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A review on Chitosan and Camel milk/Metal-Organic Frameworks (MOFs): A Synergistic Approach to Biomedical and Environmental Challengesand

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Abstract

In underdeveloped nations, multidrug resistance has grown to be a serious problem. Multidrug resistance bacterial infections lead to a significant increase in patients, death and the cost of prolonged treatment. For this, there is an urgent need to design strategies to improve the antimicrobial potential of therapeutic agents. The current review aims to synthesize chitosan-coated organic Metal-Organic Frameworks (MOFs) and camel milk and use them to treat many diseases. A chitosan has activities that include the antitumor, antimicrobial, antioxidant and anti-inflammatory. These traits position them as promising therapeutic polymers. Camel milk has also shown diverse applications, affecting various aspects such as bone health, muscle function, blood standards, brain function, pancreatic activity, immune response, cancer prevention, infection resistance, metabolism, wound healing, learning, and aging. Metal-Organometallic frameworks (MOFs) are an extremely modifiable hybrid material, consisting of metal ions bound together by organic bonds that have been used as excellent drug delivery agents for cancer and many other diseases. We also highlight the role of chitosan in remove fine suspended particles and heavy metals from polluted the environment. A discovery about the power of chitosan, which was manufactured from food waste and used as a green solution to new environmental challenges.

Keywords: chitosan, Camel milk, Metal-organic frameworks (MOFs). Biomedical, environmental applications.

1. Introduction

The use of natural materials in the current era is one of the greatest concerns from old years, in modern science [1]. It has been extensively since then; popular medicine has employed it frequently. Spider webs, its importance stands out because it is an extraordinary natural phenomenon, it was manufactured as Spidroin gel [2] and PLGA/spidroin nanoparticles for antibacterial and wound-healing potential [3] and spidroin extract against UV radiation damage [4].

Shrimp dominates aquaculture output, constituting approximately 40% (398,500 tons per year) of Thailand's total aquaculture production [5]. However, more than 40% of the by-products, shedding the inessential: Processing discards shrimp exoskeletons (shells, heads, and tails). Consequently. Chitosan, a very abundant biopolymer, is generally found in the crustacean's exoskeletons, cuticle's insect, algae, and the cell walls of fungi. On the other hand, chitosan, a less prevalent counterpart, occurs in certain fungi, specifically in the Mucoraceae family. Traditionally, commercial chitosan has been predominantly derived from chemically deacetylating chitin sourced from crustaceans. However, there is a growing trend towards producing chitosan from fungi, fueled by the rising demand for vegan-friendly alternatives. Fungal factories are revolutionizing chitosan production, offering superior control over factors like viscosity and achieving impressive deacetylation levels. This opens exciting avenues for chitosan with tailored properties. Additionally, the buzz around insect protein extraction has spurred the exploration of insect cuticles as a novel chitosan source. [6].

The family Camelidae includes camels. There are two types of camels: the Arabian or Arabian humped (Camelus bactrians) and the two-humped (Camelus dromedarius) [7]. There are one-humped Arabian camels, concentrated in the Arabian Peninsula, mostly in Africa, the Middle East, South Asia and the Maghreb. Bicameral beauties in Mongolia and

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China [8]. Camels (Camelus dromedarius) live in inappropriate conditions, poor in water and high temperature, and the one-humped camel has a social and economic pillar [9]. Camels have a clear role, especially in dry areas [10] camels enter the race and transport goods, eat their meat and drink their milk for that; they have economic and nutritional value [11]. The camel population is about twenty-nine million, based on statistics from the Food and Agriculture Organization (FAO, 2014). The milking season may reach 18 months. Breed, animal health, health, environment, management practices, and living conditions are factors affecting the milk season.

Camel milk production may be increased by the use of improved feed, water and veterinary examination because the structure of the udder is similar in camels. Because camels can withstand difficult environments, they have been a part of traveler’s daily lives for millennia.

The Camel meat, milk, wool, skin, and other products are highly valued for their flexibility in medicine, as well as their use in sports, transportation, and as a source of pride and prosperity [12]. The single-humped Arabian camel population is approximately 25 million, 159,000 originated in Egypt (FAO, 2014). In Egypt, people are not aware of the nutritive facts and health advantages of camel milk and the fact that its composition differs from that of ruminants [13]. Camel milk is known as “the white gold of the desert [14]. It retains its properties after milking for 8-9 hours [15]. The camel milk produced in 2016 was 2.7 million tons. [16], makes some derived products with high nutritional value [17]. Used to improve digestion in the digestive tract due to their smaller fat globules and hypoallergenic properties [18]. The absence of agglutinin prevents them from assembling spontaneously [17]. Human milk and camel milk are similar in that they do not contain beta-lactoglobulin, so alpha-lactalbumin is the main whey protein of camel milk [19]. Therefore, people with weakened immune systems or lactose intolerance can easily digest camel milk and consume it safely [20]. It contains higher proportion of saturated fatty acids (SFA) than unsaturated fatty acids (USFA) [21]. Indeed, camel milk is beneficial for youngsters allergic to cow's milk since it contains antimicrobial, antidiabetic, antioxidant, and anticancer qualities [17]. Additionally, it has a high concentration of antibacterial substances, including immunoglobulin, lactoperoxidase, lysozyme, and lactoferrin [22]. It has the ability to combat both bacteria and fungi, including Staphylococcus aureus, Escherichia coli, Pneumonia, Klebsiella, Candida krusei, and Candida tropical [23]. The antifungal properties of oleic and linolenic acids may be useful in the management of significant plant diseases [17]. Fresh camel milk has antioxidant activity because it contains casein, bioactive peptides, whey proteins, especially lactoferrin [24]. Materials of the twenty-first century, nanomaterials, along with biotechnology and information technology, have been major areas of review interest [25]. Currently, nanoparticles are utilized in paints that don't scratch surfaces, environmental remediation, sports equipment, electronics, cosmetics, and sensors [26, 27]. Typical properties of nanomaterials are: high density, very high surface area, and favorable chemical activity. However, because to some inevitable issues like intrinsic instability brought on by their high surface-area-to-volume ratio, nanoparticles' larger range of applications is restricted. Therefore, to stabilize these nanoparticles, zeolites and mesoporous materials have been employed; yet, MOFs have been discovered to be a superior stabilize in recent decades. MOFs are a newly emerging family of crystalline porous materials that are attracting attention worldwide for their possible applications and for their study [28, 29]. MOF typically consist of organic linkers and metal ions joined by coordination bonds, which give the structure of MOF exceptional porosity [30-32]. Combined by strong covalent and/or coordination bonding, these hybrids can generate one-dimensional (1-D) chains, (2-D) layers, or even (3-D) networks that probably unify organic and/or inorganic connectivities. In nanoparticle/MOF composites, MOFs are usually used as a template and/or a precursor to include nanoparticles into their cavities [33]. MOFs are typically utilized as a template or precursor to incorporate nanoparticles into their cavities in nanoparticle/MOF composites [34]. These hybrid framework materials are similar to ordinary inorganic materials but have significantly lower densities, more in line with traditional organic systems. Although they have the greater thermal stability of inorganic systems, they exhibit the functionality of organic materials. A great deal of work has been done in this field in recent years to find a better production method and more uses for certain combinations. MOF have proven to be successful platforms thus far in a variety of domains. The noteworthy advancements made by MOF in numerous areas, including luminescence [35, 36], gas storage [37, 38], separation [39, 40], sensing [41], drug delivery [42- 44], catalysis [45, 46], and magnetism [47], are evidence of this (Fig. 1). MOF channels are noticeable class of materials in massive published studies because of their variable shape, size, and functionality, which is quickly expanding their possible applications. However, MOFs can be altered with chemical groups to specifically impact the distribution of contrast imaging agents [48]. Additionally, MOFs have the benefit of functioning as drug transporters and magnetic resonance imaging MRI contrast agents concurrently, which helps with both diagnosis and treatment [49].

In this review: we introduced the overview of nanoparticles MOF composites and their biological applications. This review also seeks to give researchers with a complete overview of the current state and promising achievements of MOFs in the biomedical arena.

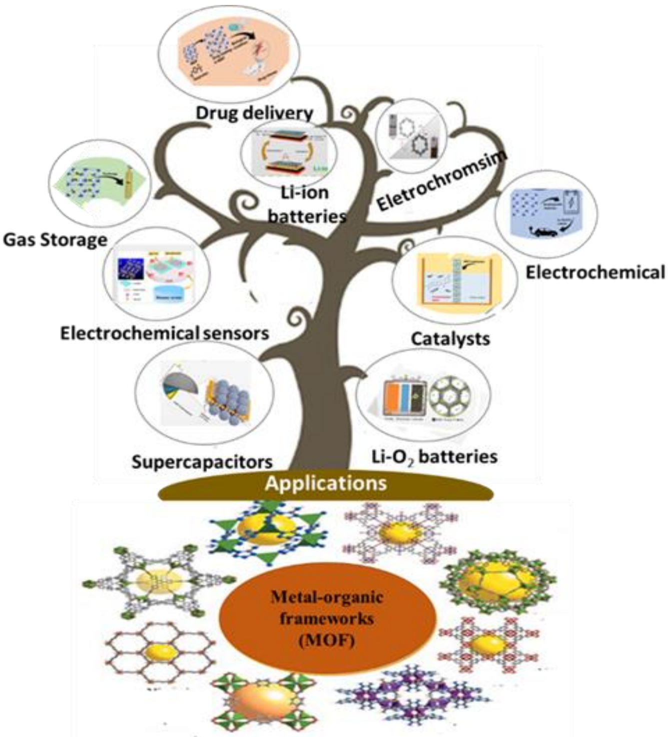

Fig.1: Representation of Metal-organic frameworks (MOF) and their application Chitosan's Intriguing Biological Attributes.

The Dynamic Biological Spectrum of Chitin, Chitosan, Oligosaccharides, and Their Derivatives unfolds an array of activities encompassing antitumoral, antimicrobial, antioxidant, and anti-inflammatory properties. These attributes position them as promising therapeutic polymers. Notably, despite their proven efficacy, it is noteworthy that regulatory agencies currently acknowledge chitosan and chitosan hydrochloride solely as excipients, rather than officially recognizing them as drugs for disease treatment (Fig.2).

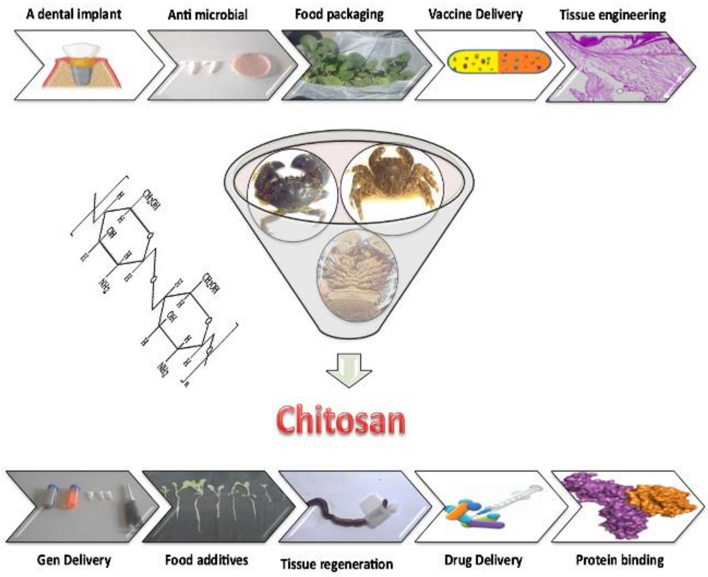

Fig. 2: Chitosan's Intriguing Biological Attributes.

Navigating the Challenge of Bacterial Resistance: Urgency for Antibiotic Alternatives. Chitosan, along with its derivatives and Chito oligosaccharides, emerges as a promising contender against microbial threats. Demonstrating antimicrobial prowess against various microorganisms, including bacteria, filamentous fungi, and yeast [50]. Chitosan presents a growth-inhibitory effect. Notably, bacterial growth resumes once the polymer is removed from the medium, underscoring the importance of understanding potential adaptability to chitosan, as it could lead to the emergence of resistant populations [51]. Unveiling the ant oxidative frontier: exploring the link between oxidative stress and ailments like Alzheimer's, Parkinson's, Huntington's, Amyotrophic Lateral Sclerosis (ALS), cancer, and diabetes [52]. Chitosan, endowed with amino and hydroxyl groups, emerges as a noteworthy player in the antioxidant activity. Its interaction with free radicals showcases scavenging ability. Delving further, certain chitosan derivatives, such as chitosan sulphates or N-2 carboxyethyl chitosan, elevate antioxidant activity [53]. The characterization of Chito-oligosaccharides also undergoes enhancement through chemical modifications, exemplified by polymer adjustments with gallic acid [54] or phenolic compounds [55]. Unraveling the Intricacies of Inflammation: A Fundamental Response Linked to Tissue Damage. The innate purpose of the inflammatory process is to mobilize circulating leukocytes and plasma proteins to the site of infection or tissue damage, aiming to eliminate the causative agent and initiate healing. While inflammation is a vital survival mechanism, its excessive inflammatory or misdirected response against the host can lead to damage. The generation of free radicals is intricately tied to the inflammatory process, with a more pronounced impact observed when chitosan's molecular weight is reduced, highlighting the heightened activity of Chito-oligosaccharides. Following the depolymerization of chitosan (300 kDa) with cellulose, degraded polymers with varying molecular weights and chito-oligosaccharides (COS) (156, 72, 7, and 3.3 kDa) underwent scrutiny for their impact on nitric oxide(NO) secretion, cytokine production, and mitogen-activated protein kinase pathways in a model featuring lipopolysaccharide (LPS)-induced murine research and analysis wing (RAW) 264.7 macrophages. Notably, chitosan samples (parent, medium, and low) demonstrated significant inhibition of nitric oxide (NO) production, while the contrary effect was observed with chitooligosaccharides. The intricacies of inhibiting NF-κB activation and nitric oxide synthase (NOS) expression varied for medium and low molecular weight chitosan. Medium chitosan (156 kDa) accomplished this through binding to CR3, while low molecular weight chitosan engaged CR3 and TLR4 receptors. Conversely, lower molecular weight chitosan activated NF-κB and heightened NOS expression by binding to CD14, TLR4, and CR3 receptors, initiating JNK signaling proteins. Generally, chitooligosaccharides receive more detailed scrutiny for this application due to their superior solubility in aqueous media and overall better performance [56].

2. Potential of Chitosan in Advancing Drug Delivery Science.

Pioneering Progress in Drug Delivery: Chitosan's Unique Biomedical Potential. Since the inception of polymer-based drug delivery systems, chitosan has emerged as a standout candidate, boasting exceptional biological and physicochemical attributes suitable for diverse biomedical and industrial applications. The defining characteristic of this biopolymer lies in its cationic nature attributed to amino groups. These amino groups confer unique characteristics upon chitosan, including mucoadhesion, transfection, in situ gelation, controlled drug release, permeation enhancement, and efflux pump inhibitory properties [57]. Additionally, they increase the significance of chitosan in central nervous system (CNS) biomedical applications. Notably, chitosan's capability to traverse the blood-brain barrier (BBB) has intensified interest in its CNS biomedical implementation. Chitosan's widespread adoption in drug delivery stems from its versatile technological properties, enabling diverse processing methods for the polymer [58]. Embarking on the Pharmaceutical Stage: Chitosan Hydrochloride's Inauguration in 2002 marked the initial approval by the Pharmacopeia. A decade later, chitosan was included as an excipient in the 29th edition of the United States Pharmacopoeia (USP) 34-NF and the European Pharmacopoeia 6. Within these compendia lie meticulous assays and established limits governing the polymer's utilization as a pharmaceutical excipient. Noteworthy is the escalating trend in publications 0documenting the polymer's role in drug delivery, with a robust surge observed since its inaugural approval in 2002, a momentum that persists to this day.

3. Environmental applications of chitosan

1. From Seafood Waste to Environmental Hero: Unveiling the Power of Chitosan.

One of the most prevalent bio-waste products is chitosan. It originates from the fish processing business. Seafood waste was the main source of chitin. The recently discovered novel sources of chitin and chitosan, such as mycorrhizal detritus, mushrooms, and krill, may be able to address the seasonal supply restrictions that have previously existed. It has great potential for use in the removal of organic and inorganic pollutants, including dangerous metals and pigments, from soil, sediments, and water, as well as the development of pollution sensors [59].

2. Chitosan: Nature's Warrior against Pollution.

One of the most hazardous and poisonous contaminants found in water is heavy metals. It is hazardous not only when consumed directly from water but also when it builds up in food, which poses a secondary risk when consuming meat, vegetables, or fish. Chitosan has a high sorption potential for heavy metals due to its great hydrophilicity, which is brought on by a large number of hydroxyls, extremely reactive functional groups, and flexibility of the polymer chain [60].

3. Harnessing Chitosan's Biocleaning Potential: A Green Solution for Environmental Challenges.

We must adopt cutting-edge, eco-friendly materials that are characterized by their biocompatibility, biodegradability, and adaptability in light of new material advancements. The scientific community is concentrating on biopolymers like chitosan, the second most abundant substance in the world after cellulose, because of this. When it comes to energy usage, sustainability, and recycling, these novel materials ought to perform well in industrial settings. The goal is to swap out conventional raw materials for new, eco-friendly ones that not only help to sustain high production rates but also lessen the materials' expenses and environmental impact. Chitosan has some intriguing and special qualities. As a result, it has multiple uses, which aids in the creation of novel, environmentally friendly products. This contributes to improving sustainability by utilizing chitosan and various materials based on it. Chitosan emerges as a champion of sustainability, offering a greener shield for food packaging and a powerful tool for sustainable agriculture. Its impact extends beyond, acting as a pollution-fighter in industrial processes like paper production. This mini-review delves into the exciting world of chitosan, exploring its composition and the multitude of applications driving the circular economy forward [61].

4. Unveiling the Environmental Arsenal of Chitosan: From Water Purification to Soil Remediation.

Environmental biotechnology is the application of biotechnology to the improvement and organisation of biological systems to reduce pollution in the environment. Chitosan, one of the many materials nature has given us for breaking down its resources, is one of the most important biomaterials that is readily available worldwide. A biopolymer obtained by deacetylating chitin that was recovered from marine debris, chitosan is used in many different applications, such as food additives and medicine delivery. Chitosan has many qualities, such as availability, affordability, strong biocompatibility, and biodegradability. These qualities make it appropriate for use in range of chemical and physiological disciplines. Because pure chitosan has a number of disadvantages, there is growing interest in modifying chitosan to improve its inherent properties and expand its applications. This study will give a brief explanation of why chitosan is becoming more and more necessary in the global industrial industry. Water has long been purified with chitosan, and new developments in the sector are making the removal procedure even more successful. In addition to being an adsorbent and flocculant, it can be used to remove biological pollutants, pesticides, heavy metals, dyes, and other contaminants from wastewater [62].

4. Effect of Chitosan Sources Variation on the Enhancement of Camel Milk Yield

Examine the effects of different chitosan sources (commercial vs. chitosan extract) on rumen fermentation, methane (CH4) emission, and camel milk production, as seen in Fig. 3. chitosan derived from shrimp residues presents a potential alternative to commercial chitosan products for modulating rumen fermentation and boosting dairy cow or camel production, all while curbing feed expenses and environmental pollution. It is surprising that the comparative effects of commercial vs extract chitosan sources on ruminal fermentation and milk production in dairy cows have never been evaluated before. Chitosan exhibits a broad-spectrum antimicrobial impact on bacteria, molds, and yeasts, making it a versatile application in both medical and food domains [5]. Notably, [63] proposed that chitosan could play a role in enhancing rumen fermentation, primarily by elevating propionate concentration and reducing the methane-to-acetate ratio. This leads to more efficient energy provision and a decline in ruminal protein disappearance. In the realm of ruminant nutrition, the studies by [64, 65] underscored chitosan's ability to mitigate in vitro methane (CH4) production, elevate C3 concentration, and consequently enhance energy utilization [66]. Evaluations from earlier studies have looked at how chitosan affects ruminal fermentation in in vivo experiments, especially when nursing cows are involved [67]. In addition to its impact on the synthesis of volatile fatty acids (VFAs), research suggests that chitosan lowers rumen bio hydrogenation [5].

DelValle et al. [67] put forth that chitosan not only enhances feed efficiency but also increases the concentration of milk unsaturated fatty acids (UFAs) in camel.

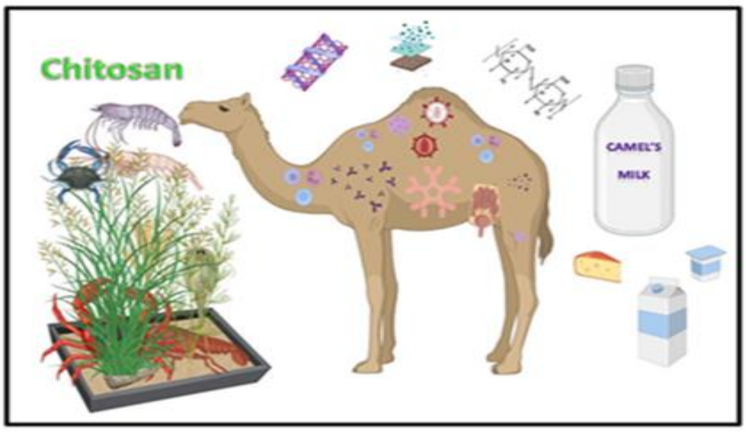

Fig. 3: Influence of chitosan sources on camel milk

5. Benefits of camel milk

As illustrated in camel milk exhibits diverse applications, affecting various aspects such as bone health, muscle function, blood parameters, brain function, pancreatic activity, immune response, cancer prevention, infection resistance, metabolism, wound healing, learning, and aging

Milk contains many ingredients in several forms emulsified, suspended or dissolved in water [68]. Because milk includes calcium and vitamin D, it helps young children's bones grow and develop, which is just one of its many wonderful health advantages. It has also been shown to be beneficial for postmenopausal women for their osteoporosis [69]. Milk is a source of nutrition and contributes to the food security and income of most people in developing countries. About 150 million households operate in milk production worldwide [70]. Camel milk contains many different few sugars that promote the creation of the Bifidobacterium environment, and help in the development of the nervous system [71]. The carotene content of camel milk was lower which makes the camel milk whiter in color, having a slightly salty taste after tasting, and good for people suffering from heart disease [72]. Fat is the most problematic substance in the arteries, including strokes It contains a small amount of fat [73]. It plays a part in rickets, diabetes, cirrhosis, autoimmune illnesses, metabolic disorders, hepatitis, TB, cancer, rickets, and rotavirus diarrhoea [74]. Immunoglobulin reduces sensitivity. So, formula is produced for infants with this allergy [75]. Camel milk does not cause any kind of allergy, and has benefits in reducing the proliferation of cancer cells [74]. Packed with biologically active compounds vital essential, they are. The range of food products derived from camel milk is still significantly restricted compared to that found in cow's milk [74]. Whey is a by-product derived from cheese making, and has gained recognition as an important functional food [76], include reducing blood sugar after eating through various interrelated mechanisms, such as increased secretion of the hormone insulin, delayed gastric emptying, and suppression of appetite and energy consumption. Furthermore, it contributes to long-term glycemic control without noticeable adverse effects [77]. While acknowledging its role in diabetes management, it is critical to consider the potential drawbacks associated with prolonged supplementation, that potentially affect bone density and kidney function. Nonetheless, a recent two-year trial on weight loss in postmenopausal women discovered that a high-protein diet had no clinically meaningful impact on bone density [78]. Studies have reported that a whey protein diet prevents the development of dimethylhydrazine-induced malignancy in mice [79], enhances liver and heart glutathione (GSH) concentrations in elderly mice, leading to increased longevity [80] and raises biliary levels of secretory immunoglobulin A (IgA) in mice [81].

6. Metal-organic frameworks (MOF)

Metal organic frameworks are also known as a comparatively novel crystalline nanoporous material. As seen in Fig. 4, the self-assembly of organic and inorganic-based ligands that serve as linkers in metallic centers and metallic ions that serve as coordination centers is how the MOFs are defined. Porous coordination, or the study of hybrid organic-inorganic coordination networks, is one of the most interesting recent advances in nanoporous research. The primary features of MOFs are their high surface area, which ranges from 1,000 to 10,000 m2/g, high degree of porosity, and adjustable architecture, which is achieved by choosing the right metal ions and linkers. These linkers result in different MOFs when coupled with metallic ions. A variety of organic linkers can be used to combine different metal ions (bound to oxygen atoms, constituting secondary structural units) in the fundamental structure of MOFs, resulting in a vast range of MOF materials. The Cambridge Crystallographic Data Centre claims to have hundreds of various secondary building units available [82]. Notably, different metal–organic frameworks can be formed by swapping out the central atom in the secondary building units while keeping the organic linker intact. The choice of organic linker and metal precursor determines the particular class of MOF.

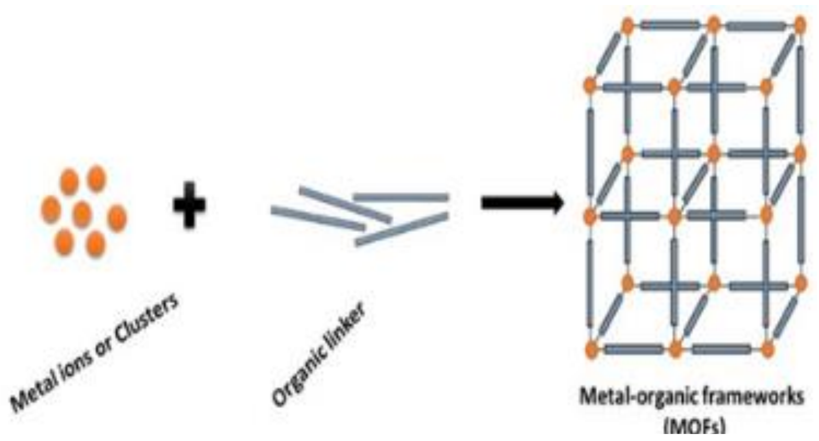

Fig. 4: A comprehensive plan for preparing metal organic frameworks (MOFs).frameworks (MOFs).

MOFs are a particular class of adaptable frameworks of porous crystalline materials with varying topologies and dimensionalities that are produced based on the geometry of the metal ions and the binding mode of the bridging ligands [83-85]. Depending on the structural dimensionality, MOFs can be grouped with or without the guest species. Coordination bonds are dispersed throughout the polymer in a single direction in one-dimensional (1D) MOFs, and tiny molecules fill in any potential vacancies. Where there are weak interactions between the layers in 2D MOFs, the single type layers are stacked using either edge-to-edge or staggered stacking. Changes to the ligand, which makes up the layers, can regulate how the channels inside stack and function. In two-dimensional systems, guest molecules can be accommodated in one of two spaces: (i) the space between the layer grids, or (ii) the space between the layers. The coordination bonds arranged in three dimensions give rise to extremely porous and stable frameworks in three-dimensional MOFs. In most MOFs, 3D pillared layers and grids are present. The connections between the building components are made easier by the non-covalent hydrogen bonding and π-π stacking (1D, 2D, 3D frameworks Fig. 5). These interactions determine their intensity and directionality in addition to transforming the framework into an infinite high-dimensional network.

It is clear from the examined literature that there is a broad range of architectures, topologies, and pore properties shown by metal–organic frameworks. Notably, the length of the carbon chain inside the organic linker largely determines the size of the pores, while the linker's introduction of functional groups affects the chemical properties and extra functionalities [86]. The capacity to modify the characteristics of MOFs by adjusting the basic materials, fabrication process, and testing conditions is an intriguing feature of these devices. MOFs' applicability for a variety of applications is greatly influenced by their chemical and thermal stability. For example, employing X-ray diffraction studies to assess the alterations in MOF characteristics at varying pH values offers valuable information regarding their chemical stability. To evaluate the thermal stability of MOFs, thermogravimetric analysis is frequently used [87]. Because of these qualities, MOFs are excellent choices for biomedical uses such as medication administration and magnetic resonance imaging (MRI) [88-90].

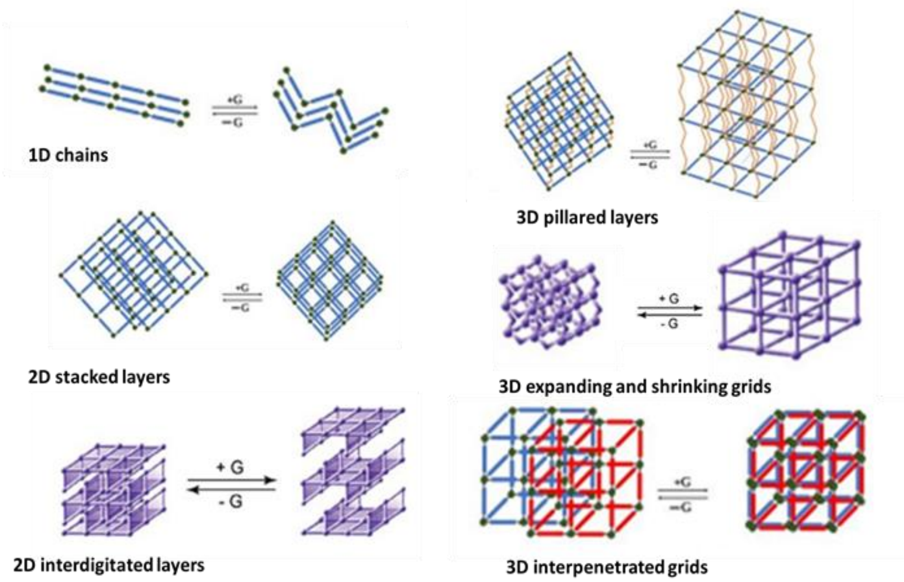

Fig. 5: MOF dimensionality: G represents the guest molecules, blue lines denote organic linkers, yellow lines denote channels, red lines denote various MOF motifs, and black dots stand for metal ions (Figure reproduced from ref. 48).

Over the past ten years, there has been a surge in interest in the unique and appealing biological metal organic frameworks, or Bio MOFs, a subclass of MOFs that opens up new uses in the biological and medical fields. An inorganic–organic framework must either contain a biomolecule or have a direct application in biology or medicine in order to be designated as a Bio MOF, even if there is no set definition for this next generation biocompatible materials. Apart from biocompatibility, the other two most crucial aspects of the design of Bio MOFs are their ability to robustly and selectively retain the targeted therapy or medicine, as well as having pores or cages of the proper size. The latter component, referred to as host-guest chemistry, is essential for aspects of supramolecular recognition. The most important applications of BioMOF are in the fields of medication administration and protection, enantioseparation, magnetic resonance imaging (MRI), photothermal therapy, biomimetic catalysis, biobanking, biosensing, and cell and other manipulations [91]. Modern drug delivery systems have looked closely at metal organic frameworks because of their exceptional drug-loading capacity, informal functionalization, perfect biodegradability, and good biocompatibility. Keskin and Kizilel (2011) [92] believed that because MOFs may modify pore size and have some potential to regulate functional groups, they are the best material for use in drug delivery applications. Synthesis of chitosan and Camel whey protein coated metal organic frameworks (MOFs) is shown in Fig. 6, 7

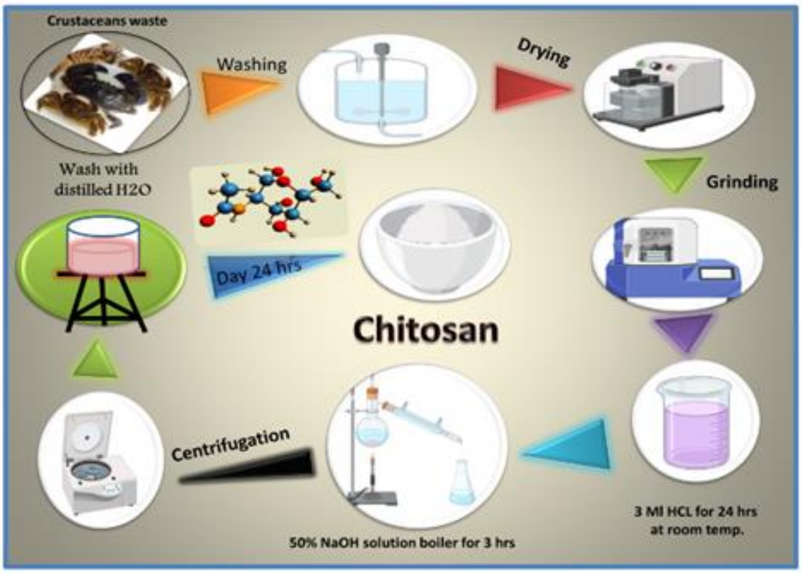

Fig. 6: Synthesis of chitosan

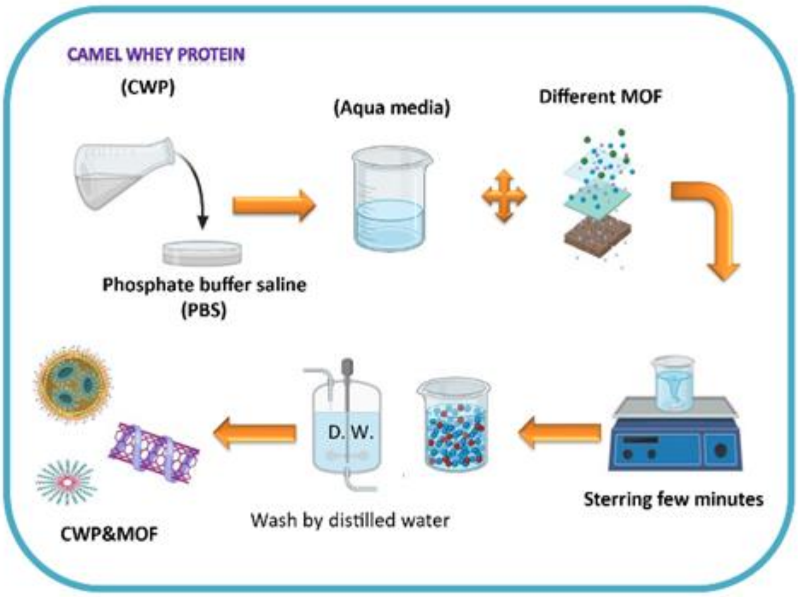

Fig. 7: Synthesis of Camel whey protein coated metal organic

The ability to create nanomaterials with regulated surface characteristics, size, and form has advanced significantly in recent years. The interaction between NPs and biological fluids, particularly proteins, has been documented in numerous investigations. Proteins are adsorbed on the NP's surface, forming a shell that is known as the protein corona. Rapid surface adsorption of proteins with lower affinity for the NP created a soft corona layer, which was later replaced by proteins with higher affinity, creating a hard corona surrounding the NP.

Protein corona can participate positively to overcome the obstacles of the oral administration of the therapeutic proteins. Proteins absorption on the surface of the NP could have a better circulation time and a promising delivery to the target site. Caracciolo et al. showed that the combination of FBS and 3β-[N-(N,N-dimethylaminoethane)- carbamoyl]-cholesterol (DCChol) dioleoylphosphatidylethanolamine DC-Chol-DOPE-DNA lipoplexes change the NP size from 244±4 nm to 741±1 nm and enhance the internalization mechanism of the NPs into cells through the modification from clathrin-dependent to caveolae-mediated [93]. Zensi et al. showed that the intravenously injection of the combination of ApoE with the HAS-coated NP into SV 129 mice has better delivery to the target site. After 15- 30 minutes from scarifying the mice, only NPs conjugated with ApoE were delivered successfully to brain capillary endothelial cells and neurons as compared to NPs only which were not taken up by the brain [94]. There is an interesting study reported that conjugation of bovine milk proteins (lactoperoxidase and lactoferrin) with Chitosan NPs showed enhancement of the cytotoxic activity as compared to the free protein alone. The study showed the nano-combination has a toxic effect against the different cancer cell lines with IC50 < 546 µg/ml and has no toxic effect on the normal cells. However, the positive control 5-FU showed a high toxic effect for both cancer cell lines and normal cells. These promising findings showed the potential of using a protein and peptide as therapeutic agents [95]. MOFs have received great attention due to their high level of porosity and tunable internal structures, and different morphologies that can be made such as polyhedrons, nanowires, and nanoflakes. Therefore, we are proposing to load CWP on novel fabricated MOFs which are biocompatible, biodegradable, and non-toxic [96].

7. Conclusions

MOFs are used as an effective carrier for drug delivery due to their biodegradability, low toxicity and integrity of their structure at loading and functions. The aim of the study is to refer to the design of new bio adhesive NMOFs using chitosan and camel milk as coating materials capable of loading and showing higher stability. Chitosan emerges as a champion for environmental cleanup, boasting the power to tackle new challenges. This versatile biomaterial, even when derived from food waste, transforms into a green solution. From water purification to moisture and humidity control, chitosan's applications offer a multifaceted approach to environmental problems.

8. Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

9. Formatting of funding sources

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