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A Review on The Uniqueness of Albumin as A Carrier in Nano Drug Delivery System

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ABSTRACT:
The quest for precision medicine hinges on targeted drug delivery, minimizing off-target effects while maximizing therapeutic impact. Among nanocarriers, albumin – the most abundant protein in human blood – emerges as a uniquely biocompatible stealth bomber. Its inherent advantages, including exceptional biodegradability, prolonged circulation, and natural affinity for diseased tissues, perfectly align with the goals of personalized medicine. Albumin readily solubilizes poorly soluble drugs, enhancing bioavailability and broadening the therapeutic arsenal. Its versatile surface allows for targeted modifications, enabling dual diagnosis and treatment (theranostics) tailored to individual needs. While challenges remain in optimizing drug loading and targeting specificity, albumin-based nanocarriers hold immense promise for revolutionizing personalized healthcare, delivering potent therapeutics with pinpoint accuracy. The burgeoning field of Nano drug delivery seeks to redefine therapeutic landscapes by engineering nanoscale carriers that meticulously deliver potent drugs to their designated targets, minimizing systemic exposure and maximizing therapeutic efficacy. This pursuit aligns perfectly with the burgeoning field of precision medicine, where personalized treatments demand exquisite control over drug delivery. Within this intricate choreography, albumin, the abundant and versatile protein resident in human plasma, emerges as a maestro, orchestrating a symphony of advantages that make it a prime candidate for Nano carrier construction.

Keywords: Albumin 1, Nanodelivery 2, Globular protein 3, Colloid osmotic pressure 4,

INTRODUCTION:

Nanotechnology has shown great potential in pharmaceutical applications, especially in the area of drug delivery. In particular, nanomaterials allowed the development of platforms for the efficient administration, protection, transport, and specific delivery of challenging therapeutic or diagnostic cargos, such as poorly soluble drugs, proteins, and gene therapeutics, in biological fluids toward cellular and intracellular targets. Nanoparticles have been designed to overcome the limitations of conventional delivery and navigation through biological barriers. In fact, in several instances, nanoparticles of various chemical structures, including lipid, polymer, and inorganic nanocarriers, have shown to effectively offer

control on the biodistribution and/or release of single or multitherapeutic agents and the possibility to overcome biological barriers against targeted drug delivery to the diseased site. However, depending on their structure, such nanocarriers have also presented drawbacks restricting their success in targeted drug delivery, including nonspecific uptake by phagocytic cells, off-target distribution, nonspecific immune activation, inadequate control over drug release in biological systems, and poor intracellular internalization. The plasmaprotein albumin has attracted attention as a natural, yet versatile, Nano delivery system due to its characteristics, including high binding capacities for both hydrophobic and hydrophilic drugs, relatively long half-life,

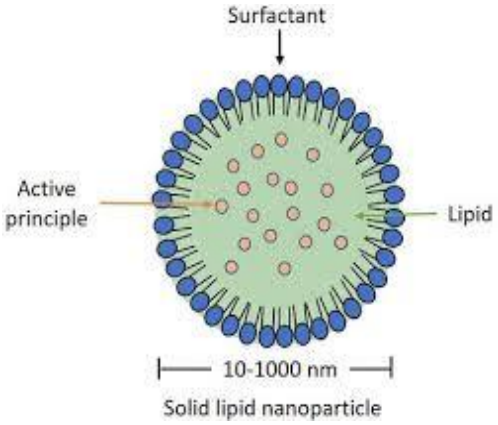
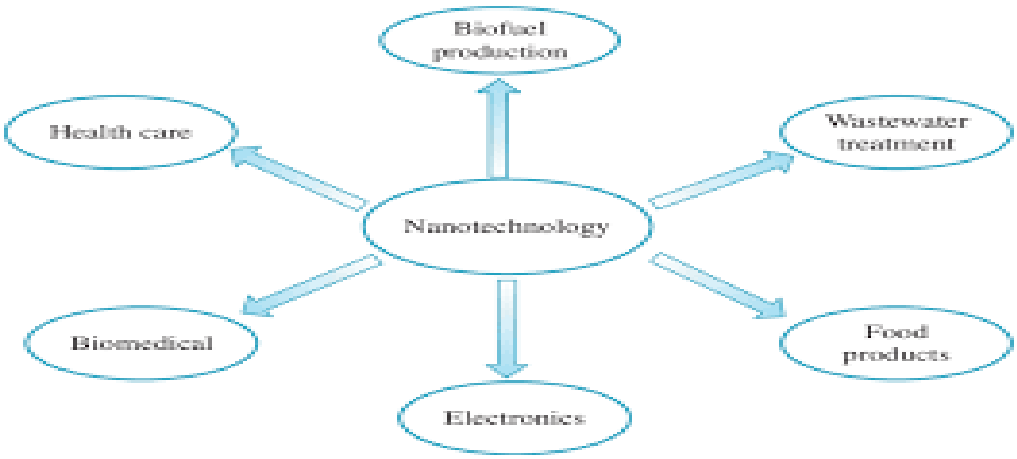


Fig No. 1: Overview of Nanoparticles

Nano drug Delivery Advantage:-

Nano drug delivery systems can overcome these limitations by:

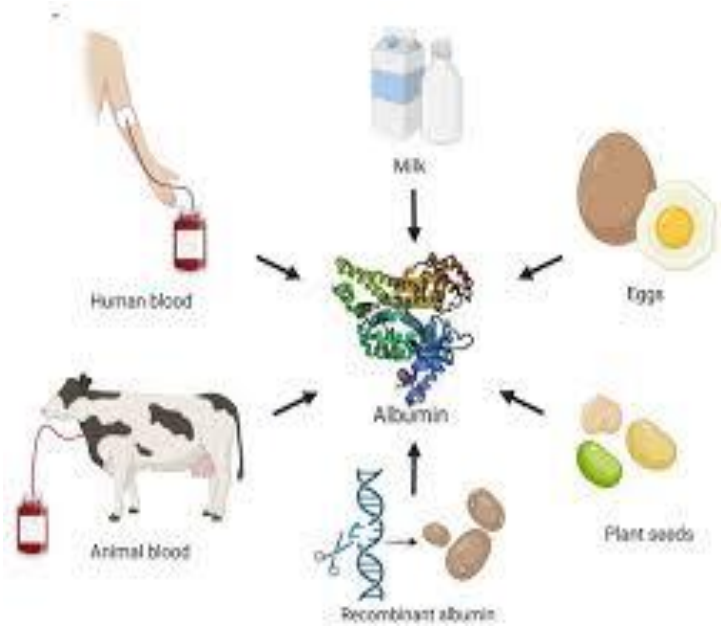
1. Enhancing drug solubility: Nanoparticles can encapsulate poorly soluble drugs, improving their bioavailability and making them more effective.
2. Targeting specific tissues: Nanoparticles can be functionalized with ligands or other targeting moieties that allow them to bind to specific receptors on diseased cells. This targeted delivery reduces the amount of drug that reaches healthy tissues, minimizing side effects
3. Controlled drug release: Nanoparticles can be designed to release their payload slowly over time, providing sustained therapeutic effects with reduced dosing frequency.
4. Protecting drugs from degradation: Nanoparticles can shield drugs from enzymes and other molecules that can degrade them, thereby improving their stability and efficacy.



Figno:- 2 Application of Nano delivery in different fields

Albumin:

Albumin is the most abundant protein in human blood plasma, accounting for about 55% of the total protein content. It is a vital molecule with a wide range of functions, playing a crucial role in maintaining body fluid balance, transporting hormones and nutrients, and binding and detoxifying harmful substances.



Figno:-3 Albumin as a Biomaterials

Physiologic roles of albumin:

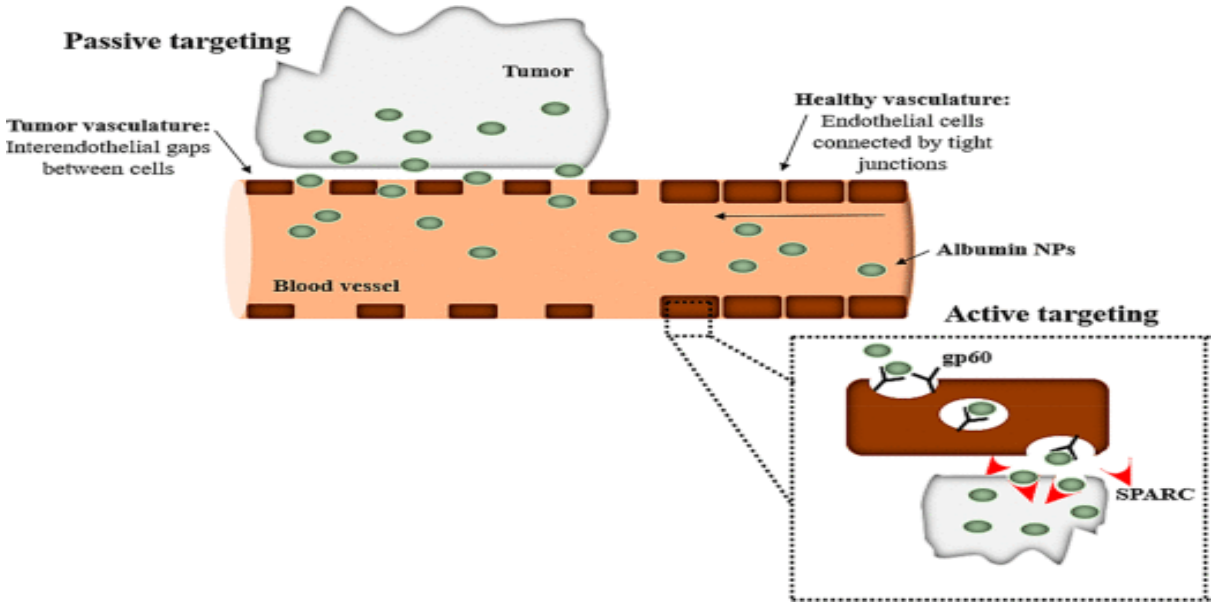
Albumin is one of the most important proteins in plasma with various vital roles. It consists 40% of the protein mass of plasma and has an amount of 35–50 g in every liter of serum. Albumin is responsible for the 80% of osmotic pressure alone. In addition, it has a role in pH maintenance through working as a buffer.

Albumin also known as a carrier of numerous molecules like fatty acids, eicosanoids, biliary acid, steroid hormones, vitamin D and C, copper, zinc, calcium.

The Unique Properties of Albumin Nano carrier in Drug Targeting

The Natural Ability of Albumin in Targeting Cancer and Other Proangiogenic Environments. The hyperpermeability of blood vessels and the impaired lymph drainage, the well-known enhanced permeation and retention (EPR) effect in solid tumors has been proposed as a responsible mechanism for passive targeting of many nano carriers in solid tumors However, the defining role of the EPR effect as a responsible mechanism for passive targeting of Nano carriers in solid tumors, even in preclinical animal models, has been questioned recently. Although it constitutes a paradigm in cancer Nano medicine, Chan et al. demonstrated that 97% of the nanoparticles under their study enter into solid tumors by endothelial cells through an active process of transcytosis and that the interendothelial gaps, which characterize the EPR effect, he case of dog albumin, a defect might exist at the location corresponding to site I. The hydrophobic interactions between DZ and BSA, rabbit serum albumin and RSA are weakened as a result of the tertiary structure change in cavity size, rather than the loss of hydrophobic residues. In conclusion,

it can be stated that RSA and rabbit serum albumin contain a drug binding site, corresponding to site I on HSA, and dog albumin contains a specific drug binding site corresponding to site II on HSA. One of the unique features that make albumin such a powerful and effective drug carrier is that it binds to receptors, which are overexpressed by the tumor. The main pathway that albumin relies on for the internalization inside the tumors is receptor-mediated endothelial transcytosis. . Albumin binds with high affinity to the gp60 receptor, a 60 kDa glycoprotein (albondin). This receptor is found on the surfaces of endothelial cells of the tumors, and after the connection with albumin, it binds to caveolin-1, an intracellular protein that gives rise to an invagination of the cell membrane, leading to the formation of transcytosis vesicles (caveolae) transporting albumin inside the vesicles (caveolae) transporting albumin inside the tumor. . Moreover, SPARC (secreted protein acidic rich in cysteine), also known as antiadhesin, osteonectin, BM40, and 43K protein, which is overexpressed by many types of tumors and absent in normal tissues, attracts albumin and contributes to its accumulation inside the tumor.



Figno-3: Schematic representation of passive versus active targeting.

Functions of Albumin:

Albumin is the most abundant protein in human blood plasma, making up about 55% of total protein content. This versatile molecule plays a crucial role in maintaining our health through various functions, earning it the nickname "the workhorse of human blood.

1. **Maintaining Fluid Balance:** Imagine albumin as a tiny sponge in your bloodstream. Its large size and negative charge attract water molecules, creating a colloid osmotic pressure. that draws fluid from the interstitial space (between cells) into the blood vessels. This helps maintain blood volume and prevents edema (fluid build-up) in tissues. Think of it like a dam holding back water, ensuring the right amount of fluid stays within the blood vessels and doesn't leak out.
2. **Transporting Molecules:** Albumin acts as a delivery truck, carrying essential molecules throughout the body. Its pockets act like binding sites, holding onto various cargo like:

Hormones: Insulin, thyroid hormones, and sex hormones hitching a ride to reach their target cells.

Fatty acids: These energy-rich molecules get transported from the intestines or fat stores to muscles and other tissues for fuel.

Bile acids: These digestive helpers get a lift to the intestines to aid in fat breakdown.

Vitamins: Fat-soluble vitamins like A, D, E, and K rely albumin for a smooth journey through the bloodstream.

Metals: Copper, zinc, and calcium hitch a ride with albumin for distribution and utilization. **3**. Buffering pH: Our body needs a precise pH balance (slightly alkaline) for optimal function. Albumin acts like a chemical buffer, picking up excess hydrogen ions when the pH dips acidic and releasing them when it gets too alkaline. This helps keep the pH within a narrow range, crucial for enzyme activity and overall cellular function.

3. Binding and Detoxifying Toxins: Albumin acts as a bouncer in the bloodstream, binding and neutralizing potentially harmful substances like:

Drugs: By binding to drugs, albumin can slow down their release, preventing them from reaching toxic levels in tissues.

Metals: Heavy metals like mercury and lead can be harmful, but albumin binds them and prevents them from causing damage.

Toxins:. From bacterial toxins to metabolic waste products, albumin helps neutralize and eliminate them from the body.

PREPARATION METHODS OF ALBUMIN NANOPARTICLES

There are several different techniques that can be used to prepare albumin NPs, including

- Desolvation
- emulsification
- nanoparticle albumin-bound technology (Nab-technology)
- thermal gelation
- green chemistry
- and nano-spray drying.

Desolvation

In the desolvation or coacervation process for preparing albumin NPs, ethanol is added drop by drop to an aqueous solution of albumin in order to achieve the desolvation of the albumin solution. The stirring of the solution must be continued until the whole solution becomes turbid. Because of the diminishing water-solubility, the albumin phase separates and aggregates. In addition, through gradual addition of glutaraldehyde solution, particle cross-linking occurs and discrete albumin NPs form . Incubation of the particles at different temperatures under constant stirring can be used in order to avoid the addition of the cross-linker . it shows the stepwise preparation of albumin NP through desolvation method followed by formation of a core-shell structure. A study reported that the lowest concentration of glutaraldehyde which is required for manufacture of albumin NPs with good stability is about 40% Sadeghi et al. explained that compared to the use of pure acetone, ethanol, and mixtures of ethanol with acetone resulted in more spherical NPs .Another study used a desolvation method with a membrane contactor for the large scale production of BSA NPs, with comparable characteristics to particles that were produced by small-scale methods . Moreover, it was suggested that the desolvation technique, which was used to prepare folate-coated BSA-NPs, was promising and effective for delivering poorly water solubility drugs . Fisetin-loaded

HSA NPs with an 84% encapsulation efficiency and a diameter of 220±8 nm were reported using this method. Initial burst release and then sustained and slow release was obtained in vitro . Particle properties including size may be affected by desolvating agent, cross-linker, pH of HSA solution, centrifugation and other characteristics of preparation method resulting in the desired particle size .

Emulsification

In this approach, albumin NPs are formed by the homogenization of aqueous albumin droplets contained in an oil phase. According to this method, drug and cholesterol are dissolved in a mixture of chloroform and ethanol, and then this solution is added to aqueous albumin solution. A crude emulsion is prepared by shearing the resulting mixture, and then this preparation is homogenized using a high-pressure homogenizer. After these steps, evaporation under vacuum is used to produce an organic dispersion of the drug-albumin NPs . In the emulsification method, two different approaches are used for stabilization of the albumin NP: thermal heating or chemical treatment using a cross-linking agent.

Nab-technology

Nab technology is a specific method used to prepare albumin NPs and can also be used for the encapsulation of lipophilic drugs into the NPs. The drug and HSA are mixed in an aqueous solvent. Drug-albumin NPs are then synthesized by passing the solution through a jet nozzle under high pressure. The size range of the NPs produced is about 100-200 nm . A recent study formed a lapatinib-loaded HSA NPs (LHNP) preparation by adding a lapatinibchloroform-ethanol mixture to the HSA solution and then the solution was subjected to high shear forces to form a coarse emulsion. This emulsion was passed through a micro fluidizer and followed by evaporation and filtering of the NPs suspension to achieve the final emulsification. Thereafter the NPs were frozen, lyophilized and stored. The drug can be added to the chloroform and ethanol before the process of emulsification. In this study the LHNP showed high cytotoxicity resulting in apoptosis of tumor cells and serious damage to tumor spheroids was demonstrated.

Nab-paclitaxel (the first FDA approved nanotechnology based drug) was manufactured by this method for the treatment of metastatic breast cancer and recently for other types of cancers . This product has particles about 130 nm diameter and shows increased drug tumor accumulation and superior antitumor efficacy compared to conventional drugs as found using this formulation in preclinical and clinical experiments.

Self-assembly

Another popular process for preparation of albumin NPs is self-assembly. Adding a lipophilic drug and decreasing the number of amine groups on the surface of the protein increases the hydrophobicity of albumin which causes the HSA to undergo self-assembly and results in formation of micelles . In this regard a study added succinylated cholesterol to BSA followed by stirring under argon. Dissolution of the cholesteryl (chol)-BSA, and then gradual addition of paclitaxel was used to produce a albumin-drug composite (paclitaxel-Chol-BSA) under stirring conditions. The paclitaxel-Chol-BSA structure was prepared via self-assembly with high colloidal stability in comparison to structures without Chol. The NPs had a 147.6 ± 1.6 nm hydrodynamic diameter and a high drug-loading capacity Paclitaxel-Chol-BSA NPs acted as an efficient agent showing sustained drug release . Administration of paclitaxel-Chol-BSA NPs resulted in enhanced cellular uptake compared to paclitaxel-BSA and paclitaxel dissolved in Cre/EtOH (i.e. Cremophor El:ethanol . The cytotoxicity evaluation of paclitaxel-Chol-BSA NPs against cancerous cells using a MTT assay, showed lower viability and higher cytotoxicity of paclitaxel induced by these NPs, compared to paclitaxel-BSA and paclitaxel-Cre/EtOH as controls . Another study prepared a BSA-

NPs based DDSs using self-assembly between negatively charged cyclic peptide (cRGD)-modified BSA loaded with DOX and a positively charged cellpenetrating peptide (KALA) through electrostatic interactions Han et al. used this method for the fabrication of cationic BSA NPs for gene delivery and treating metastatic lung cancer.

Other methods

Thermal gelation is another approach for preparation of albumin NPs, and is a sequential process including protein-protein interactions and heat-induced unfolding. For example in one approach solutions of albumin and lysozyme are mixed. The pH of this mixed solution was regulated and afterwards, it was stirred and heated. NPs prepared in this way had a spherical shape and a core-shell structure. Nanoparticle production using natural materials, called "green chemistry" or green synthesis, can be used to provide safer NPs with reduced adverse side effects. For example Lam et al. used glucose instead of glutaraldehyde as a cross-linking agent for modification of BSA to prepared NPs for delivery of berberine with reduced potential biological toxicity Using glucose and BSA, both of which have good biocompatibility and biodegradability can lead to more rapid degradation of nanoparticles in biological environments. The last process, nano-spray drying, is commonly utilized for manufacturing a dry powder. To generate droplets, nano-spray dryers use a vibrating mesh technology. At the first stage, a piezoelectric crystal drives the spray head, then the mixture passes through a small spray cap which has a thin perforated membrane named "spray mesh". The piezoelectric actuator moves at an ultrasonic frequency and its movement causes the spray mesh to vibrate up and down. The vibration causes production of numerous droplets with a precise size This method can be used for preparation of dry powder with uniform-sized particles from a liquid phase.

Because of the possibly undesirable use of organic solvents and crosslinking agents in emulsification, the desolvation method can be an alternative due to its robustness and reproducibility. On the other hand, nab-technology particles can be used for intravenous applications without using any surfactants and denaturing of the HSA . In addition, thermal gelation can be used for fabrication of nanoscale hydrogels, and self-assembly can be used for high loadin of poorly water-soluble drugs, and lastly nano-spray drying provides a single-step continuous and scalable process for preparation of NPs continuous and scalable preparation of NPs.

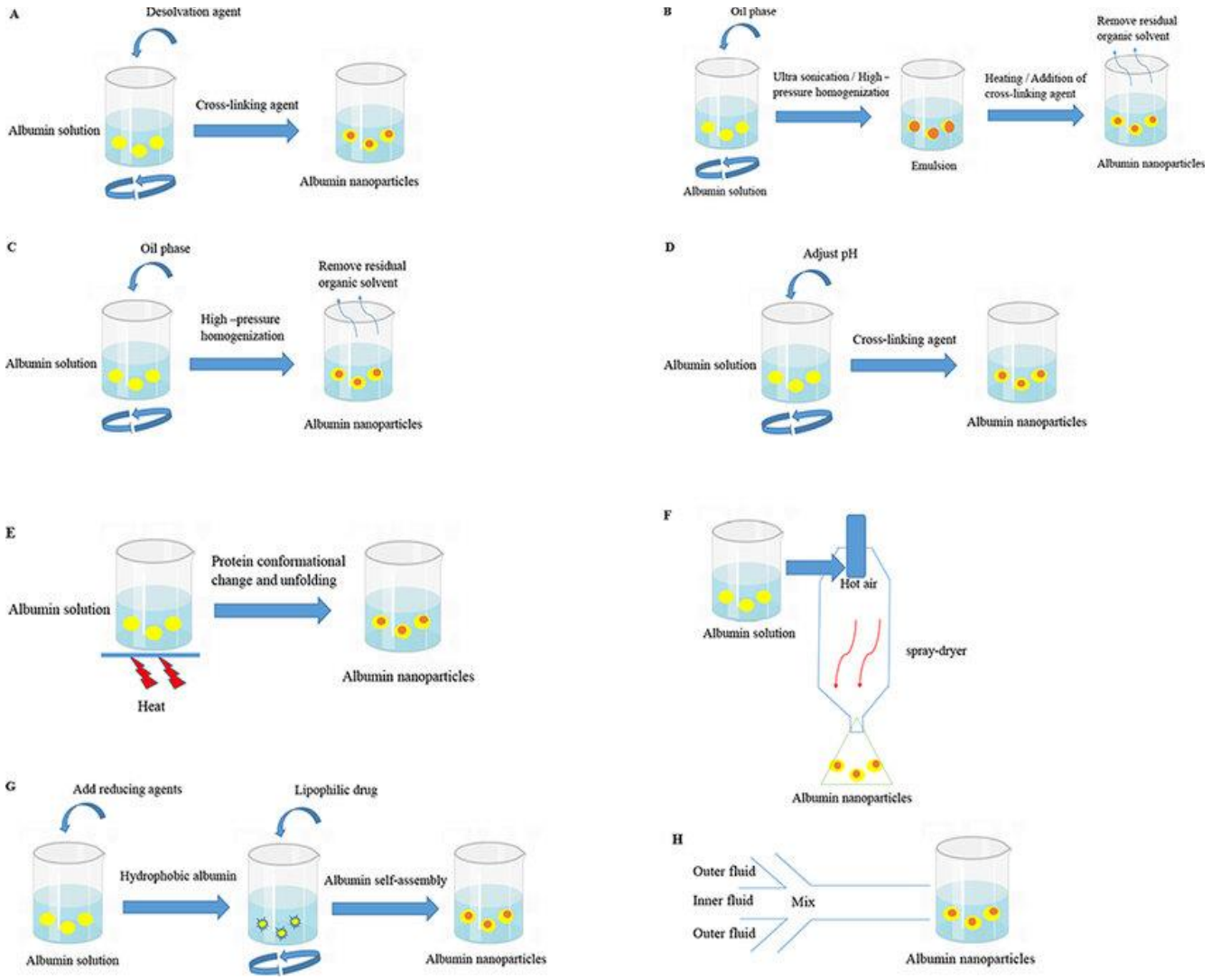


Fig-4:Main methods for the preparation of albumin nanoparticles: (A) desolvation, (B) emulsification, (C) self-assembly, (D) thermal gelation, (E) Nano spray drying.

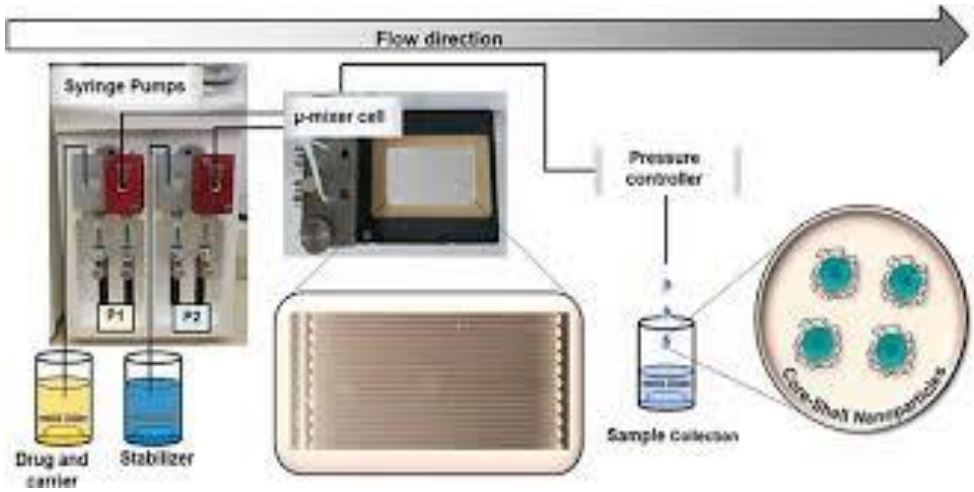


Fig -5:Flow system used to prepare BSA core−shell nanoparticles with the pumps and the μ-mixer cell.

CHARACTERISTICS OF ALBUMIN FROM DIFFERENT SPECIES:

It is the most abundant protein in blood plasma, constituting approximately 60% of all proteins in the blood. It is a highly water-soluble small globular protein and has a molecular weight of 67 kDa and an average halflife of 19 days. It shows stability at a pH range of 4−9 and can be heated for 10 h at 60 °C. It can be extracted from Albumin many sources including human serum (human serum albumin, HSA) (Figure 1), bovine serum (bovine serum albumin, BSA), rat serum (rat serum albumin, RSA), and egg white (ovalbumin, OVA), but the two types most used for drug delivery are HSA10 and BSA of fundamental importance.

Figure-6: Structure of human serum albumin, a single polypeptide containing 585 amino acids. The three homologous domains [(I) residues 1−197, (II) residues 189−385, (III) residues 381−585] assemble to form a heart-shaped protein. Each of the domains is composed of two subdomains (A, B) with common structural motifs. The domains of albumin are shown in purple (IA), red (IB), green (IIA), orange (IIB), blue (IIIA), and violet (IIIB). The yellow sticks indicate the disulphide bridges, and the yellow spheres represent the free cysteine residue at position 34 (cys34) in domain IA.

Human serum albumin:

Serum albumin Human is made up of a single chain of 585 amino acids. Its secondary structure is highly flexible, characterized by 67% α helix and 17 disulfide bridges with 6 turns that act as cross-linkers for the three homologous domains. Human serum albumin is a protein produced by hepatocytes in the liver, at a rate of 9–12 g/day, and is one of the most abundant (levels of plasma albumin in the range from 3.5 to 5 g/dL and important proteins in blood plasma. Although albumin is the most abundant plasma protein, the majority of albumin is not in blood circulation. As much as 60% of albumin is stored in the interstitial space. Even though its biological half-life is 19 days, it only lasts 16–18 h in circulation. The transcapillary movement of albumin is reversible, as it can return inside the plasma through the lymphatics to maintain constant plasma protein concentrations. Its production is modulated by the body's needs In particular, the synthesis is stimulated by insulin, thyroxine, and cortisol or conditions like hypoalbuminemia, whereas it is hindered by potassium and exposition of hepatocytes to excessive osmotic pressure. Furthermore, an adequate supply of nutrients is fundamental to trigger albumin production. In fact, poor adsorption of nutrients reduces the liver's ability to produce protein. Degradation of albumin can take place in any tissue, but it occurs mainly in the liver and kidney. The balance between albumin production, degradation, and movement between intravascular and interstitial spaces determines the effective plasma albumin concentration.

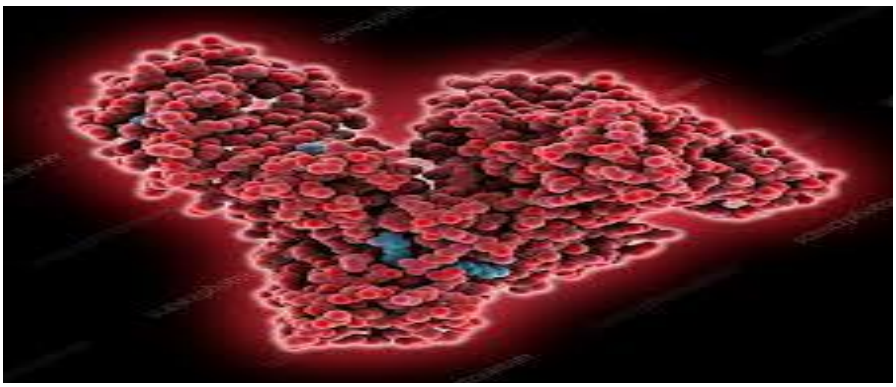


Fig-7: Human serum albumin

Advantages of Using HSA as Drug Carrier

a. Human Serum Albumin (HSA) is native to the body. It is biodegradable in nature, nontoxic and non-immunogenic.

b. HSA is a robust macromolecule. It is stable over a wide pH range 4-9, could be heated at 60°C for up to 10 h without deleterious effect, is unchanged by denaturing agents and solvents at moderate concentrations. Therefore, albumin could remain stable under typical processing conditions.

c. As the most abundant protein in plasma, albumin is readily available. It has been used in clinical setting for more than 30 years

d. The half-life of albumin is 19 days in blood circulation.

Disadvantages of HAS:

In spite of its wide range of properties and endogenous origin, it shows potential for allergic reactions and transmission of infections. Hyper oncotic albumin may cause kidney damage.

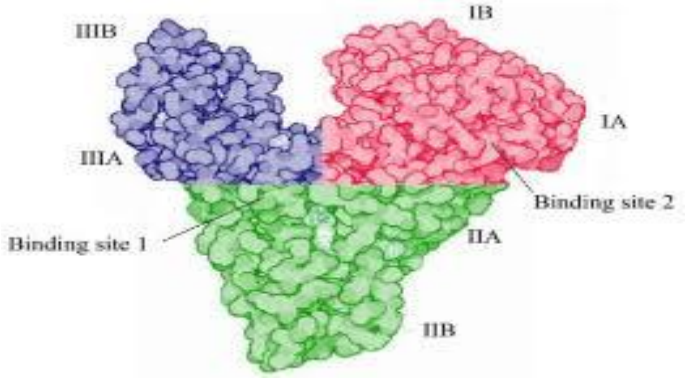


Fig-8: The structure of Human Serum Albumin (HSA). The three domains of HSA are coloured as follows: domain I: red; domain II: green; domain III: blue

Bovine Serum Albumin (BSA):

BSA and HSA exhibit high homology in structure, making them widely studied as model proteins. BSA is a watersoluble spherical protein containing a polypeptide chain composed of 583 amino acid residues with an isoelectric It makes up approximately 60% all proteins animal serum. BSA has a unique hydrophobic region in its molecular structure and is also used to study the interaction between albumin and drugs. The properties of rich, low cost, easy to purify, unusual ligand-binding properties, and widely accepted characteristics in the pharmaceutical industry (easy process ability and scalability) have been widely used in drug delivery systems. BSA is rich in functional groups, such as carboxyl and amino

groups, and has a strong affinity with metal nanoparticles. It is often used as a coating agent for metal nanoparticles to improve their colloidal stability and biocompatibility, and endow them with the characteristics of easy functionalization and low toxicity, which is conducive to the application of metal nanoparticles in biomedicine and other fields. Compared to HSA, the limitation of BSA is its potential immunogenic response.

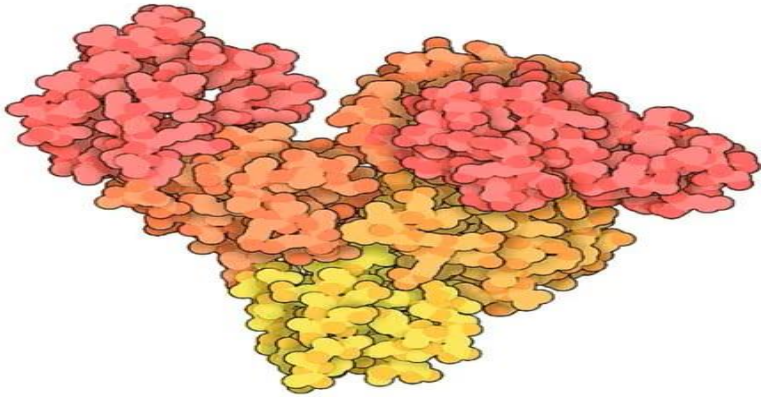


Fig-9:Bovine serum albumin

Rat serum albumin (RSA):

RSA prepared from rat serum has structural properties similar to other albumin species with a molecular weight of 64.3 kDa and an isoelectric point at pH 8.6.There are only a few reports for the use of rat albumin protein compared to the other albumin species.

Fig-10:Rat serum albumin

Ovalbumin (OVA):

OVA is the main storage protein in egg white, and is a monomeric phosphoglycoprotein with a molecular weight between 42-47 kDa and an isoelectric point around pH 4-5 It has a 3D structure with a helical reactive loop arrangement and 365 amino acids in the polypeptide .OVA is very economical compared with other proteins, and considering its ability to form emulsions, gels, foams, combined with its sensitivity to heat and pH, is a good choice for drug delivery applications . In contrast to mammalian serum albumins, OVA is strongly recognized by the immune system and can be used in antigen delivery systems.The creation of a conjugate between poly (propyl-acrylic acid) (PPAA) and OVA increased MHC-1 presentation and T-cell activation, so it was suggested it could be vaccine delivery system that that targets CD8-expressing T-cells.

Fig-11:Ovalbumin

Here are some nanodrugs that have been used in albumin carriers:

- Abraxane® (nab-paclitaxel) This FDA-approved drug is used to treat tumors. It's made of albumin-bound paclitaxel, and is known for its long drug residence time in tumors, short infusion time, and reduced risk of hypersensitivity reactions.
- Doxorubicin-albumin nanoparticles These nanoparticles are self-assembled and have TRAILs chemically linked to their surfaces. The TRAILs help cancer cells undergo apoptosis.
- Gemcitabine-loaded albumin nanoparticles (FA-Gem-BSANPs) Folic acids are conjugated to the surface of these nanoparticles to help them be taken up by tumors that overexpress folate receptors.
- Wpep-HSA-PTX NPs These nanoparticles have a stimuli-responsive drug release pattern and enhanced cellular uptake.
- Transferrin-conjugated TRAIL/DOX HSA-NPs These nanoparticles are used to treat multi-drug resistant (MDR) cells.
- Albumin microbubbles These spherical carriers are about the same size as red blood cells and can be used for imaging and therapy. Albumin is a promising drug delivery approach because it's the most abundant plasma protein in the body and has multiple binding sites. It's made up of a single polypeptide with 585 amino acids that form a heart-shaped protein.

FUTURE OF NANODRUG DELIVERY

The field of nanodrug delivery is still in its early stages, but it has the potential to transform the way we treat diseases. As researchers continue to develop new and improved nanocarriers and targeting strategies, nanodrug delivery is poised to play an increasingly important role in personalized medicine. Nanotechnology, the manipulation of matter at the atomic and molecular level, is poised to revolutionize the very way we deliver medications.

Moving beyond the limitations of traditional methods, these tiny titans are ushering in a future of:

1. **Targeted Precision:** Imagine nano-sized drones strategically navigating the labyrinthine vasculature, delivering their therapeutic payloads directly to diseased cells. Nanoparticles can be functionalized with ligands, homing in on specific receptors overexpressed on target tissues. This targeted approach minimizes off-target side effects, maximizing therapeutic efficacy while reducing damage to healthy organs.
4. **2.Enhanced Solubility**: Many potent drugs struggle with poor solubility, hindering their bioavailability. Nanotechnology offers a solution. By encapsulating these drugs within nano-carriers, their solubility dramatically increases, allowing them to enter the bloodstream and reach their target sites where they can truly make a difference.
2. **Controlled Release:** The days of frequent redosing may soon be a relic of the past. Nano-carriers can be engineered to release their payloads gradually over time, extending therapeutic action and reducing

the burden of medication schedules. This controlled release also minimizes peak drug concentrations, further mitigating potential side effects.

3. **Multifunctional Magic:** Beyond simple drug delivery, nanoparticles can be transformed into versatile theranostic agents. Imagine a single nanoparticle simultaneously diagnosing and treating a disease. By integrating imaging markers and therapeutic payloads, these multifunctional marvels can provide real-time feedback on treatment efficacy, allowing for personalized adjustments and optimal outcomes.
4. **Personalized Pharmacies:** Nanotechnology may one day unlock the potential for individualized medicine. By analyzing a patient's unique genetic and cellular makeup, scientists could design and fabricate personalized nanoparticles customized to target their specific disease profile. This tailored approach has the potential to revolutionize how we treat a vast array of illnesses.

CHALLENGES AND BEYOND

Despite its immense promise, the path to nanomedicine's full potential is not without hurdles. Ensuring biocompatibility, optimizing targeting specificity, and controlling drug release mechanisms remain active areas of research. Additionally, costeffective manufacturing processes need to be established for wider clinical translation. However, the ongoing research efforts fueled by the immense potential of nanotechnology hold the promise of unlocking a new era in healthcare. From tackling stubborn cancers to managing chronic diseases, these nano-sized pioneers offer a glimpse into a future where precision, personalization, and efficacy define the very notion of medical care.

Outlook

Albumin is an attractive protein for preparing nanoparticles with potential therapeutic applications. However, current reports indicate that various albumin-based nanocomplexes are usually synthesized by strategies such as electrostatic adsorption, chemical conjugation and biomineralization.These methods may lead to the presence of multiple components in the complexes, and there is a lack of comprehensive studies on the biocompatibility and toxicity of these complexes, which has seriously hindered the further development and widespread clinical application of albuminbased complexes. In response to these problems, measures could also be taken to focus on the reduction of impurities and more comprehensive toxicity testing of the complexes during the process of design and synthesis. The use of glutar aldehyde as a crosslinking agent or UV irradiation for crosslinking during the preparation of albumin nanoparticles can increase the potential toxicity of the obtained albumin nanoparticles.

CONCLUSIONS:

The field of nanomedicine is becoming more and more appealing as it provides efficient and smart solutions for the delivery of therapeutics in the treatment of cancer, inflammatory diseases, and other conditions. Over the past few years, the great potential of albumin as a drug delivery system attracted the attention of many researchers due to its biocompatibility, biodegradability, nonimmunogenicity, and nontoxicity. It is not a foreign body; it is not rejected by the immune system since it is the most abundant protein in the plasma, and that makes it even more appealing. Its high affinity for hydrophobic drugs, the possibility for surface modification, and the high loading capability allow us to overcome the great barriers imposed by the nature of many compounds available in the market nowadays. It is a versatile drug carrier, which could be used not only for the transport of therapeutics but also for imaging applications and gene therapy.

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