13%–15%, while it's protein content should fall within the ranges 1.5% to 3.0%. Mariod (2018) also reported that the main amino acids found in GA are mostly threonine, serine, hydroxyproline, aspartame, and proline, while it contain minerals such as K, Ca, Na, Mg, P, Fe, and very low doses of Cr, Pb, Zn, Mn, Co, Ni, Cu, and Cd with some variations in chemical compositions and properties caused by factors such as genotypic differences (species), climatic conditions, soil compositions, ages, and plant pathogens (Mariod, 2018).

2.1 The two major forms of Gum Arabic

GA comes in two major forms namely, *Acacia Senagal (or Senegalia senegal)* and *Acacia seyal (or sometimes referred to as Vachellia seyal).* These two species have significant differences in terms of chemical compositions and functional properties. These differences are therefore to be considered, especially regarding their implications for biomedical research, and particularly in the context of kidney disease, where GA was established as a promising dietary supplement with anti-inflammatory and reno-protective potential (Badry et al., 2025; Noha et al., 2022).

In terms of structure, *A. senegal* gum is richer in arabinogalactan-protein (AGP) fractions, which makes it show greater molecular branching. It also contains a higher level of associated protein than to *A. seyal* (Lopez-Torrez et al., 2015). This confers it with higher solubility and better activity, which in turn translates to stronger emulsifying properties that may enhance proper dispersion and bioavailability in physiological systems (Aphibanthammakit et al., 2020). In contrast, *A. seyal* gum is generally more compact and can easily crumble, due to its lower AGP content and hence its reduced emulsifying capacity (Flindt et al., 2005). However, *A. seyal* tends to have higher ash, polyphenol and tannin content, and this may increase antioxidant capacity (Flindt et al., 2005). This can increase antioxidant signatures in some assays but may also produce batch variability and influence gut-microbiota interactions and bioavailability of other compounds. For biomedical uses, especially including renal studies, higher tannin/polyphenol content could modulate antioxidant and inflammatory readouts (Al-Assaf et al., 2007). Antioxidant and anti-inflammatory mechanisms are central to the reno-protective effects of GA. Most clinical studies reporting renal benefits in terms of reductions in creatinine and serum urea levels, as well as inflammatory markers, have used GA preparations derived primarily from *A. senegal* (Khalid et al., 2021; Elamin et al., 2017).

Given these species-dependent differences, explicit reporting of GAs' botanical origin as well as other basic compositional metrics such as protein/AGP content, mineral/ash levels, polyphenol/tannin concentrations, etc, is very important in research related to renal diseases. Such details will aid in proper cross-study comparisons and conclusions about GA's reno-protective effects and will mitigate the risk of confoundment by compositional variability. A brief comparison between *Acacia senegal* and *Acacia Seyal* was illustrated in Table 1.

Table 1: Comparison between *Acacia senegal* and *Acacia Seyal*

Characteristic	***A. Senegal***	***A. seyal***	**Implications for Kidney Research**	**Reference(s)**
Clinical usage	Predominates in renal studies	Less common	Most renal evidence is linked to *A. senegal.*	(Elamin et al., 2017; Khalid et al., 2021)
Emulsifying capacity	Strong	Weak	Relevant to oral formulations and nutrient delivery.	(Aphibanthammakit et al., 2020)
Polyphenols, tannins, ash, mineral content	Lower	Higher	- Potentially greater antioxidant activity but higher variability.	(Flindt et al., 2005)

Characteristic	***A. Senegal***	***A. seyal***	**Implications for Kidney Research**	**Reference(s)**
			- May alter electrolyte balance in renal patients.	
AGP/protein content	Higher	Lower	May enhance solubility, dispersion, and gut fermentation.	(Badry et al., 2025; Noha et al., 2022)
Molecular branching	Highly branched	Less branched	Influences stability and bioavailability.	(Lopez-Torrez et al., 2015)

Given the compositional differences above, authors should explicitly state the botanical source (and ideally the fractionation/AGP content, tannin/ash and protein content) when reporting renal effects — otherwise comparisons across studies may be confounded by species differences. Clinical evidence is promising but limited by small sample sizes and variable reporting of material characteristics. In Tables 2 and 3, some biochemical as well as Amino Acids compositions of *Acacia senegal* and *Acacia Seyal* were presented as illustrated from the works of Lopez et al., (2015).

The result was presented in Table 2.

Table 2. Biochemical constituents of *Acacia senegal* and *Acacia Seyal* (in a dry condition) as reported by Lopez-Torrez et al., (2015)

Component	***A. senegal***	***A. seyal***
Total dry matter **(mg g^{-1})**	889.0	893.0
Sugars **(mg g^{-1})**	940.0	950.0
Proteins **(mg g^{-1})**	27.0	10.0
Minerals **(mg g^{-1})**	33.0	40.0
Galactose (%)	35.8	36.9
Arabinose (%)	30.3	47.6
Rhamnose (%)	15.5	3.0
Glucuronic acid (%)	17.4	6.7
4-O-Me-Glucuronic acid (%)	1.0	5.8

Table 3. Compositions of Amino Acids for *A. senegal* and *A. seyal* gums as reported by Lopez-Torrez et al., (2015).

Amino acids (mg/g)	*A. senegal*	*A. seyal*
Alanine	0.49	0.22
Arginine	0.31	0.12
Aspartic acid	1.24	0.49
Glutamic acid	0.92	0.28
Glycine	0.79	0.25
Histidine	1.37	0.27
Hydroxyproline	6.26	2.13
Isoleucine	0.31	0.13
Leucine	1.83	0.60
Lysine	0.63	0.12
Phenylalanine	0.82	0.21
Proline	1.61	0.56
Serine	2.50	0.95
Threonine	1.42	0.34
Tyrosine	0.31	0.14
Valine	0.71	0.31
Total	**21.5**	**7.1**

3.0 Mechanisms and Benefits of Gum Arabic for Kidney Health

3.1 Nephroprotective Efficacy:

GA, is increasingly considered in nephrology for its potential as a nephroprotective agent against CKD. While GA is relevant globally in the food and pharmaceutical industries due to GRAS status by the FDA, its primary therapeutic mechanism lies in the modulation of the Gut-Kidney Axis. As a water-soluble dietary fibre that is highly fermentable, GA acts as a prebiotic, fostering a favourable shift in the gut microbiota. This modulation is crucial for inhibiting the systemic burden of uremic toxins such as urea and creatinine, which are typically elevated in CKD patients. By increasing faecal bulk and enhancing the binding and elimination of nitrogenous waste, GA effectively employs the bowel as an auxiliary excretory pathway, thereby enhancing the

metabolic workload on the compromised renal system (Alobaidi, 2024); (Farman et al., 2020).

Beyond this direct detoxifying effects, GA has shown significant benefits through its inherent anti-inflammatory and antioxidative properties. Chronic inflammation and oxidative stress are known to be key detrimental factors in the progression of renal fibrosis and structural damage in CKD. The use of GA as a supplement has been clinically associated with a reduction in serum levels of pro-inflammatory markers and the enhancement of endogenous antioxidant defenses, often linked to the activation of the Nrf2 signalling pathway (Ali et al., 2013). Furthermore, its effects contribute to improved metabolic control, including potential attenuation of hyperphosphatemia and enhanced blood-sugar management, factors which significantly complicate CKD. The evidences reported suggests that GA, typically recommended at a maximum daily intake of 30 g/day, offers a valuable, low-cost strategy to manage symptoms and slow the progression of CKD. Caution regarding **drug-excipient interactions** is advised. Emphasis should be placed on the need for professional medical consultation (Anmar Pretorius & Dayoub, 2025).

3.2 Some clinical studies: GA was reported to play a very important role in the improvement of kidney health. The use of GA in patients with chronic kidney disease (CKD) may positively affect the reduction of serum creatinine levels and may downgrade the stage of CKD if given to patients with early CKD. Thanks to the anti-oxidative and anti-inflammatory nature of GA, which was found to have a positive effect on the background inflammation in CKD, and due to its positive effects on the metabolic profiles of some patients (Alshelleh et al., 2023).

Nasir (2008) was reported that GA aids in enhancing the excretion of Mg and Ca ions from the Kidneys and intestines by slowing down the urinary excretion of some inorganic phosphate and simultaneously reducing plasma concentrations of 1, 25-dihydroxy vitamin D. It also assists in creatinine clearance and urinary antidiuretic hormone excretion and lowers daily urine output, thereby subsequently improving overall renal functionality (Nasir et al., 2008).

When GA was applied to decrease the opposing effects of chronic renal failure (CRF), it was reported to have shown an improved effect on nephrotoxicity by clearing creatinine from the patient's body and enhancing the excretion of Mg^{2+}, Na^{+}, Ca^{2+}, and phosphates. It was also found to decrease the amount of plasma phosphate and urea (Salih, 2018; Prasad et al., 2022).

To assess the effect of GA on the metabolic profile of 36 CRF patients, a study was conducted by administering them with 50g/day of GA twice a month for 3 months. Serum urea, uric acid, creatinine, calcium and phosphate were measured, and results were found to have significantly decreased by 23%. The study

concluded that GA substantially decreases the adverse effects of CRF (Ali et al., 2008).

Another study was conducted on rats suffering from CRF. A dose of GA; 1ml/day/kg body weight was added to different percentages of pomegranate juice and orally administered to the rats, and its effects on the subject's kidneys were studied and observed. The results showed an improvement in the functionality of the renal systems (Khojah, 2017).

Al Mosawi (2007) reported that a four (4) year dialysis freedom was achieved and reported on an eleven (11) year old girl who suffered from end-stage renal failure (ESRF). The study reported a novel form of kidney replacement therapy. The traditional conservative management of CRF, which involves dietary and pharmacological methods, was supplemented by the addition of 1g/kg/day of GA to the patient. The result showed an astonishing 4-year ESRF dialysis freedom to the girl who initially needed four sessions of intermittent peritoneal dialysis to mitigate uremic symptoms despite conservative measures. Subsequently, the girl was managed with a new regimen combining the traditional conservative management of CRF with the addition of GA. Interestingly, the girl experienced a four-year dialysis and an improved well-being, coupled with good participation in hobbies and outdoor activities, free of acidotic and significant uremic symptoms (Al Mosawi, 2007).

In another clinical study by Elamin (2017), 36 CKD patients were given 10 to 40 g/day/month of GA to study its systemic effects on the patients. Results showed a slight but statistically significant drop in serum sodium level from 138 to 136 mmol/L, and a huge drop in C-reactive protein level. This was reported to show a positive impact on the patient's health and life span (Elamin et al., 2017).

These and many more findings have therefore established GA as an effective substance in enhancing the health of the kidneys and in the fight against CKD.

3.3 Blood sugar control in diabetic patients with CKD

GA was also found to be good at controlling blood sugar. Administration of water induced with 15% GA for 60 days was found to inhibit the effects of type I diabetes that resulted from elevated damage produced from alloxan monohydrate-induced oxidative stress induced in rats (Ahmed et al., 2015). GA was also found to improve renal function and decrease systemic inflammation, oxidative and nitrosative stress in streptozotocin-induced diabetes in rats with adenine-induced CKD. When treated with GA (15% w/w), a significant amelioration was observed in the renal actions of adenine and streptozotocin, especially concerning histopathological damage. This shows that GA is a vital diet for the suppression of the progression

of CKD in rats with diabetes induced by streptozotocin (Al Za'Abi et al., 2018). Similar research found that the intake of drinking water containing 10% GA suppresses the effects of transforming growth factor-β1 in streptozocin-induced diabetic mice over a month, and also found that the GA has an anti-hyperglycemic effect by decreasing intestinal and plasma glucose levels, thereby dropping down the insulin level (Qureshi et al., 2018).

Additionally, consumption of GA reduces urine volume and the percentage of glucose urea. The protective and preventive impact of GA regarding the complications of diabetes was documented because GA improved nerve damage that leads to pain, weakness, numbness or tingling in one or more parts of the body (neuropathy) and nephropathy (the final stage of nephropathy, which is termed as kidney failure or end-stage renal disease (ESRD). According to the Centre for Disease Control (CDC), diabetes is the most common factor in ESRD and albuminuria, which is a huge sign of kidney disease that means one has excess albumin in the urine (albumin is a protein that is found in the blood. A healthy kidney doesn't allow albumin to get into the urine).

In addition, GA consumption significantly decreases proteinuria, serum phosphate concentration, and enhances the filtration rate of the glomerulus, which in turn improves renal function (Munir Salama et al., 2021; Ahmed et al., 2015). Ibrahim et al. (2003) performed a study to ascertain the effects of GA on the biochemical, histopathological, and immunohistochemical effects observed in diabetic rats induced using alloxan. After 21 days, the rats were sacrificed and analysed. Results obtained showed that GA treatment of diabetic rats significantly increases their body weights, reduces their blood glucose levels, enhances their insulin levels, exerts an anti-inflammatory effect, and improves the pancreas tissue structure. Therefore, GA showed an overall improvement on the pharmacological effects in diabetic rats and is therefore recommended to be employed as diabetic therapy to decrease the hyperglycaemic damage. The study thus concluded that GA may be applicable for many autoimmune and inflammatory disease treatments. (Ibrahim et al., 2023).

In similar study, the effect of experimental diabetes-kidney-failure induced by gentamicin and the positive impact of administration of GA was studied. The results were found to have increased the phenolic and total flavonoid content. For the study, different diabetic rat groups were fed on a basal diet with an intake of drinking water (at various concentrations of 5, 10, 15, and 20 g of GA dissolved in 100 ml of water/day). The results indicated that the lipid profile of the rats gradually reduced in triglycerides from 128.30 to 77.53 mg/dL, total cholesterol dropped from 163.18 mg/dL to 111.19 mg/dL, and glucose

dropped from 192.52 mg/dL to 111.24 mg/dL. Their kidney functions proved that urea, creatinine, blood urea nitrogen, uric acid, and bilirubin dropped from 1.34, 0.95, 2.24, 45.61, and 0.66 mg/dl to 0.78, 29.84, 2.12, 16.25, and 0.18 mg/dL, respectively, after GA was taken. The results also indicated that calcium and sodium levels gradually spiked, and there was a gradual decrease in potassium, phosphorus, and magnesium. The research findings established that the oral treatment of the rats with GA had inhibited the side effects of gentamicin and streptozotocin, as shown by the improvement of their lipid profile, kidney function, some minerals in serum, and antioxidant enzyme in kidney tissues, which may be referred to as its content of antioxidant active ingredients (Alshehry, 2022).

GA is therefore established as a beneficial dietary material in inhibition the progression of CKD in diabetic patients. This is due to GA's rich and enhanced composition of phenols and flavonoids causing its high antioxidant activity. Results from various researchers showed an improvement in diabetic patients with kidney failures when taking considerable doses of GA, as well as their kidney functions, lipid profile, as well as some minerals in their blood serum, and antioxidant enzymes in the kidney. GA could therefore be considered as a safely-edible, protective substance against diabetic and kidney damage.

4.0 Dosage and Safety Considerations of Using GA

4.1 Dosage considerations: Some studies have established that administering a considerable dosage of GA could be effective. A study was carried out on 47 patients carrying haemoglobin S (HbS). In the study, GA was administered in a dose of 30 g/day for 12 weeks in patients with sickle cell anaemia. It was observed that there is a reduction in bilirubin, and serum urea. The results show that GA enhanced the level of haemoglobin-F (HbF) and significantly reduced the level of HbS. This positive effect of GA clearly highlighted that GA degradation has resulted in short-chain fatty acids, which subsequently stimulated HbF expression in the patients red blood cells (Al-Jubori et al., 2023).

In another study by Kaddam et al at (2017) to demonstrate the beneficial effect of GA in the management of sickle cell anaemia, a dosage of 30 g/day was administered for twelve weeks. The results showed that GA ingestion produced a reduction in some of the oxidative stress markers, such as hydrogen peroxide and hydroxyl radicals, with an improvement in antioxidant activity (Kaddam et al., 2017). Interestingly, Glover et al. (2009) explored the reduction effect of GA on systolic blood pressure after taking a dose of 25 g/day for 8–12 weeks. A significant beneficial effect of dietary supplementation with GA on blood pressure in

both normal individuals and patients with impaired renal function resulting from diabetes mellitus was clearly observed (Glover et al., 2009).

In another study, GA was shown to be a prebiotic fibre that supports the growth of lactic acid bacteria and bifidobacteria, which is important for some groups of people, especially the elderly who have a low level of bifidobacteria populations. GA was found to have exerted a prebiotic effect at a dose of 10g/day. This GA fibre may affect the physiological status of humans by hindering glucose absorption, stool mass increment, bile acids trapping and other effects (Calame et al., 2008; Cherbut et al., 2003).

4.2 Side effects of Gum Arabic

GA is generally recognised as safe (GRAS) by the FDA, excessive consumption or individual sensitivities may lead to certain side effects. The most commonly reported side effects of GA are gastrointestinal issues. Because of its high fibre content, consuming large quantities can cause bloating, gas, and abdominal discomfort. Studies have reported that a daily intake of more than 30 grams may lead to these symptoms due to the gut's microbiota fermentation of the indigestible fibre (Castellani et al., 2010). A study by Phillips and Phillips reported that a dose of 40 grams per day led to flatulence and diarrhoea in some (Phillips & Phillips, 2011).

Allergic reactions to GA, although rare, have been reported. These reactions could be mild skin rashes and hives to more pronounced symptoms such as anaphylactic shock. Some case reports in medical literature have linked GA exposure to occupational asthma in workers handling the powder, suggesting a potential for inhalation-related allergies (Romita et al., 2018; Tschannen et al., 2017). Therefore, it is recommended that individuals with a history of allergies to legumes or other plant-based gums should exercise caution and wear maximum protective gear while in contact with GA.

Furthermore, there are some concerns regarding potential interactions with certain medications. As a good soluble fibre, GA may affect the absorption of some drugs by either binding to them or inhibit gastric emptying. This may potentially reduce the bioavailability of certain oral medications, such as cholesterol-lowering drugs and antibiotics. Even though Al-Jubori et al., (2023) has established otherwise, it is still important to note the importance of timing medication intake away from GA consumption to avoid or minimise such possible interactions(Al-Jubori et al., 2023)

In conclusion, while GA is a safe and beneficial additive for most people, it may not be without potential side effects. The most common issues are likely to be gastrointestinal, due its high fibre content. Allergic reactions, though not frequent, are a possibility, and caution is advised

for individuals with recorded sensitivities. It is also paramount to consider potential drug interactions, especially for those on long-term medication. As with any other dietary supplement and food additive, moderation has proven to be key. Therefore, individuals with some existing health conditions or concerns are highly encouraged to always consult a healthcare professional for suitability and recommended dosages.

5.0 Conclusion, research gaps and recommendations.

In conclusion, this review has discussed the chemistry, sources, composition and efficacy of Gum Arabic in the context of kidney health. The review also highlights the importance of Gum Arabic with respect to diabetic patients due to the risks of developing CKD. The recommended dosage of intake shouldn't exceed 30 g/day, while side effects may range from mild to severe depending on individual differences. Even though, GA is recommended as a vital food supplement in both healthy and kidney-related patients in mitigating or controlling the risks associated with chronic kidney diseases, the following research gaps still exists:

i. The lack of sufficient evidence on GA's effect on dialysis-free survival.
ii. Lack of accurate and updated data on the exact mechanisms of GA's renoprotection.
iii. Lack of large-scale, multi-dimensional, randomised and controlled trials (RCTs) to confirm long-term efficacy and safety of GA over several years.
iv. Safety and drug interaction gaps exist due to a lack of critical data on pharmacokinetic interactions between GA as a highly effective fibre and adsorbent, and common kidney disease medications, e.g., phosphate binders, immunosuppressants, or certain antibiotics. This should be considered as a major safety gap.

This review, therefore, recommends that researchers critically consider the above-mentioned gaps as future studies.

References

Ahmed, A. A., Fedail, J. S., Musa, H. H., Kamboh, A. A., Sifaldin, A. Z., & Musa, T. H. (2015). Gum Arabic extracts protect against hepatic oxidative stress in alloxan induced diabetes in rats. *Pathophysiology*, *22*(4), 189–194. https://doi.org/10.1016/J.PATHOPHYS.2015.08.002

Ahmed, Shakeel., & Hussain, C. Mustansar. (2018). *Green and sustainable advanced materials. Volume 1, Processing and characterization*. 358. https://books.google.com/books/about/Green_and_Sustainable_Advanced_Materials.html?id=6nx7DwAAQBAJ

Ai, C., Zhao, C., Xiang, C., Zheng, Y., Zhong, S., Teng, H., & Chen, L. (2023). Gum arabic as a sole wall material for constructing nanoparticle to enhance the stability and bioavailability of curcumin. *Food Chemistry: X*, *18*, 100724. https://doi.org/10.1016/J.FOCHX.2023.100724

Akram Ahmed Aloqbi. (2020). *Gum Arabic as a natural product with antimicrobial and anticancer activities - Archives of Pharmacy Practice*. Archives of Pharmacy Practice. https://archivepp.com/article/gum-arabic-as-a-natural-product-with-antimicrobial-and-anticancer-activities

Al Mosawi, A. J. (2007). 'The use of acacia gum in end stage renal failure.' *Journal of Tropical Pediatrics*, *53*(5), 362–365. https://doi.org/10.1093/TROPEJ/FMM033

Al Za'Abi, M., Al Salam, S., Al Suleimani, Y., Manoj, P., Nemmar, A., & Ali, B. H. (2018). Gum Acacia Improves Renal Function and Ameliorates Systemic Inflammation, Oxidative and Nitrosative Stress in Streptozotocin-Induced Diabetes in Rats with Adenine-Induced Chronic Kidney Disease. *Cellular Physiology and Biochemistry*, *45*(6), 2293–2304. https://doi.org/10.1159/000488176

Al-Assaf, S., Phillips, G. O., Aoki, H., & Sasaki, Y. (2007). Characterization and properties of Acacia senegal (L.) Willd. var. senegal with enhanced properties (Acacia (sen) SUPER GUM^{TM}): Part 1-Controlled maturation of Acacia senegal var. senegal to increase viscoelasticity, produce a hydrogel form and convert a poor into a good emulsifier. *Food Hydrocolloids*, *21*(3), 319–328. https://doi.org/10.1016/J.FOODHYD.2006.04.011

Ali, A. A., Ali, K. E., Fadlalla, A. E., & Khalid, K. E. (2008). The effects of gum arabic oral treatment on the metabolic profile of chronic renal failure patients under regular haemodialysis in Central Sudan. *Natural Product Research*, *22*(1), 12–21. https://doi.org/10.1080/14786410500463544

Ali, A., Rehman, K., Majeed, H., Khalid, M. F., & Akash, M. S. H. (2020). Polysaccharide-Based Adhesives. *Green Adhesives: Preparation, Properties and Applications*, 165–180. https://doi.org/10.1002/9781119655053.CH8

Ali, B. H., Al-Husseni, I., Beegam, S., Al-Shukaili, A., Nemmar, A., Schierling, S., Queisser, N., & Schupp, N. (2013). Effect of Gum Arabic on Oxidative Stress and Inflammation in Adenine–Induced Chronic Renal Failure in Rats. *PLOS ONE*, *8*(2), e55242. https://doi.org/10.1371/JOURNAL.PONE.0055242

Al-Jubori, Y., Ahmed, N. T. B., Albusaidi, R., Madden, J., Das, S., & Sirasanagandla, S. R. (2023a). The Efficacy of Gum Arabic in Managing Diseases: A Systematic Review of Evidence-Based Clinical Trials. *Biomolecules*, *13*(1). https://doi.org/10.3390/BIOM13010138

Al-Jubori, Y., Ahmed, N. T. B., Albusaidi, R., Madden, J., Das, S., & Sirasanagandla, S. R. (2023b). The Efficacy of Gum Arabic in Managing Diseases: A Systematic Review of Evidence-Based Clinical Trials. *Biomolecules 2023, Vol. 13, Page 138*, *13*(1), 138. https://doi.org/10.3390/BIOM13010138

Al-Jubori, Y., Ahmed, N. T. B., Albusaidi, R., Madden, J., Das, S., & Sirasanagandla, S. R. (2023c). The Efficacy of Gum Arabic in Managing Diseases: A Systematic Review of Evidence-Based Clinical Trials. *Biomolecules 2023, Vol. 13, Page 138*,

13(1), 138. https://doi.org/10.3390/BIOM13010138

Alobaidi, S. (2024). Therapeutic Potential of Gum Arabic (Acacia senegal) in Chronic Kidney Disease Management: A Narrative Review. *Journal of Clinical Medicine*, *13*(19), 5778. https://doi.org/10.3390/JCM13195778

Alshehry, G. A. (2022). [Retracted] The Role of Gum Arabic for a Protective Kidney Dysfunction Induced Gentamicin on Diabetes Rats. *Advances in Materials Science and Engineering*, *2022*(1), 8617445. https://doi.org/10.1155/2022/8617445

Alshelleh, S. A., Alhawari, H., Oweis, A. O., & Alzoubi, K. H. (2023). Arabic gum as a natural therapeutic agent for diabetic patients with CKD: A retrospective study. *Electronic Journal of General Medicine*, *20*(4), em497. https://doi.org/10.29333/EJGM/13183

Anmar Pretorius, and, & Dayoub, M. (2025). Trends and Challenges in Gum Arabic Markets in Key Producing Countries in Africa (Sudan, Chad, Nigeria, and Senegal). *Commodities 2025, Vol. 4, Page 16*, *4*(3), 16. https://doi.org/10.3390/COMMODITIES4030016

Aphibanthammakit, C., Barbar, R., Nigen, M., Sanchez, C., & Chalier, P. (2020). Emulsifying properties of Acacia senegal gum: Impact of high molar mass protein-rich AGPs. *Food Chemistry: X*, *6*, 100090. https://doi.org/10.1016/J.FOCHX.2020.100090

Atgié, M., Garrigues, J. C., Chennevière, A., Masbernat, O., & Roger, K. (2019). Gum Arabic in solution: Composition and multi-scale structures. *Food Hydrocolloids*, *91*, 319–330. https://doi.org/10.1016/J.FOODHYD.2019.01.033

Badry, H., El-Beih, N. M., Hussein, A. M., Abd El-Kareem, H. F., & El-Sayed, W. M. (2025). Dose-dependent therapeutic effects of gum acacia on kidney and metabolic dysfunction in adenine-induced chronic kidney disease in rats: involvement of antioxidant pathways. *The Journal of Basic and Applied Zoology 2025 86:1*, *86*(1), 1–11. https://doi.org/10.1186/S41936-025-00467-0

Calame, W., Weseler, A. R., Viebke, C., Flynn, C., & Siemensma, A. D. (2008). Gum arabic establishes prebiotic functionality in healthy human volunteers in a dose-dependent manner. *British Journal of Nutrition*, *100*(6), 1269–1275. https://doi.org/10.1017/S0007114508981447

Castellani, O., Gaillard, C., Vié, V., Al-Assaf, S., Axelos, M., Phillips, G. O., & Anton, M. (2010). Hydrocolloids with emulsifying capacity. Part 3 – Adsorption and structural properties at the air–water surface. *Food Hydrocolloids*, *24*(2–3), 131–141. https://doi.org/10.1016/J.FOODHYD.2009.07.009

Cherbut, C., Michel, C., Raison, V., Kravtchenko, T., & Severine, M. (2003). Acacia Gum is a Bifidogenic Dietary Fibre with High Digestive Tolerance in Healthy Humans. *Microbial Ecology in Health and Disease*, *15*(1), 43–50. https://doi.org/10.1080/08910600310014377

Dashtdar, M., & Kardi, K. (2018). Benefits of Gum Arabic, for a Solitary Kidney Under Adverse Conditions: A Case Study. *Chinese Medicine and Culture*, *1*(2), 88–96. https://doi.org/10.4103/CMAC.CMAC_22_18

Dave, P. N., & Bamaniya, S. (2025). Synthesis, Characterization, and Effective Adsorption of Naproxen Sodium from Wastewater

Using Eco-Friendly Gum Acacia-Grafted-Poly(N,N-Dimethylacrylamide)/CoFe2O4 Hydrogel Nanocomposite. *Water, Air, and Soil Pollution*, *236*(8), 1–24. https://doi.org/10.1007/S11270-025-08151-3/FIGURES/12

De, A., Nayak, A. K., Kundu, A., Das, B., & Samanta, A. (2021). Gum arabic-based nanomaterials in drug delivery and biomedical applications. *Biopolymer-Based Nanomaterials in Drug Delivery and Biomedical Applications*, 165–182. https://doi.org/10.1016/B978-0-12-820874-8.00009-9

ELA FOODS. (2017). *Gum Arabic Producing States In Nigeria And Its Uses*. https://www.finelib.com/about/nigeria-cash-crops/gum-arabic-producing-states-in-nigeria-and-its-uses/156

Elamin, S., Alkhawaja, M. J., Bukhamsin, A. Y., Idris, M. A. S., Abdelrahman, M. M., Abutaleb, N. K., & Housawi, A. A. (2017a). Gum Arabic Reduces C-Reactive Protein in Chronic Kidney Disease Patients without Affecting Urea or Indoxyl Sulfate Levels. *International Journal of Nephrology*, *2017*, 9501470. https://doi.org/10.1155/2017/9501470

Elamin, S., Alkhawaja, M. J., Bukhamsin, A. Y., Idris, M. A. S., Abdelrahman, M. M., Abutaleb, N. K., & Housawi, A. A. (2017b). Gum Arabic Reduces C-Reactive Protein in Chronic Kidney Disease Patients without Affecting Urea or Indoxyl Sulfate Levels. *International Journal of Nephrology*, *2017*(1), 9501470. https://doi.org/10.1155/2017/9501470

Ezera, J. E., Berthrand, N., & Jidimma, W. (2019). *JOJ scin Effects of Graded Quantities of Xanthan Gum on the Physicochemical and Flocculation Properties of Gum Arabic*. https://doi.org/10.19080/JOJS.2019.02.555579

Farman, M. S., Salman, M. I., & Hamad, H. S. (2020). 701 A multifaceted review journal in the field of pharmacy Effect of Gum Arabic Administration on Some Physiological and Biochemical Parameters in Chronic Renal Failure Patients. *Systematic Review Pharmacy*, *11*(6), 2020. https://doi.org/10.31838/srp.2020.6.103

finelib. (2017). *Gum Arabic - Agro Products Supplier*. Finelib. https://elaagroexport.com.ng/product/gum-arabic/

Flindt, C., Al-Assaf, S., Phillips, G. O., & Williams, P. A. (2005). Studies on acacia exudate gums. Part V. Structural features of Acacia seyal. *Food Hydrocolloids*, *19*(4), 687–701. https://doi.org/10.1016/J.FOODHYD.2004.09.006

Glover, D. A., Ushida, K., Phillips, A. O., & Riley, S. G. (2009). Acacia(sen) SUPERGUM™ (Gum arabic): An evaluation of potential health benefits in human subjects. *Food Hydrocolloids*, *23*(8), 2410–2415. https://doi.org/10.1016/J.FOODHYD.2009.06.020

Hassabo, A. G., Abd El-Salam, N. A., Mohamed, N. A., Gouda, N. Z., & Othman, H. (2023). Potential Application of Natural Gums Suitable as Thickeners in Textile Printing. *Journal of Textiles, Coloration and Polymer Science*, *20*(1), 57–65. https://doi.org/10.21608/JTCPS.2023.185110.1153

Ibrahim, R. M., Abdelhafez, H. M., EL-Shamy, S. A. E. M., Eid, F. A., & Mashaal, A. (2023). Arabic gum ameliorates systemic modulation in Alloxan monohydrate-induced diabetic rats. *Scientific Reports 2023 13:1*, *13*(1), 1–11.

https://doi.org/10.1038/s41598-023-31897-x

Jaafar, N. S. (2019). Clinical effects of Gum Arabic (Acacia): A mini review. In *Iraqi Journal of Pharmaceutical Sciences* (Vol. 28, Issue 2, pp. 9–16). University of Baghdad - College of Pharmacy. https://doi.org/10.31351/vol28iss2pp9-16

Kaddam, L., Fadl-Elmula, I., Eisawi, O. A., Abdelrazig, H. A., Salih, M. A., Lang, F., & Saeed, A. M. (2017). Gum Arabic as novel anti-oxidant agent in sickle cell anemia, phase II trial. *BMC Hematology*, *17*(1), 1–6. https://doi.org/10.1186/S12878-017-0075-Y/FIGURES/6

Khalid, S. A., Musa, A., Saeed, A., Elkhair Ali Ali, N., Abugroun, E. A., Mohamed, G., Elnima, E. I., Alkarib, S. Y., Gbir Agib, E., Phillips, G. O., & Phillips, A. O. (2021). Gum Arabic in renal disease (GARDS Study): Clinical evidence of dietary supplementation impact on progression of renal dysfunction. *Journal of Functional Foods*, *82*, 104515. https://doi.org/10.1016/J.JFF.2021.104515

Khojah, E. Y. (2017). AENSI Journals Advances in Environmental Biology Biological effects of low protein diet with gum Arabic on rats chronic kidney disease. In *Advances in Environmental Biology* (Vol. 11, Issue 4). http://www.aensiweb.com/AEB/http://creativecommons.org/licenses/by/4.0/

Li, Y., Han, K., Wan, Z., & Yang, X. (2020). Salt reduction in semi-solid food gel via inhomogeneous distribution of sodium-containing coacervate: Effect of gum arabic. *Food Hydrocolloids*, *109*, 106102. https://doi.org/10.1016/J.FOODHYD.2020.106102

Li, Y., Wan, Z., & Yang, X. (2019). Salt reduction in liquid/semi-solid foods based on the mucopenetration ability of gum arabic. *Food & Function*, *10*(7), 4090–4101. https://doi.org/10.1039/C8FO02593B

Lopez-Torrez, L., Nigen, M., Williams, P., Doco, T., & Sanchez, C. (2015). Acacia senegal vs. Acacia seyal gums – Part 1: Composition and structure of hyperbranched plant exudates. *Food Hydrocolloids*, *51*, 41–53. https://doi.org/10.1016/J.FOODHYD.2015.04.019

Mariod, A. A. (2018). Chemical Properties of Gum Arabic. *Gum Arabic: Structure, Properties, Application and Economics*, 67–73. https://doi.org/10.1016/B978-0-12-812002-6.00006-3

Munir Salama, S., Ali Fadlalmola, H., Mohammed Abdel Hafeez, M., Ali Mohamed Ahmed, S., Awad Mohamed, R., Mohammed Ali Elatta, N., & Adam Mariod, A. (2021). Effectiveness of Gum Arabic in Diabetes and its Complications: A Narrative Review. *Sudan Journal of Medical Sciences*. https://doi.org/10.18502/sjms.v16i3.9703

Musa, H. H., Ahmed, A. A., & Musa, T. H. (2019). Chemistry, Biological, and Pharmacological Properties of Gum Arabic. In *Reference Series in Phytochemistry* (pp. 797–814). Springer Science and Business Media B.V. https://doi.org/10.1007/978-3-319-78030-6_11

Nasir, O., Artunc, F., Saeed, A., Kambal, M. A., Kalbacher, H., Sandulache, D., Boini, K. M., Jahovic, N., & Lang, F. (2008). Effects of Gum Arabic (Acacia senegal) on Water and Electrolyte Balance in Healthy Mice. *Journal of Renal Nutrition*, *18*(2), 230–238. https://doi.org/10.1053/J.JRN.2007.08.004

Noha, , Shebl, Fetaih, H. A., & Dessouki, A. (2022). Effect of Gum Arabic on Chemically Induced Acute Renal Injury in Albino Rats. *Egyptian Academic Journal of Biological Sciences, B. Zoology*, *14*(2), 411–424.

https://doi.org/10.21608/EAJBSZ.2022.274522

Obaid, S. S. (2020). The Medical Uses of Gum Acacia-Gum Arabic (GA) In Human. *Academic Journal of Research and Scientific Publishing* |, *1*(10), 5–7. www.ajrsp.comwww.ajrsp.com

Olivier Masbernat Kevin Roger, M. M., Veronique Schmitt, M., Aquitaine Peter Fischer, C. M., Tech Hochschure Zurich, E., Denis Renard, M., Angers, I., Kevin Roger, P. M., Toulouse, C., Mme ODILE AUBRUN, M., & Olivier Masbernat, M. M. (2018). *Composition and structure of gum Arabic in solution and at oil-water interfaces*. 255. https://doi.org/10.34894/VQ1DJA

Patel, S., & Goyal, A. (2015). Applications of Natural Polymer Gum Arabic: A Review. *International Journal of Food Properties*, *18*(5), 986–998. https://doi.org/10.1080/10942912.2013.809541

Phillips, A. O., & Phillips, G. O. (2011). Biofunctional behaviour and health benefits of a specific gum arabic. *Food Hydrocolloids*, *25*(2), 165–169. https://doi.org/10.1016/J.FOODHYD.2010.03.012

Prasad, N., Thombare, N., Sharma, S. C., & Kumar, S. (2022). Gum arabic – A versatile natural gum: A review on production, processing, properties and applications. *Industrial Crops and Products*, *187*, 115304. https://doi.org/10.1016/J.INDCROP.2022.115304

Prasad Niranjan. (2025). Natural Gums and Resins. In H. Schulz, V. S. Jayakumar, & N. Prasad (Eds.), *Natural Gums and Resins*. CABI. https://doi.org/10.1079/9781800626690.0000

Qureshi, J. A., Memon, Z., Mirza, K. M., & Saher, F. (2018). Herbal Approach towards the Cure of Diabetes Mellitus— A Review. *Asian Journal of Medicine and Health*, *12*(2), 1–12. https://doi.org/10.9734/AJMAH/2018/42470

Romita, P., Bufano, T., Antelmi, A., Gelardi, M., & Foti, C. (2018). Occupational allergic rhinitis and contact urticaria caused by Gum Arabic in a candy factory worker. *Contact Dermatitis*, *78*(6), 427–428. https://doi.org/10.1111/cod.12970

Salih, N. K. M. (2018). Applications of Gum Arabic in Medical and Health Benefits. *Gum Arabic: Structure, Properties, Application and Economics*, 269–281. https://doi.org/10.1016/B978-0-12-812002-6.00023-3

Shao, P., Feng, J., Sun, P., Xiang, N., Lu, B., & Qiu, D. (2020). Recent advances in improving stability of food emulsion by plant polysaccharides. *Food Research International*, *137*, 109376. https://doi.org/10.1016/J.FOODRES.2020.109376

Shirwaikar, A., Shirwaikar, A., Prabhu, S., & Kumar, G. (2008). Herbal Excipients in Novel Drug Delivery Systems. *Indian Journal of Pharmaceutical Sciences*, *70*(4), 415. https://doi.org/10.4103/0250-474X.44587

Tiamiyu, Q. O., Adebayo, S. E., & Yusuf, A. A. (2023). Gum Arabic edible coating and its application in preservation of fresh fruits and vegetables: A review. *Food Chemistry Advances*, *2*, 100251. https://doi.org/10.1016/J.FOCHA.2023.100251

Tschannen, M. P., Glück, U., Bircher, A. J., Heijnen, I., & Pletscher, C. (2017). Thaumatin and gum arabic allergy in chewing gum factory workers. *American*

Journal of Industrial Medicine, *60*(7), 664–669. https://doi.org/10.1002/AJIM.22729

Verma, C., & Quraishi, M. A. (2021). Gum Arabic as an environmentally sustainable polymeric anticorrosive material: Recent progresses and future opportunities. *International Journal of Biological Macromolecules*, *184*, 118–134. https://doi.org/10.1016/J.IJBIOMAC.2021.06.050