Synthesis and characterization of Aluminium Oxide nanoparticles

Diptiben Ghelani[1] and Suuny Faisal[1]

[1]Affiliation not available

October 4, 2022

Synthesis and characterization of Al_2O_3 nanoparticles

Sunny Kamran

KEYWORDS: phytochemicals, inflammatory, antispasmodic,nanotubes

ABSTRACT:

Nano technology is the branch that deals with the particles ranging from 1 to 100nm. Two approaches are basically adopted for the production of nano particles that is bottom –up and top –down approaches. There are three main methods physical method, chemical methods and biologically synthesis method. In recent years, a new route for the synthesis has received great attention due to its efficiency, less toxicity, safer and capability to design new route for manufacturing. Green synthesized particles at its nano scale range are commercially and economically very beneficial for the environment. This method uses a reducing agent that reduces the metal salt to form metal oxide. Current study shows that *Trachyspermum ammi* extract possess different phytochemicals (carbohydrates, thymol, steroids, flavonoids, terpenoids, saponins, anthroquinone and phenols) which reduces the metal salt to its metal oxide. Al_2O_3 nanoparticles are chemically, ecologically and economically advantageous and provoke antimicrobial, inflammatory, antispasmodic, antiviral, antioxidant and many other properties.

INTRODUCTION:

Biochemical NP production, is easy, cost-effective, more repeatable, and has well-defined physicochemical characteristics, in addition to being ecologically benign. Organic, Inorganic, and hybrid bio NPs are of the three types. Maximum macro-molecules and the cellular structures can generate NPs in response to environmental circumstances and sample treatment. As recently reviewed, the capacity of biological structures to generate NPs has been observed in an extensive range of living species, comprising yeast, fungus, plants, algae, and bacteria (eubacteria, cyanobacteria) (Durán & Marcato, 2012).

Oxides and metallic bio NPs are two types of inorganic bio NPs. The fabrication of Inorganic Bio NPs is generated by undefined reducing agents in the media by activating the system into the cell to decrease deadliness. The benefits of using biological patterns is the large variety of tridimensional (3D) bio configurations that can be used as originals to generate NPs with a wide range of characteristics and properties (Durán & Seabra, 2012).

Green synthesis of nanoparticles includes three aspects solvent, capping agent and reducing agent. This generation of chemicals firstly embraces extraction then characterization and after that preparing the precursor and at the end degradation of organic matter (Devatha & Thalla, 2018). The nanoparticles are becoming more prevalent in daily consumer items, industrialized procedures, and medical goods, it is critical that the employees and end-users are safeguarded from possibly harmful NPs. It implies that the NPs may need to be confiscated inside the yield so that they are not unconfined into the atmosphere during substance usage or reprocessing (Sharifi et al., 2012).

Nano chemistry's basic and ultimate objective is the size, shape and dimensionality at its atomic or molecular level (Ozin, 1992). So the technology used for achieving the goal that is to have the size and shape in nano range (1- 100 nm) is nanotechnology. The most important function is the interaction of atoms with the complex molecules by advanced methods may be in vitro or in vivo efficacy (McNeil, 2005). Nano technology is basically new and advanced level of invention whose need is increasing globally, socially and economically for atoms at its nano scale (Adlakha-Hutcheon et al., 2009). The production of Aluminum oxide nanoparticles can be done in a variety of ways (Al_2O_3 NPs or Nano alumina). The solution combustion technique is an energy-efficient and environmentally benign approach for producing low-cost nano adsorbents (Prabhakar & Samadder, 2018).

Trachyspermum ammi (Umbelliferae), also known as Ajwain in India, is found across the country's northwestern regions (Ramaswamy et al., 2010). It is utilized as a therapeutic plant in Ayurveda medicine for its antispasmodic, stimulating, energizer, and carminative qualities. Spices include scent compounds that have been used in aroma therapy since early times, implying the offer on certain health welfares additionally to a pleasing essence. They also prevent other unwanted dietary variations that impact on nutritional quality, taste, and consistency (Baratta, Dorman, Deans, Biondi, & Ruberto, 1998). The plant's seed spice is highly prized in medicine. The acrimonious and strong and spicy fruits are used to flavor and reservation of meals, as well as in fragrance and medicine (Aruna & Sivaramakrishnan, 1992)

LITERATURE REVIEW:

The study of very small materials, known as nanotechnology, is composed to have a significant influence on the environment (Wesley, Raja, Raj, & Tiroutchelvamae, 2014). Nano technology is considered as the study for construction, characterization, functionalization, operation, change, and manufacturing of nanoscale objects (1-100nm) and their application at the nanoscale level (1-100nm) (Nikalje, 2015).

Nanotechnology, as a concept, refers to all elements of controlling and producing techniques and equipment by influencing materials at the nano level (Ernst, 2009). The capacity to manipulate and restructure the atomic and molecular scales of matter in the unit area of 1 nm to the 100 nm, and to utilize the unique characteristics and occurrences associated with such scales as opposed to single atoms, molecules, or bulk behaviors (Roco, 1999). Nanotechnology has drawn many scholars to the train and improvement of knowledge at the nanoscale since it is a diverse area. Nanotechnology was made possible by advances in Science discipline and the capacity to regulate things at the nanoscale. It has also provided opportunities that go beyond conventional scientific boundaries, where all science fields are integrated and inextricably linked (Tretter, Jones, Andre, Negishi, & Minogue, 2006). This is an admirable goal: to have all science fields collaborate in order to gain a deeper knowledge of how they are all associated to or linked to one another (Taylor, Jones, & Pearl, 2008).

Concept of Nano technology dates back to the 1959, the most of its progress happens in 1980s and the early 1990s. In a report named as ‘There’s plenty of room at the bottom’, by Richard Feynman presented nanotechnology on 1959. Feynman discussed the aptitude to operate the atoms and the molecules, as well as creation of Nano-scale devices (Lin, Wu, Cho, & Chen, 2015).

Utilizing a technique of creating things with precise atomic specifications using designed protein molecules, combining contemporary scientific ideas with Feynman's notions (Drexler, 1981). Metals, plastics, polymers, and composite materials benefit from nano-structural aluminum oxide fibres, which increase strength and improve performance. The huge quantity of

Hydroxyl groups on Nano-fibers creates a positive ion charged specie in water, attracting and retaining negative specie such as bacteria, virus, organic and non-organic colloids, and negative charged species i.e. macro molecules (Chandra Mouli & Parthiban, 2012).

2.1 MORPHOLOGY

2.1.1 Nano-cage: This family of nanomaterials, first described in 2002, comprises a resonating central and spongy walls with the nanoparticles of metals (MNPs) in them. The size range is from 15 to 150 nanometers (Sun, Mayers, & Xia, 2002). As Multi-Photon Luminescence tracers, contrast mediators for Photoacoustic imaging and Multimodal imaging, photo thermal mediators for target killing of malignant matter, and the drug distribution automobiles for intelligent discharge in reaction to peripheral incentives that are near-infrared waves or High-intensity concentrated Ultrasound (Xia et al., 2011).

2.1.2 Nano-crystals: Investigators created a single liquid–solid–solution phase transition synthesizing method for producing semiconducting magnetic Nano- crystals particles of appropriate size to one formula unit, concentration, morphology, internal workings, and physical and chemical properties. (J. Park, Joo, Kwon, Jang, & Hyeon, 2007). The synthesis strategy has been nicely evaluated by NPs for fabricating singly dispersed nanocrystals with numerous interactions and possessions using a wide range of materials such as noble metals, Semi-conductors, electrically charged magnets, scarce fluorescent, therapeutic, organic photoelectric conductive polymers, and semiconducting Nanoparticles has effectively addressed the synthetic techniques for creating narrow size distribution Nano-crystals of alloys, semiconductors, and oxides of metals. Photovoltaic cells, firm displays, optoelectronic devices, and field-effect transistor (FET) sensors are all examples of semiconductor devices. are all examples of memory devices (Suryanarayana & Koch, 2000).

2.1.3 Nano-belt: A nano-belt is a thin, flat sheet of ribbon-like structures with a dimension of 30–300 nm. The production of 1D ultra-long nano belts distinguished by a trapezoidal cross-section and is very well crystallographic surfaces has been described, allowing for novel optical confinement, micro cavity, metabolism, as well as electromechanical influence (Chen et al., 2016). Lanthanum hydroxide nano-belts made with a composite-hydroxide-mediated synthesis technique. Nano-belts have a significant impact on self-powered nano gadgets and systems.

They're used in FETs, high - sensitivity gas and bioelectronics, attenuators, and linear actuators with nanoscale resolution, among other things (Xudong Wang, Song, & Wang, 2007).

2.1.4 Nano fibers: These are two-dimensional fiber constructions with a diameter of less than 100 nano meters. Electrospinning is the most widely used process for producing NFs from a large range of polymeric materials, transition metals and oxides of metal, organic compounds-based on carbon, highly ordered heterodimers, and other materials (Teo & Ramakrishna, 2006). Other approaches for manufacturing Nano composites include emulsified polymers, assembly, molten blasting, and phase's segregation. Synthetic biology, submersible pumps, implanted devices, biomaterials, medication delivery mechanisms, and electrical equipment are examples of applications. (Ellison, Phatak, Giles, Macosko, & Bates, 2007).

2.1.5 Nano particles (NP): Nanoparticles are defined by IUPAC as particles of any shape with diameters between 1.109 and 1.107 nm. (NP). To design many scientific, mechanical, and ecological methods are available for nanoparticles of diverse types of material (polymeric materials, Inorganic materials, metallic, etc.) of variable size, surface composition, and topographical. (Luo, Morrin, Killard, & Smyth, 2006). Our analysis aims to gather all nanoparticles designs synthesis techniques. NPs are utilized in several of purposes, encompassing biological applications (nano sensors, synthetic biology, pharmaceutical administration, biological controllers, micro / nano technologies, and so forth), electrical and optical devices, the food service industry, and the rest of the economy. industry, among others (Joye & McClements, 2014).

2.1.6 Nanotubes (NT) and Nano rods (NR): A nanotube (NT) is a tiny tube with a diameter measured in nanometers (often 100 nm). The majority of the nano tubes are vacuous. Nano Rods, but from the other side, is a rigid structure having parameters ranging from 1 to 100 nm with a 3 to 5 display size. (Dai, 2002). Electric discharging, plasma treatment, and physical vapor deposition are some of the processes utilized to create conductive nanostructures and nano rods (CVD). Another chemical technique for creating soft nano tube structures is emulsion polymerization. Carbon nanotubes (CNT) in particular have the potential to design wonder technologies (De Volder, Tawfick, Baughman, & Hart, 2013). CNT yarns and sheets had previously been identified as having potential superconductors, controllers, and acoustic shielding are just a few of the uses. Attempts are being made to use these nanomaterials in medicinal fields and research article are still ongoing (Qi et al., 2016).

2.1.7 Nano wires: Graphene is a programmable 1-dimensional nanomaterials fabric having dimensions varies from 10 to 12 feet. Nanostructures have the potential to made in two ways: top-down and bottom-up (Schmidt, Wittemann, Senz, & Gösele, 2009). Pharmaceutical, electromechanical, photocatalytic, and optoelectronic chemical vapour deposition, physical vapour deposition, PACVD, and other processes are routinely employed to make nanowires. Because semiconductor nanowires have excellent electrical and optoelectronic properties, they may be utilized to make p–n junctions, semiconductors, photovoltaic cells, and detectors are all examples of electronic devices (Majumdar, Singha, Mondal, & Kundu, 2013).

2.1.8 Quantum dots (QD): Quantum dots are semiconducting nanocrystals that are tiny sufficient to exhibit fundamental mechanical characteristics and to contain vibrational modes that are restricted in all 3 components. The optical and electrical properties of these are strongly size dependent. Within the quantum dot volume, there can be as few as 100 to 1000 [narrow space (1/6-em) 1000 atoms, with a diameter of 10 to 50 atoms (Dhand et al., 2015). The organometallic technique, which consists of 3 main parts: antecedents, natural lubricants, and fluids; (ii) aqua production utilizing relatively brief thiols as stabilizers; and (iii) physiological approach using microbiology., are the three ways to design QD (Seth, Mondal, Patra, & Samanta, 2016). They can be used in optics, light-emitting semiconductors, assays, biosensors, and medical diagnostics because of their excellent optical and electronic features (Jamieson et al., 2007).

2.1.9 Nano composites (NC): It's a multiphase material with at least one constituent phase with a diameter of less than 100 nanometers. The potential of nanocomposites rests in their multifunctionality, which allows them to achieve new combinations of qualities that are impossible to achieve with standard pure materials (Fischer, 2003). Nano-tools are a set of methodologies and procedures for creating and evaluating nanostructured materials and electronics. The introduction of novel synthetic technologies and important developments in supramolecular chemistry have aided in the manufacture of nanostructured materials (Iqbal, Preece, & Mendes, 2012). Nano crystalline products have been developed having ultimate control regarding dimension, morphology, and performance. developed thanks to advances in synthetic processes (Rao, Müller, & Cheetham, 2006).

Nanomaterials have gotten a lot of interest in the last decade because of their wide range of uses. The subject of fabrication of nanoparticles has shown to be highly active. Numerous procedures are used, which include gas convection, chemical vapor deposition synthesis, structural demoralization, chemical coagulation, Sol-Gel methodology, electrochemical methods, and transmission electron microscopy, ionized cluster beam, solvent metal - ligand source, single unit consolidation, vapor deposition, and gas agglomeration, coagulation / flocculation in the existence of targeting ligands, reaction in surfactant micelles, and others. The method produces nanomaterials are different for different materials (Rajput, 2015).

The top-down strategy is overwhelmingly popular in business world for the manufacturing of many synthetic or artificial materials, with the electronics industry representing as an improved version, in which characteristics of metal - oxide - semiconductor transistors (MOSFETs) are engrained onto a silicon dioxide substrate using selective laser sintering, a fiber lasers methodology (Xue Wang, Ruditskiy, & Xia, 2016).

Nanoparticles of acceptable and regulated composition are sought for industrialization in a variety of sectors. There have been two fundamental techniques that are typically used to manufacture nanoparticles:

(1) A top-down method in which production is started with the corresponding bulk materials, which releases out gradually, resulting in the production of microscopic nanoparticles. Top-down approaches for commercial processing of nanoparticles include selective laser sintering, electromagnetic lithography, grinding processes, electrodeposition, ion and laser ablation, and others.

(2) A bottom-up approach where in the particles of matter combine or integrate to form a diverse spectrum of nanoparticles. Bottom-up methods include self-assembly of copolymerization of monomers/subunits and pharmacological or electromechanical processes. Nano structuring condensation, hydrate polymerization, beam decomposition, chemical vapour deposition (cvd), fusion or flare jet production are all examples of bio-assisted manufacture. (Daraio & Jin, 2012).

In general, nano Particles manufacturing procedures can be distributed in three groups

- physical techniques
- chemical techniques

- Bio-assisted techniques

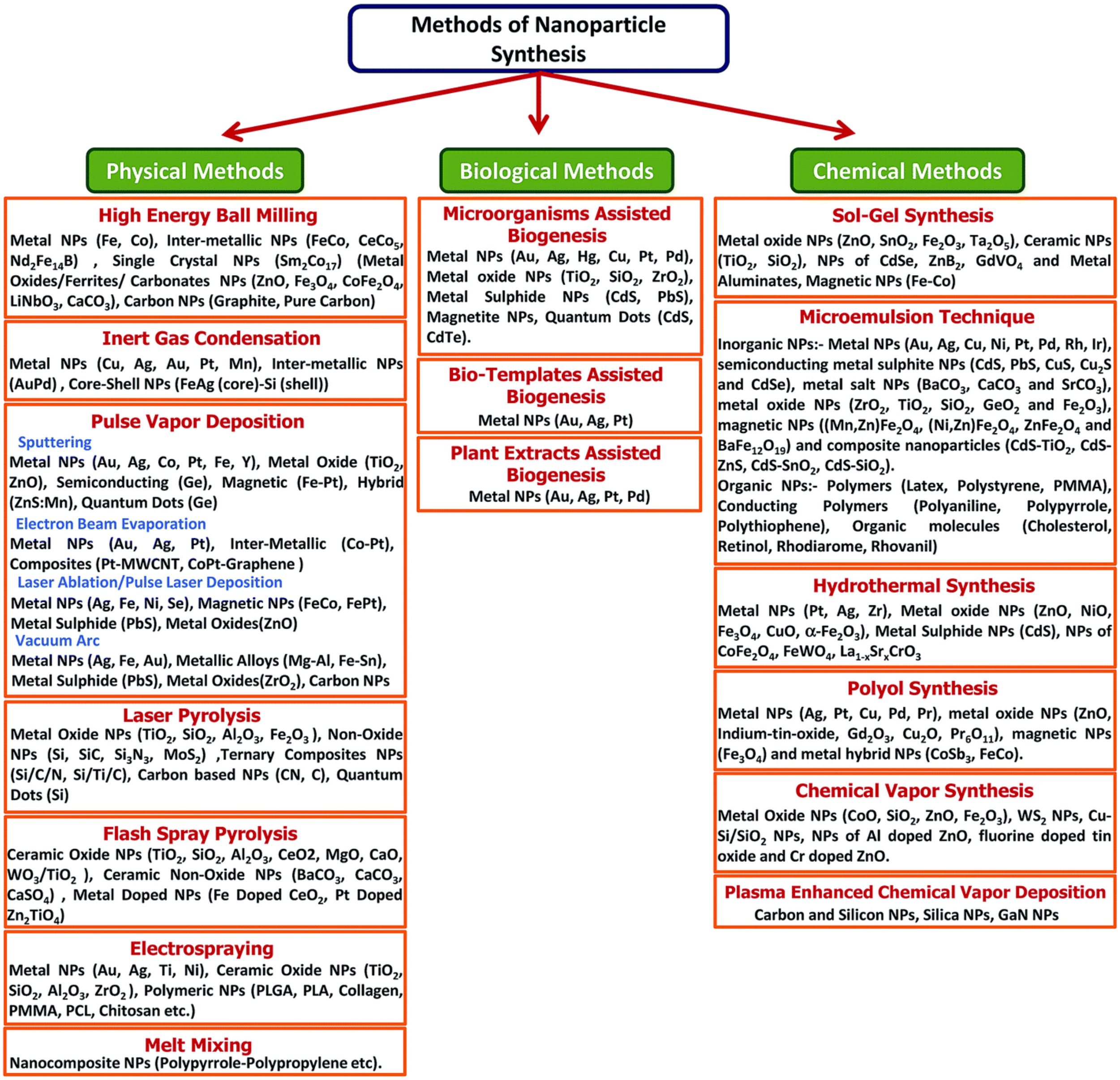

Figure: 2.1 Methods of nanoparticles synthesis

2.2 Synthesis of nanoparticles using physical techniques

Mechanical pressure, increased radioactive isotopes, heat energy, or electrical potential are used in physical techniques to cause substance erosion, melting, vaporization, or precipitation. Some techniques, which predominantly employ a top-down method, are advantageous even though they are liquid and produce homogenous narrow size distribution nanoparticles. Similarly, the high quantities of waste created during synthesizing reduces the cost-effectiveness of physical techniques. Physical processes for creating nanoparticles include high-energy ball milling, laser ablation, electro spraying, shielding gas precipitation, mechanical physical vapour deposition, laser decomposition, lightning magnetron sputtering, and molten mixing.

2.2.1 High energy ball milling (HEBM)

John Benjamin in 1970, introduced High energy ball milling, to produce oxides scattering enhanced composites that are strong enough to withstand high heat and compression, is a dependable and fuel synthesis technique for generating Nanoparticles of diverse lengths and diameters (Xing et al., 2013).

In the HEBM process, the acceleration of the moveable rollers is transmitted to the grinded substance. As a consequence, one‘s chemical properties are severed, and the grinded components are prolapsed into finer molecules with recently established substrates. Rotary media, milling speed, ball-to-powder relative density, milling type (dry or wet), high energy ball mill type (vibrator mill, celestial mill, etc.), milling ambience, and milling timeframe all influence the extent of radiant energy seen between balls and the substance during the procedure, influencing the external and surface morphology of the end product. The HEBM mechanism is characterized as a thermomechanical fabrication technique since it may incorporate exceptionally high local heating (>1000 °C) and increased pressure (multiple G Pa). (Salah et al., 2011).

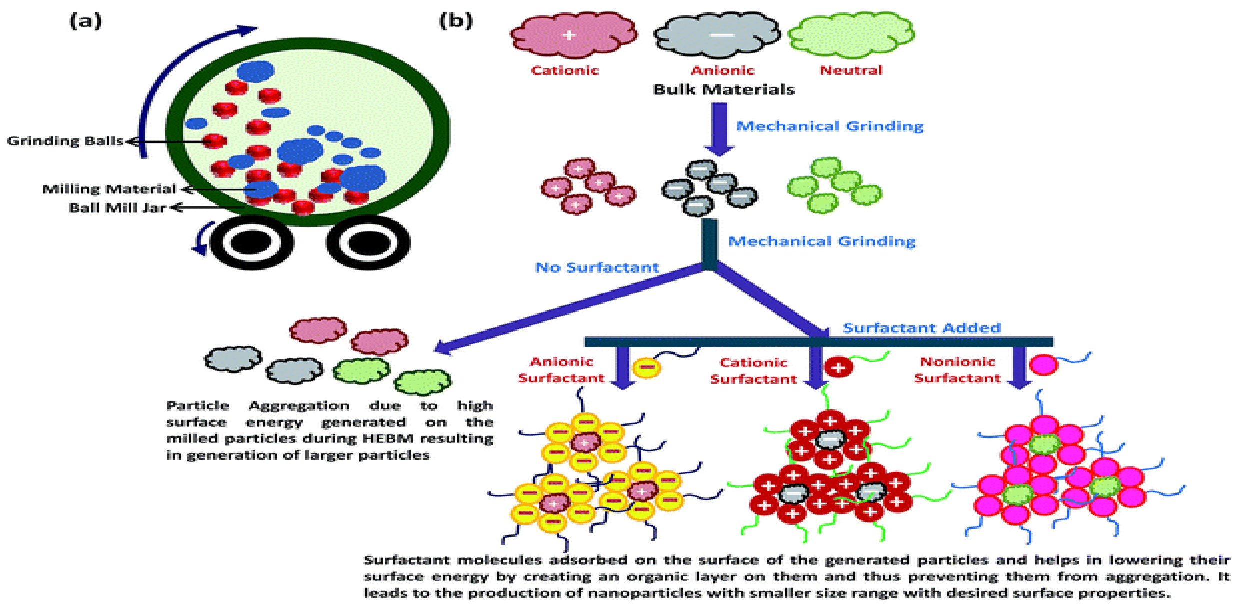

Figure: 2.2 High Energy Ball Milling Techniques

2.2.2 Inert gas condensation (IGC)

Inert gas condensation is a simple process for producing nanoparticles that employs inert gases (such as He or Ar) and a compressed N_2 sample container. The vaporized ingredients are transported employing inert gases and condense onto a compressed nitrogen surface. We used this approach is used to manufacture manganese nanoparticles and used the IGC (inert gas condensation) process to analyze the effect of tempering on the morphology of the implanted nanoparticles. (Ward, Brydson, & Cochrane, 2006).

IGC was revealed to be an extremely effective method of generating elevated silver and platinum nanoparticles. A sputtering depositing technique was used to generate those nanoparticles and also described the formation of Ag nanoparticles that used the IGC technique, and observed also that evaporated temperatures (ranging from 1123 K and 1423 K) as well as inert gas (He) pressure had a substantial impact on the morphological, crystalline structure, and dimension variation (varying between 0.5 and 100 Torr) (Raffi, Rumaiz, Hasan, & Shah, 2007).

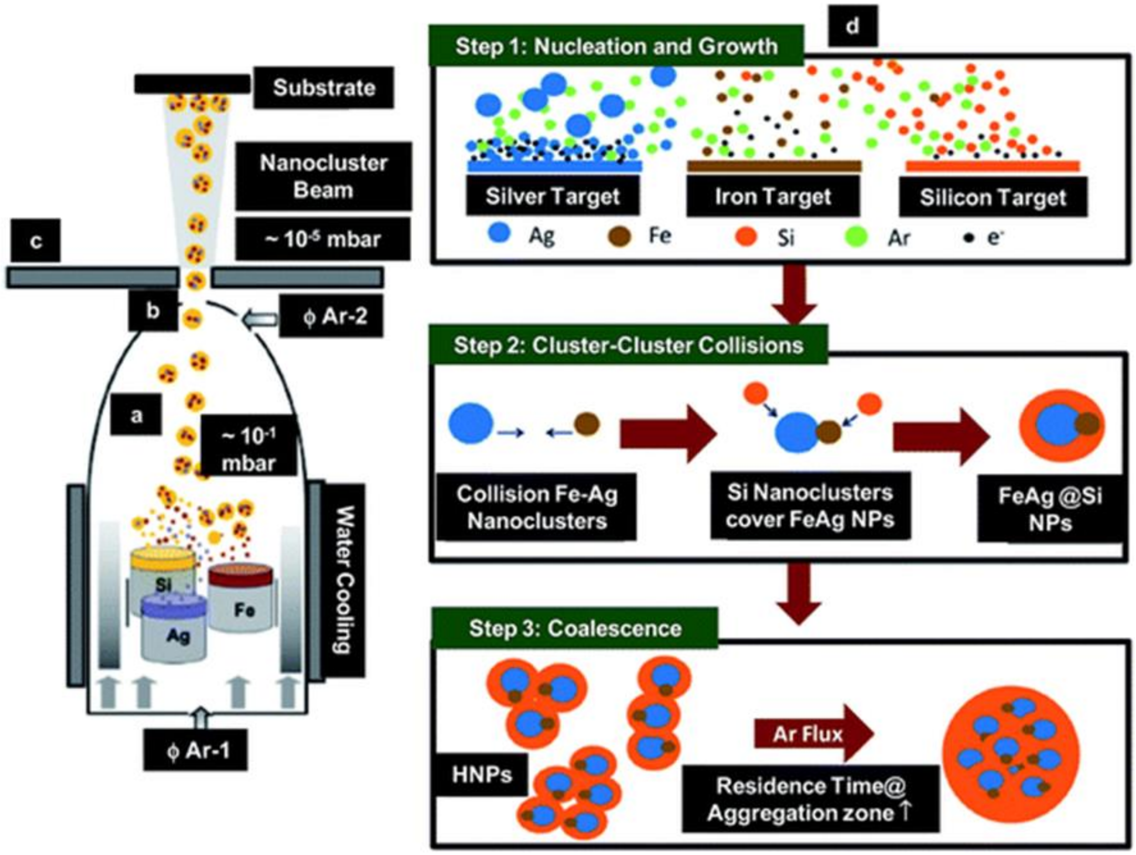

Figure: 2.3 Inert Gas Condensation

2.2.3 Physical vapor deposition (PVD)

Physical vapor deposition is a phrase used to describe a collection of methods to produce nano particles and implant thin films that are generally a few nm to many micrometers wide. PVD is a sustainable arc discharge technique that consists of three fundamental aspects:

(1) Solid source vaporization

(2) Vaporized material conveyance

(3) Nucleation and growth to produce thin films and NPs.

For the synthesis of NPs, the most often utilized PVD methods include (a) plasma sputtering, (b) electron beam evaporation, (c) pulsed laser deposition and (d) vacuum arc technique. Schematic figure given below:

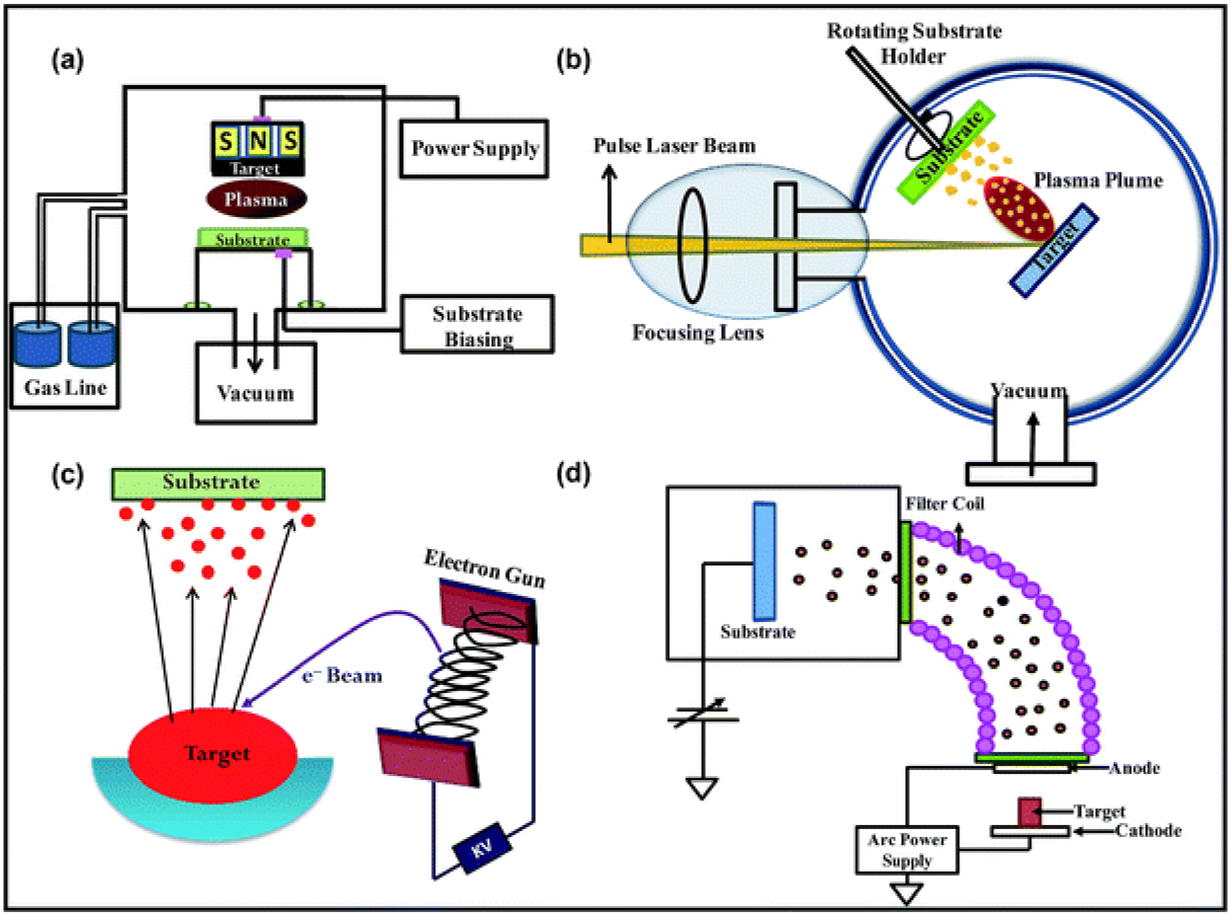

Figure: 2.4 Schematic Diagram of Physical Vapour Deposition

2.2.4 Chemical methods for the synthesis of nanoparticles

Some of the most often used chemical processes for the production of NPs include the sol–gel method, micro emulsion method, hydrothermal synthesis, polyol synthesis, chemical vapour synthesis, and plasma accelerated chemical vapour deposition technique.

2.2.5 Sol–gel method

The sol–gel manufacturing approach has 2 kinds of components 'sol,' that is a colloidal suspension of granular suspended particles, and 'gel,' which seem to be polymeric materials comprising liquid. As a consequence, such mechanism generates 'sols' in the liquids, which subsequently combine to create a networks of suspended particles or web polymerization. The fundamental phases of the sol–gel procedure are hydrolyzed and condensed, whereby the latter consumption of water to separate the molecules of the originator, while the latter stage is the first stage in the development of the gel state. This one is proceeded via condensing, that leads to the development of nanostructures, whereupon the additional water is evaporated to predict the overall strength of the sample (Zha & Roggendorf, 1991).

2.2.6 Micro emulsion technique

Micro emulsions are stable chemical, morphologically homogenous, optically transparent, and isolated system colloidal carriers consisting of at least three aspects: polar phase (often water), non-polar phase (typically hydrocarbons liquid or oil), and stabilizer. Emulsifiers produce an interfacial layer between both the organic and aqueous phases, lower surface tension in between emulsification and the additional phase, and serve as an electrostatic obstruction to protect particles in aggregating (Solanki & Murthy, 2011).

A micro emulsion framework comprises of narrow size distribution circular drops (diameters stretching from 600 nm to 8000 nm) with water-in-oil (w/o) or oil-in-water (o/w) based on the emulsifier used. The w/o reverse micellar technique provides an efficient relevant to the target for the nanoparticle synthesis. As shown in picture following, a reverse micelle is a water-in-oil micro emulsion whereby the surfactant's hydrophilic head of the groups create the wet core and stay within, while the organic tails of the solvent molecules are pointed outwards:

(a) Typical reverse micelle system,

(b) Different steps take part in one micro emulsion process and

(c) Sequence of reactions involved in the 2 micro emulsion nanoparticles synthesis.

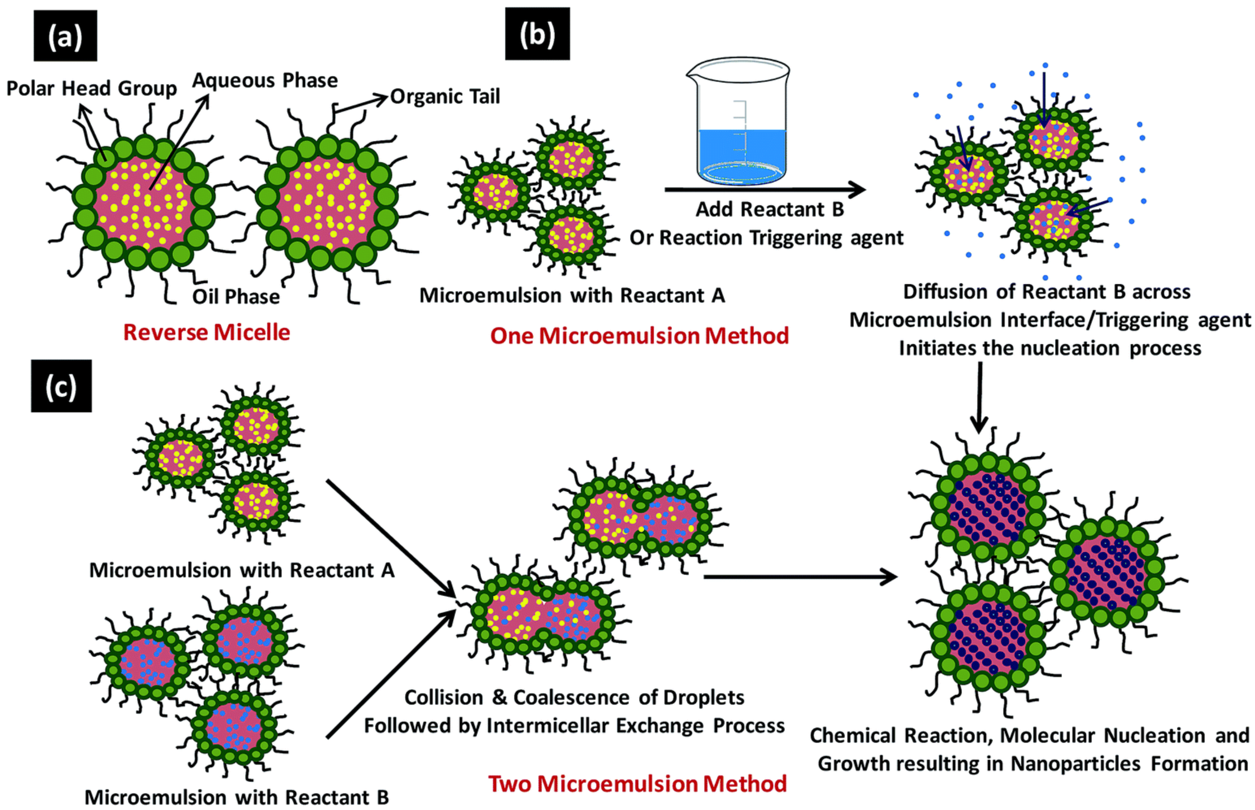

Figure: 2.5 Two Micro emulsion Method

2.2.7 Hydrothermal synthesis

This process is used to create oxide of metals, ferric oxide, and lithium iron phosphate nanoparticles by maintaining hold across particle characteristics by changing the properties of relatively close or extreme water at different temperature and high settings. It is possible to accomplish it in two ways: batching hydrothermal and continuously hydrothermal. The latter can carry out a system with the required proportion stages, but the latter can generate a quicker rate of response in less time (Hayashi & Hakuta, 2010).

2.2.8 Polyol synthesis

The polyol procedure is a metal-containing molecule synthesis technique that employs poly (ethylene glycol) as that of the reaction mixture, acting as a solvents, capping agents, and interfacial operator simultaneously, with soluble stabilizing or protective agents (Rahman &

Green, 2009). This electrochemical method was used to create a diverse range of metallic-based Nanoparticles (Ag, Pt, Pd, Pr, Cu), metallic oxides nano particles (ZnO, indium-tin-oxide; ITO, Gd_2O_3, Cu_2O), magnetically nanoparticles, and metal hybrid NPs. Researchers utilized the polyol method to create Pt nano particles with varying $NaNO_3$ and H_2PtCl_6 molar ratios. They also reported tailoring the dimensions, surface characteristics, and crystalline structure of nanomaterials by decelerating the reduction of Pt(II) and Pt(IV) species (attained by ethylene glycol) facilitated by variable concentrations ranging of nitrate ionic species, that have a high binding affinity stable compounds with Pt(II) and Pt(IV) (Herricks, Chen, & Xia, 2004). The morphology advancement of oxides of nano particles in polyol processes using two different polyols.

2.2.9 Chemical vapour deposition (CVD) & chemical vapour synthesis (CVS)

Chemical vapour deposition (CVD) and chemical vapour synthesis (CVS) are two processes for depositing solid coatings from the vapour stage using chemical reactions that occur at enormously elevated temperatures. Ultra-minute particles can be discovered in thin films made by the CVD process under specific conditions. Consequently, if the CVD classification is reformed/raised for the conditions listed further down, this approach can also be used to synthesize NPs:

High temps I (in hot wall reactors)

High supersaturations

(ii) (High partial pressure of monomers at a low vapour pressure of the bulk solid)

(iii) Long periods of residence (low gas flows or long reactors)

(iv) Chemical vapour deposition (CVD) and chemical vapour synthesis on small substrates (CVS).

As a consequence, whenever the conventional methods are adjusted such that the CVD technique requires nanoparticles instead of thin metallic sheets, the altered technique is known as CVS. The phrases chemically vapor reactivity (CVR), chemical vapour precipitate (CVP), and chemical vapour condensation (CVC) all refer to the same phenomenon (CVC). The three types of predecessors (solid, liquid, and gas) are produced in the furnace as vapors under circumstances that need molecules would go through the crystallization processes.

CVS additionally employs a variety of substrates to produce multi-component or hybridized Nanoparticles. Erbium (Er) has just been merged into Si nanoparticles by the use of substrates such as organometallic Erbium and di-silane compounds, and composites Nanoparticles are created by enclosing one material inside another (e.g. silicon tetrachloride in reaction with sodium chloride that consequence in the production of sodium chloride-enclosed silicon particles (Vallejos et al., 2011).

2.2.10 Bio-assisted methods for the synthesis of nanoparticles

To manufacture and create NPs, bio assisted methods, also called as biosynthesized or green synthesis, provides environmentally approachable, low-toxicity, low-cost, and economical approach. In the manufacture of metal and metallic oxide nano particles synthesis, these approaches use natural systems such as bacteria, fungus, viruses, yeast, actinomycetes, plant extracts, and so on. Three types of bio-assisted approaches can be distinguished:

(i) Microorganism-based biogenic production

(ii) Biomolecules as templates for biogenic production

(iii) Herbal extract-based biogenic synthesis

2.2.11 Biogenic synthesis using microorganisms

Prokaryotic microbes, actinomycetes, fungi, phytoplankton, and yeast are among the bio-reactors used to manufacture nanoparticles. This technique for generating a diverse spectrum of NPs required significant scientific effort (Ag, Au, Pd, TiO2, CdS, etc.). Microscopic creatures gather target ions in their atmosphere and employ enzymes generated by cellular processes to transform the metallic ions into the constituent of metal.

Nanoparticles can be distinguished as intracellular or extracellular based on where it is produced. In the intracellular method, metal ions are carried inside the microbiological cell to produce nanoparticles in the presence of catalysts. Extracellular nanoparticles synthesis necessitates the capture of metallic ions on the extracellular environment as well as ion reduction in the presence of protein (Zhang, Yan, Tyagi, & Surampalli, 2011).

2.2.12 Biomolecules as templates to design nanoparticles

To make NPs, several biomolecules such as nucleic acids, membranes, viruses, and diatoms were employed as templates. DNA is recognized as a good biomolecular template with a great affinity for transition metal ions. It was demonstrated that a DNA hydrogel could be produced and crosslinked before transition metal ions (e.g. gold, Al (III) metal ions) were merged into DNA macromolecules, consequential in the manufacture of Au nanoparticles. A reduction of Al(III) occurs, resulting in the creation of Au atoms and metal clusters, which evolve into Al nanoparticles on the DNA chain (Zinchenko, Miwa, Lopatina, Sergeyev, & Murata, 2014).

2.3 Plant extracts for nanoparticles synthesis

Biosynthesis of nanoparticles by means of plant extractions or biomass is a fast, clean, non-toxic, and environmentally acceptable technique. This technique has mostly been used to manufacture noble metal NPs, metal oxides, bimetallic alloys, and other materials. It has properly delineated several plants bio metabolites that could aid in the synthesis of nano particles due to their appreciated role as reducing and capping agents (Iravani, 2011).

The rate of photosynthesis of NPs is substantially faster than that of other biosynthetic methods, and it is sometimes comparable to that of chemical pathways. The synthesis of Aluminum Nano triangles using lemongrass leaf extract and aqueous $AlCl^{3+}$ ions has been described.

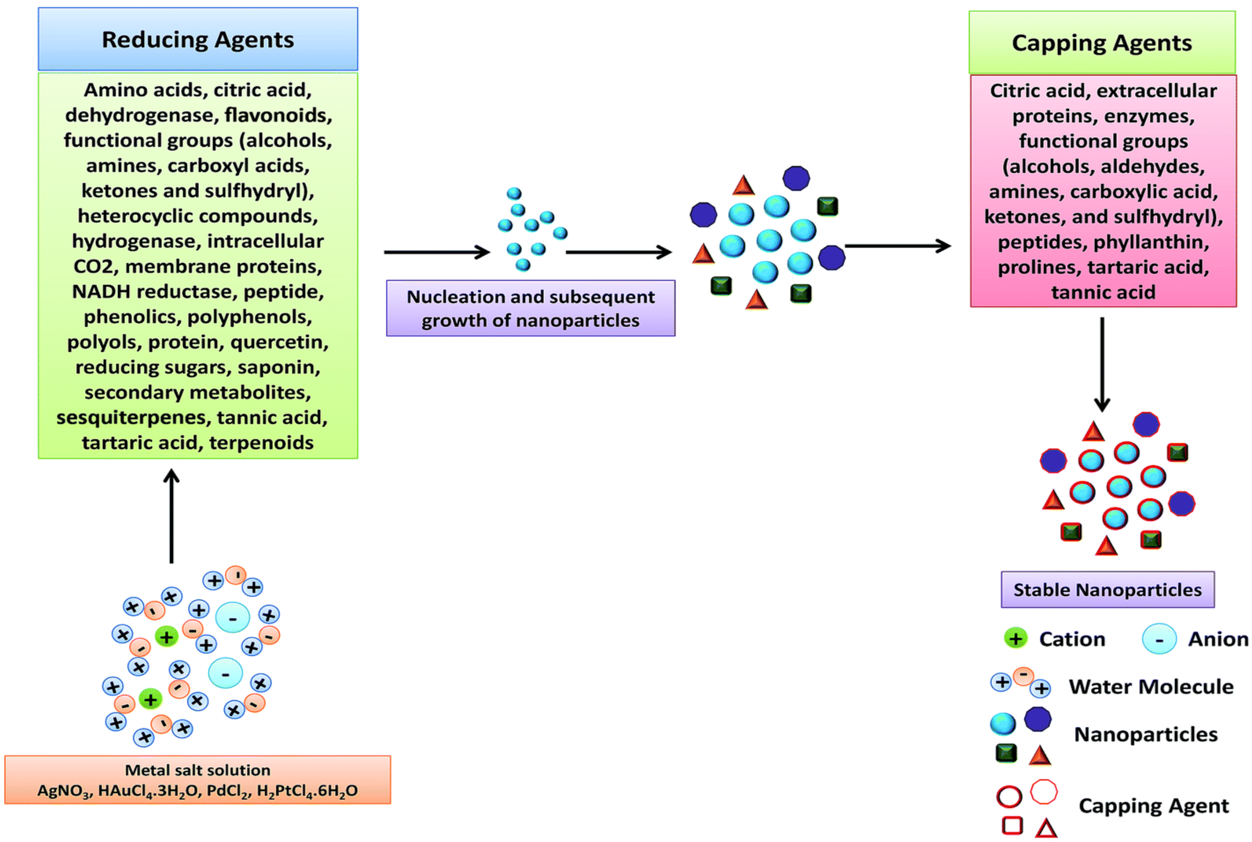

Figure: 2.6 Synthesis of nanoparticles from reducing and capping agents

2.4 Trachyspermum ammi

Trachyspermum ammi is an Egyptian inherent that is grown in Iraq, Iran, Afghanistan, Pakistan, and India. It is grown in Madhya Pradesh, UP, Gujarat, Rajasthan, Maharashtra, and other parts of India. The Apiaceae family is an extremely high prized and therapeutically significant seed. The roots are diuretic, and the seeds have astringent properties. Aphrodisiac qualities are excellent. The seeds have a moisture content of 2–4.4%. *Trachyspermum ammi* oil is a brown-colored oil (Bairwa, Sodha, & Rajawat, 2012). Thymol is the key ingredient in this oil, and it's used to treat gastrointestinal issues, a lack of appetite, and bronchial issues. On humans, the oil has antifungal, antibacterial, and anti-aggregatory properties (Ishwar & Singh, 2000).

Trachyspermum ammi is a customary potential herb that is commonly used to treat a variety of human and animal illnesses. Stimulant, antispasmodic, and carminative effects are all present in the fruit. Flatulence, atonic dyspepsia, and diarrhea can all be treated with it. Ajwain seed is bitter and pungent, and it has anthelmintic, carminative, laxative, and stomachic properties. It correspondingly treats tumors, aches, and piles in the abdomen. The essential oil in the seeds comprises about 50% thymol, which is a powerful germicide, antispasmodic, and fungicide. In toothpaste and perfumes, thymol is also utilized (Luitel, Rokaya, Timsina, & Münzbergová, 2014).

Other designations of *Trachyspermum ammi*

Yamini, Yaminiki, Yaviniki (Sanskrit)

Jain (Assamese):

Yamani, Yauvan, Yavan, Javan, Yavani, Yaman Yoyana (Bengal)

Bishop's weed (English)

Ajma, Ajmo, Yavan, and Javain (Gujrat words).

Kannada: Oma, Yom, Omu

Hindi: Ajwain, Jevain

Oman, Ayanodakan (Malayalam)

Onva (Marathi)

(Tamil) Omam Oriya: Juani

Vamu (Telugu)

Trachyspermum ammi has a lot of vitamins and minerals, along with phytochemicals that enhance wellness, such as carotenoids (-carotene and lutein) and antioxidants, which provide a lot of antioxidant defense.

2.5 Nomenclature of *Trachyspermum ammi*

- Kingdom Plantae, plant
- Subkingdom Tracheobionta
- Super Division Spermatophyta
- Division Magnoliophyta

- Class Magnoliopsida
- Order Apiales
- Family Apiaceae
- Genus Trachyspermum
- Species Ammi

2.6 Botanical Explanation

It is extensively developed in dry and semi-arid environments with high salt levels in the soil. *Trachyspermum ammi* is a 60-90 cm tall annual herb with many branches. Flowers are actinomorphic, white, male, and bisexual; stem is striated; inflorescence is a compound umbel with 16 umbellets, each containing up to 16 flowers; The petals of the corolla are bilobed, and the stamens alternate with the petals. The stamens are 5 and alternate with the petals; the ovary is lower; the stigma is knob-like; the fruit is fragrant, ovoid, cordate, and cremocarp with a persistent stylopodium; and the leaves are pinnate with a prolonged stylopodium.

There are 7 pairs of lateral leaflets and one terminal leaflet. Fruit is made up of two parts. Grayish brown mericarps, ovoid, compressed, about 2 mm long and 1.7 mm wide, with 5 ridges and 6 vittae in each mericarp. There are 5 major ridges that are distinct (Bukero & Philipos).

2.7 Microscopic description

Epicarps are a single layer of tangentially extended tabular cells, mesocarps are thick-walled, rectangular to polygonal obliquely elongated cells with some vittae, and 6 carpophores and vascular bundles appear as groups of thick-walled dramatically elongated cells, integument, barrel-shaped of tangentially elongated cells, endosperm consisting of thin walled cells loaded with Powder microscopy reveals the presence of oil globules and endosperm cell clusters.

2.8 Phytochemicals

Trachyspermum ammi processes fiber (11.9%), carbohydrates (38.6%), alkaloids, glycosides, humidity (8.9%), nutrients (15.4%), fat (18.1%), phenolic, flavonoids, and inorganic material (7.1%) that includes calcium, phosphorus, iron, as well as nicotinic acid (Asif, Sultana, & Akhtar, 2014). Ajwain foods containing 2% to 4% reddish active ingredient, the majority of which is thymol (35 percent to 60 percent). The whole thymol fraction having para-cymene, -

terpenine, - and -pinenes, dipentene, -terpinene, and carvacrol (thymene) (Claeson, Malmfors, Wikman, & Bruhn, 2000).

S.No.	Components	Concentrations (%)							
		Iran		India		Pakistan		Egypt	Turkey
		Kehsan	Tehran	Delhi	Gorukhpur	Jaipur	Peshawar	Cairo	Sanliurta
1	α-Thujene	0.4	0.17	-	0.2	-	-	-	-
2	α-Pinene	0.3	0.06	2.29	0.2	2.91	0.20	-	-
3	β-Pinene	1.9	0.39	8.12	1.7	8.95	1.42	-	-
4	p-Cymene	-	16.16	12.30	30.8	13.50	-	24.00	33.1
5	β-Myrcene	0.7	0.33	1.67	0.4	1.11	0.60	-	-
6	o-Cymene	19.0	-		-	-	37.44	-	-
7	α-Terpinene	-	-	1.32	0.2	2.62	0.36	-	-
8	α-Phellendrene	-	-	-	-	-	0.52	-	-
9	β-Phellendrene	0.4	-	0.97	0.6	0.91	-	-	-
10	Limonene	0.2	-	0.44	-	0.57	-	-	-
11	γ-Terpinene	20.6	17.52	55.75	23.2	-	21.07	24.00	28.6
12	γ-terpinolene	-	-	-	0.2	55.63	-	-	-
13	4-Terpineol	0.1	-	0.65	0.8	-	-	-	-
14	Sabinene	-	0.02	0.29	-	0.44	-	-	-
15	cis-Limonene oxide	0.7	-	-	-	-	-	-	-
16	cis-β-terpineol	-	-	0.42	-	0.39	-	-	-
17	p-Cymene-3-ol	-	-	-	-	-	38.00	-	-
18	Dodecane	0.2	-	-	-	-	-	-	-
19	β-Fenchyl alcohol	0.1	-	-	-	-	-	-	-
20	Thymol	45.9	64.51	15.56	39.1	16.77	-	42.00	24.1
21	Ethylene methacrylate	6.9	-	-	-	-	-	-	-
22	p-Menth-1-en-1-ol	-	-	-	-	0.39	0.12	-	-
23	Tetra decane	0.2	-	-	-	-	-	-	
24	Carvacrol	-	-	-	0.3	-	-	4.70	-
25	Hexadecane	1.1	-	-	-	-	-	-	-

Table 2.1 Concentration of different compounds in *Trachyspermum ammi*

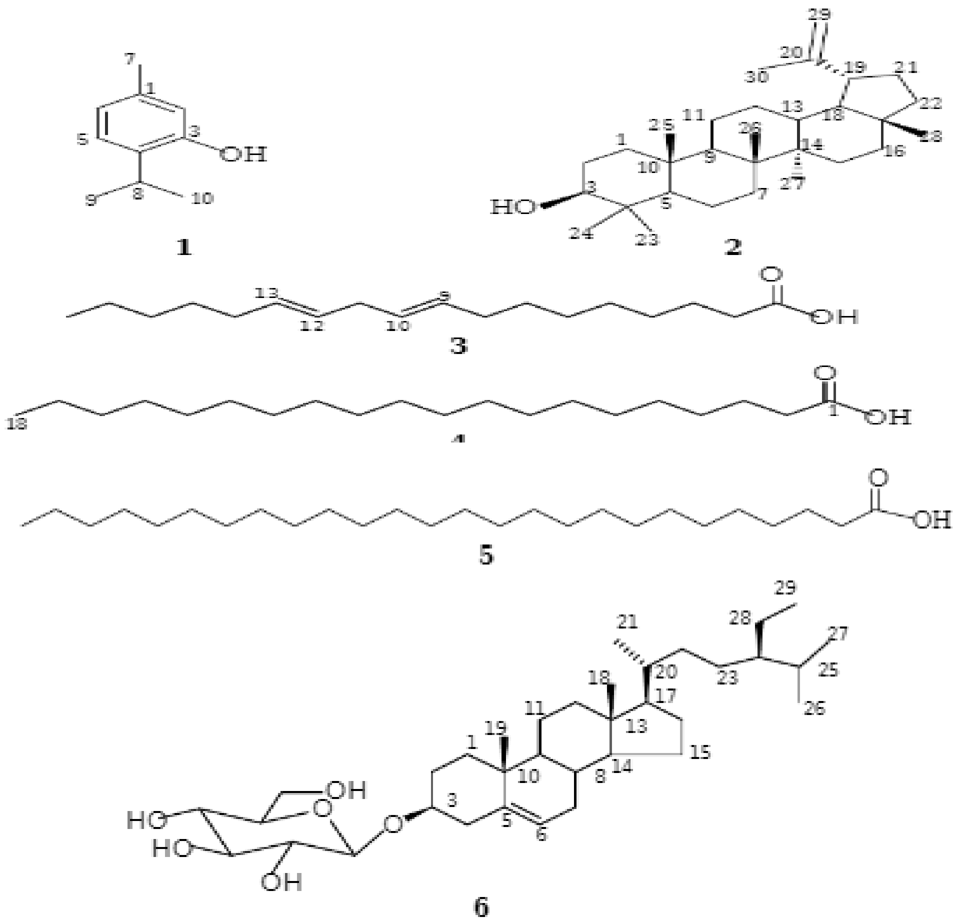

Figure: 2.7 Phytochemicals of Trachyspermum

Camphene, myrcene, and -3-carene are also found in minute amounts in the plants. Alcoholic extraction contains saponins, which are very hygroscopic. The fruits processes a yellow, crystalline flavonoid and a microtubule substance, as well as 6-O-glucopyranosyloxythymol, glucoside, and 25 percent oleoresin containing 12 percent essential oil (thymol, -terpinene, para-cymene, and - and -pinene). *T. Ammi's* primary oil constituents are carvone (46%), limonene (38%), and dillapiole (3%) (Choudhury, Ahmed, Kanjilal, & Leclercq, 1998).

Various compounds present in the *Trachyspermum ammi* but the main components is the (1) thymol, (2) lupeol, (3) linoleic acid, (4) stearic acid, (5) eicosnaoic acid, (6) β-sitosterol-3-O-β-D-Glucoside.

2.9 Pharmacological effects

Through its unique aromatic fragrance and powerful flavor, *Trachyspermum ammi* is extensively used as a spice in curries. Its seedlings should be used in trace amounts to flavor a types of ingredients, as stabilizer's, in medicine, and in the manufacture of essential oils for perfumery. *Trachyspermum ammi* is also used to cure gastrointestinal issues, a crushed fruit paste is used topically to ease colic problems, and a hot and dry fermentation of the fruits is given to the chest to cure asthmatic diseases (Akhtar, Siddique, Bi, & Mujeeb, 2011).

Antimicrobial, hypolipidemic, gastrointestinal stimulant, antihypertensive, hepatoprotective, antispasmodic, bronchodilating, antilithiasis, diuretic, abortifacient, galactogogic, antiplatelet-aggregatory, antiplatelet-aggregatory, anti-inflammatory, antitussive, antifilarial, gestroprotective, nematicidal, anthelmintic are some of the medicinal consumptions of *T. ammi*. Its fruits possesses stomachic, carminative, and expectorant, antiseptic, and amoebiasis, and antibacterial effects.

2.9.1 Antihypertensive, antispasmodic and Broncho-dilating activity

Plants utilize hypersensitive response (HR) to reduce the risk of infection by pathogenic organisms. HR can be found in the greater part of vegetation and is caused by a variety of phytopathogens including oomycetes, viruses, fungi, and even invertebrates.

An antihypertensive impact of *T. ammi* treated with intravenous in vivo, but also the anti - spasmodic and bronchodilating behaviour in vitro, illustrated that calcium channel barrier has been discovered to moderate the spasmolytic impact of industrial materials, and it is believed that this method thought to be due to their results obtained and aided the customary use of *T. ammi* in agitated disease is the situations of the gut (Gilani, Jabeen, Ghayur, Janbaz, & Akhtar, 2005).

2.9.2 Antiplatelet-aggregatory

Platelet activation and agglomeration were the primary causes of thrombotic events. The obstruction of a vascular artery leads to serious pathological conditions such as uneven angina, ischemic stroke, and heart attack. Because of the prevalence of thrombotic diseases, new antiplatelet stimulants for identifying and controlling arterial thrombosis without negative consequences are required. For a long time, customary medicinal herbs have been used to treat human ailments. Several pharmacological approaches have been used to identify and implement important clinical and safe products based on ancient herbal remedies.

In vitro antiplatelet aggregation experiments on human volunteers' blood indicated that a desiccated fragile extraction of *T. ammi* seed reserved prostaglandin synthesis caused by arachidonic acid, collagen, and adrenaline. The focus of this research was to provide evidence to maintenance the customary use of *T. ammi* in postpartum women (Srivastava, 1988).

2.9.3 Antiviral activity

Estimated virus yields in cultured cells contaminated with a certain quantity of viruses and administered with a harmless dosage of the experimental agent is used to determine antiviral activity (Ahsan et al., 1990).

2.9.4 Anthelmintic activity

Naturally wormers, anthelmintic plants are worm, often known as gastrointestinal nematodes, can cause illness in small ruminants and cattle, resulting in productivity and economic damages (e.g. Condensed tannins are found in the leaves and stems of several plants, including *sainfoin* and *birdsfoot* leaf.

T. ammi's anthelmintic effectiveness has been proven against certain helminths, including Ascaris lumbricoides in persons and Haemonchus crump in lambs. (I.-K. Park, Kim, Lee, & Shin, 2007). *T. Ammi* exerts its anthelmintic effect by interacting with parasitic metabolism through activation of ATPase, resulting in a loss of energy supplies. (Kostyukovsky, Rafaeli, Gileadi, Demchenko, & Shaaya, 2002). It has often been discovered that the plants has cholinergic activity with peristaltic movements of the gut, that assists in the elimination of parasitic infections and may play a part in its anthelmintic effects (Jabbar, Iqbal, & Khan, 2006).

2.9.5 Nematicidal activity

Pine Wilt illness is characterized by the pinewood nematode (PWN), Bursaphelenchus xylophilus. PWN is inhibited by the ingredients of *T.ammi* oil (camphene, pinene, myrcene, limonene, terpinene, terpinen-4-ol, thymol, and carvacrol). PWN bodies are cured with the muscle activation inhibitors levamisole hydrochloride and morantal tatrate. Amino and hydroxyl groups have already been postulated as methyl isothiocyanate targeted cells in worms. In insect pests, certain essential oils have already been found to disrupt the neuromodulator octopamine or GABA-gated chloride channels. Thymol and carvacrol have strong anti-PWN properties. These findings suggest that the nematicidal activity of *T.ammi* oil is primarily because of thymol and carvacrol functionality. The LC50 values for nematicidal activity of *T.ammi* vital oils were 0.431 mg/ml (Singh, Maurya, Catalan, & De Lampasona, 2004).

2.9.6 Antioxidant

A chemical which prevents tissues against free radical damage (uneven molecules made by the method of oxidation during normal metabolism). Free radicals may have a role in tumor, cardiovascular diseases, strokes, and perhaps other aging-related disorders.

T. Ammi has a lot of vitamins and minerals, along with phytochemicals that enhance wellness, such as carotenoids (-carotene and lutein) and antioxidants, which provide a lot of antioxidant defense. Two in vitro tests were used to evaluate the antioxidant potential of a *T. Ammi* seed extraction mixes: the hydrogen peroxide (H_2O_2) scavenging analysis and the nitric oxide radical scavenging assay. At a concentration of 200g/ml, *T. Ammi* extract reduced hydrogen peroxide by up to 70.04 percent. It blocked 72.80 out of a hundred of nitric oxide radical rummaging at a dose of 200g/ml, although ascorbic acid hindered 94.96 percent at the same dosage (Bajpai & Agrawal, 2015).

2.9.7 Antimicrobial activity

Plants contain several types of bioactive components, including tannins, terpenoids, alkaloids, and flavonoids, all of them have antibacterial activities in cultured cells. Phytochemical composition and antibacterial activities are also discussed.

Except for P. aeruginosa, *Trachyspermum ammi* seed oil shown antimicrobial activity against fifty-five bacterial strains with a lowest or minimum inhibitory concentration of 2% (v/v). *Trachyspermum ammi* diethyl ether fraction demonstrated strong anti-bacterial & anti-fungal activity against multidrug resistant strains of *Candida albicans*, *Candida krusei, Candida tropicalis, Candida glabrata*, *E coli*, and reference cultures of *Streptococcus mutans* and *Streptococcus bovis*. *Trachyspermum ammi* may reduce pathogenic bacteria for example *Candida albicans, Clostridium spp., and Bacillus fragilis*, and hence may be useful in dysbiosis therapy (Hawrelak, Cattley, & Myers, 2009).

2.10 Characterization of nano particles

Characterization is the study of many facts like structure of nanoparticles, the material from which nanoparticles can be formed and many other properties. There are different techniques for the characterization of nanoparticles. These techniques are atomic force microscopy, particles size analysis, scanning electron microscopy, X-ray diffraction, transmission, electron microscopy Fourier transform infrared spectroscopy, X-ray photoelectron spectroscopy and Raman spectra etc. SEM and TEM are the essential techniques. SEM is depends upon electron scanning method. TEM is depends on electron transmittance properties and XRD is based on the structural properties.

The characterized biosynthesized nanoparticles by SEM and XRD exposed the crystalline structure and spherical geometry. XRD and SEM analysis indicates magnitude of the particles was found to be about 60-70 nm in range. The size of particle approximately 100 nm measured by PSA of synthesized Aluminum oxide powders. The triumphant structure of Aluminum oxide nanoparticles was confirmed by retaining SEM-EDX, XRD, and PSA analysis.

The characterization of synthesized Al_2O_3 nanoparticles UV-Vis spectroscopy was used. Crystalline nature of the biosynthesized nanoparticle was exposed by X-ray Diffraction (XRD) and confirms the size of the nanoparticle as 25.7nm. EDX with SEM was used to confirm the shape, composition and size of green manufactured Al_2O_3 nanoparticle.

Different techniques are used for characterization. For crystalline size X-Ray Diffractometer (XRD), for geometrical studies Field Emission Scanning Electron Microscope (FESEM), for to analyses the absorption patterns UV-Visible spectroscopy (UV-Vis), for analyzing the functional groups Fourier Transform Infrared (FTIR) spectroscopy is used which take part in the reaction. The development of Aluminum oxide nano-particles was checked by comprehensive characterization techniques. Fourier transform Infrared (FT-IR) spectral data analysis is use for the confirmation of presence of metal oxides and biomolecules. The surface geometry that is of Al_2O_3 particles observed by Scanning electron microscope (SEM) showed the hexagonal-shaped Al_2O_3 crystallites. The formation of pure cubic Al_2O_3 crystalline nano particles shown by X-ray diffraction (XRD). The surface geometry of Al_2O_3 nanoparticles observed by Scanning electron microscope (SEM) showed the hexagonal-shaped Al_2O_3 crystallites.

CONCLUSION:

Trachyspermum ammi (reducing agent) is the herb that has many effective uses, basically its therapeutic use, its use in spices and more importantly the pharmacological applications due to its anti-oxidant property. Green Al_2O_3 synthesized nanoparticles from *Trachyspermum ammi* also exhibit these properties along with some advancement. These nano particles create prolific response as a result of phytochemicals present on the surface of nanoparticles. This process is cost effective, the characterization SEM, XRD ensures the presence of Al_2O_3 nanoparticles and confirm its size in nano scale.

REFERENCES:

[1]. Adlakha-Hutcheon, G., Khaydarov, R., Korenstein, R., Varma, R., Vaseashta, A., Stamm, H., & Abdel-Mottaleb, M. (2009). Nanomaterials, nanotechnology *Nanomaterials: risks and benefits* (pp. 195-207): Springer.

[2]. Ahsan, S., Shah, A., Tanira, M., Ahmad, M., Tariq, M., & Ageel, A. (1990). Studies on some herbal drugs used against kidney stones in Saudi folk medicine. *Fitoterapia, 61*(5), 435-438.

[3]. Akhtar, J., Siddique, K. M., Bi, S., & Mujeeb, M. (2011). A review on phytochemical and pharmacological investigations of miswak (Salvadora persica Linn). *Journal of Pharmacy and Bioallied Sciences, 3*(1), 113.

[4]. Aruna, K., & Sivaramakrishnan, V. (1992). Anticarcinogenic effects of some Indian plant products. *Food and Chemical Toxicology, 30*(11), 953-956.

[5]. Asif, H. M., Sultana, S., & Akhtar, N. (2014). A panoramic view on phytochemical, nutritional, ethanobotanical uses and pharmacological values of Trachyspermum ammi Linn. *Asian Pacific Journal of Tropical Biomedicine, 4*, S545-S553.

[6]. Bairwa, R., Sodha, R., & Rajawat, B. (2012). Trachyspermum ammi. *Pharmacognosy reviews, 6*(11), 56.

[7]. Bajpai, V. K., & Agrawal, P. (2015). Studies on phytochemicals, antioxidant, free radical scavenging and lipid peroxidation inhibitory effects of Trachyspermum ammi seeds. *Indian J Pharm Educ Res, 49*, 58-65.

[8]. Baratta, M. T., Dorman, H. D., Deans, S. G., Biondi, D. M., & Ruberto, G. (1998). Chemical composition, antimicrobial and antioxidative activity of laurel, sage, rosemary, oregano and coriander essential oils. *Journal of Essential Oil Research, 10*(6), 618-627.

[9]. Bukero, G., & Philipos, M. Experimental Study on Cost Benefit Analysis of Lemon Verbena (Lominat) Cultivation for Herbal Production: The Case of Wondo Genet District, Southern Ethiopia.

[10]. Chandra Mouli, P., & Parthiban, S. (2012). Nanotechnology in dentistry-a review. *Int J Biol Med Res, 3*(2), 1550-1553.

[11]. Chen, F., Zhang, X. H., Hu, X. D., Zhang, W., Zeng, R., Liu, P. D., & Zhang, H. Q. (2016). Synthesis and characteristics of nanorods of gadolinium hydroxide and gadolinium oxide. *Journal of Alloys and Compounds, 664*, 311-316.

[12]. Choudhury, S., Ahmed, R., Kanjilal, P. B., & Leclercq, P. A. (1998). Composition of the seed oil of Trachyspermum ammi (L.) Sprague from Northeast India. *Journal of Essential Oil Research, 10*(5), 588-590.

[13]. Claeson, U. P., Malmfors, T., Wikman, G., & Bruhn, J. G. (2000). Adhatoda vasica: a critical review of ethnopharmacological and toxicological data. *Journal of Ethnopharmacology, 72*(1-2), 1-20.

[14]. Dai, H. (2002). Carbon nanotubes: synthesis, integration, and properties. *Accounts of chemical research, 35*(12), 1035-1044.

[15]. Daraio, C., & Jin, S. (2012). Synthesis and patterning methods for nanostructures useful for biological applications *Nanotechnology for biology and medicine* (pp. 27-44): Springer.

[16]. De Volder, M. F., Tawfick, S. H., Baughman, R. H., & Hart, A. J. (2013). Carbon nanotubes: present and future commercial applications. *science, 339*(6119), 535-539.

[17]. Devatha, C. P., & Thalla, A. K. (2018). Green synthesis of nanomaterials *Synthesis of inorganic nanomaterials* (pp. 169-184): Elsevier.

[18]. Dhand, C., Dwivedi, N., Loh, X. J., Ying, A. N. J., Verma, N. K., Beuerman, R. W., . . . Ramakrishna, S. (2015). Methods and strategies for the synthesis of diverse nanoparticles and their applications: a comprehensive overview. *RSC Advances, 5*(127), 105003-105037.

[19]. Drexler, K. E. (1981). Molecular engineering: An approach to the development of general capabilities for molecular manipulation. *Proceedings of the National Academy of Sciences, 78*(9), 5275-5278.

[20]. Durán, N., & Marcato, P. D. (2012). Biotechnological routes to metallic nanoparticles production: mechanistic aspects, antimicrobial activity, toxicity and industrial applications *Nano-antimicrobials* (pp. 337-374): Springer.

[21]. Durán, N., & Seabra, A. B. (2012). Metallic oxide nanoparticles: state of the art in biogenic syntheses and their mechanisms. *Applied microbiology and biotechnology, 95*(2), 275-288.

[22]. Ellison, C. J., Phatak, A., Giles, D. W., Macosko, C. W., & Bates, F. S. (2007). Melt blown nanofibers: Fiber diameter distributions and onset of fiber breakup. *Polymer, 48*(11), 3306-3316.

[23]. Ernst, J. V. (2009). Nanotechnology education: Contemporary content and approaches. *Journal of technology studies, 35*(1), 3-8.

[24]. Fischer, H. (2003). Polymer nanocomposites: from fundamental research to specific applications. *Materials Science and Engineering: C, 23*(6-8), 763-772.

[25]. Gilani, A., Jabeen, Q., Ghayur, M., Janbaz, K., & Akhtar, M. (2005). Studies on the antihypertensive, antispasmodic, bronchodilator and hepatoprotective activities of the Carum copticum seed extract. *Journal of Ethnopharmacology, 98*(1-2), 127-135.

[26]. Hawrelak, J. A., Cattley, T., & Myers, S. P. (2009). Essential oils in the treatment of intestinal dysbiosis: A preliminary in vitro study. *Alternative Medicine Review, 14*(4).

[27]. Hayashi, H., & Hakuta, Y. (2010). Hydrothermal synthesis of metal oxide nanoparticles in supercritical water. *Materials, 3*(7), 3794-3817.

[28]. Herricks, T., Chen, J., & Xia, Y. (2004). Polyol synthesis of platinum nanoparticles: control of morphology with sodium nitrate. *Nano Letters, 4*(12), 2367-2371.

[29]. Iqbal, P., Preece, J. A., & Mendes, P. M. (2012). Nanotechnology: The “Top-Down” and “Bottom-Up” Approaches. *Supramolecular chemistry: from molecules to nanomaterials*.

[30]. Iravani, S. (2011). Green synthesis of metal nanoparticles using plants. *Green Chemistry, 13*(10), 2638-2650.

[31]. Ishwar, S., & Singh, V. (2000). Antifungal properties of aqueous and organic solution extracts of seed plants against Aspergillus flavus and A. niger. *Phytomorphology, 50*(2), 151-157.

[32]. Jabbar, A., Iqbal, Z., & Khan, M. N. (2006). In vitro anthelmintic activity of Trachyspermum ammi seeds. *Pharmacognosy Magazine, 2*(6), 126.

[33]. Jamieson, T., Bakhshi, R., Petrova, D., Pocock, R., Imani, M., & Seifalian, A. M. (2007). Biological applications of quantum dots. *Biomaterials, 28*(31), 4717-4732.

[34]. Joye, I. J., & McClements, D. J. (2014). Biopolymer-based nanoparticles and microparticles: Fabrication, characterization, and application. *Current Opinion in Colloid & Interface Science, 19*(5), 417-427.

[35]. Sarfraz, S., Javed, A., Mughal, S. S., Bashir, M., Rehman, A., Parveen, S., ... & Khan, M. K. (2020). Copper Oxide Nanoparticles: Reactive Oxygen Species Generation and Biomedical Applications. *Int. J. Comput. Theor. Chem*, *8*, 40-46.

[36]. Rafique, S., Hassan, S. M., Mughal, S. S., Hassan, S. K., Shabbir, N., Perveiz, S., ... & Farman, M. (2020). Biological attributes of lemon: a review. *Journal of Addiction Medicine and Therapeutic Science*, *6*(1), 030-034.

[37]. Hanif, M. A., Hassan, S. M., Mughal, S. S., Rehman, A., Hassan, S. K., Ibrahim, A., & Hassan, H. (2021). An overview on ajwain (Trachyspermum Ammi) pharmacological effects: current and conventional. *Technology*, *5*(1), 1-6.

[38]. Khalid, Z., Hassan, S. M., Mughal, S. S., Hassan, S. K., & Hassan, H. (2021). Phenolic Profile and Biological Properties of Momordica charantia'. *Chemical and Biomolecular Engineering*, *6*(1), 17.

[39]. Hassan, S. M., Mughal, S. S., Hassan, S. K., Ibrahim, A., Hassan, H., Shabbir, N., ... & Shafiq, S. (2020). Cellular interactions, metabolism, assessment and control of aflatoxins: an update. *Comput Biol Bioinform*, *8*, 62-71.

[40]. Khattak, A. K., Syeda, M. H., & Shahzad, S. M. (2020). General overview of phytochemistry and pharmacological potential of Rheum palmatum (Chinese rhubarb). *Innovare Journal of Ayurvedic Sciences*, *8*(6), 1-5.

[41]. Latif, M. J., Hassan, S. M., Mughal, S. S., Aslam, A., Munir, M., Shabbir, N., ... & Perveiz, S. (2020). Therapeutic potential of Azadirachta indica (neem) and their active phytoconstituents against diseases prevention. *J. Chem Cheml Sci.*, *10*(3), 98-110.

[42]. Khalid, Z., Hassan, S., Shahzad, S., & Khurram, H. (2021). A review on biological attributes of Momordica charantia. *Adv Biosci Bioeng*, *9*(1), 8-12.

[43]. Hafeez, M., Hassan, S. M., Mughal, S. S., Munir, M., & Khan, M. K. (2020). Antioxidant, Antimicrobial and Cytotoxic Potential of Abelmoschus esculentus. *Chemical and Biomolecular Engineering*, *5*(4), 69.

[44]. Afzal, N., Hassan, S. M., Mughal, S. S., Pando, A., & Rafiq, A. (2022). Control of Aflatoxins in Poultry Feed by Using Yeast. *American Journal of Chemical and Biochemical Engineering*, *6*(1), 21-26.

[45]. Shabbir, N., Hassan, S. M., Mughal, S. S., Pando, A., & Rafiq, A. (2022). Eletteria cardamomum and Greenly Synthesized MgO NPs: A Detailed Review of Their Properties and Applications. *Engineering Science*, *7*(1), 15-22.

[46]. Mubeen, N., Hassan, S. M., & Mughal, S. S. (2020). A Biological Approach to Control Aflatoxins by Moringa Oleifera. *International Journal of Bioorganic Chemistry*, *5*(2), 21.

[47]. Mubeen, N., Hassan, S. M., Mughal, S. S., Hassan, S. K., Ibrahim, A., Hassan, H., & Mushtaq, M. (2020). Vitality and Implication of Natural Products from Moringa oleifera: An Eco-Friendly Approach. *Computational Biology and Bioinformatics*, *8*(2), 72.

[48]. Aslam, A., Hassan, S. M., Mughal, S. S., Hassan, S. K., Ibrahim, A., Hassan, H., ... & Shafiq, S. (2020). Comprehensive Review of Structural Components of Salvia hispanica & Its Biological Applications. *International Journal of Biochemistry, Biophysics & Molecular Biology*, *5*(1), 1.

[49]. Mughal, S. S., & Hassan, S. M. (2022). Comparative Study of AgO Nanoparticles Synthesize Via Biological, Chemical and Physical Methods: A Review. *American Journal of Materials Synthesis and Processing*, *7*(2), 15-28.

[50]. Rafique, S., Hassan, S. M., Mughal, S. S., & Afzal, N. (2020). Asma Shafi 2, Sehrish Kamran 3 Department of Chemistry, Lahore Garrison University, Lahore, Punjab, Pakistan 2 Deparment of polymer, Punjab University Lahore, Pakistan 3 Department of Allied sciences, FMH College of medicine and dentistry. *GSJ*, *8*(9).

[51]. Abbas, F., Tahir, M. U., Farman, M., Mumtaz, M., Aslam, M. R., Mughal, S. S., ... & Khan, A. R. Synthesis and Characterization of Silver Nanoparticles Against Two Stored Commodity Insect Pests.

[52]. Aslam, A., Hassan, S. M., Mughal, S. S., Perveiz, S., Mushtaq, M., Munir, M., ... & Ayub, A. R. Investigation of Biological Activity of Salvia hispanica.

[53]. Tahir, M. U., Abbas, F., Tahira, M., Shahzad, H. M., Sharif, S., Raza, A., ... & Ziad, M. SYNTHESIS OF MANGANESE-TIN BIMETALLIC MATERIALS AND STUDY OF ITS CATALYTIC APPLICATIONS.

[54]. ul Mustafa, Z., ullah Khan, A., Mudasar, A. S., & Mughal, S. S. Edge Functionalization of Phosphorene with different Chemical Functional Groups.

[55]. Muneer, M., Mughal, S. S., Pervez, S., Mushtaq, M., Shabbir, N., Aslam, A., ... & Abbas, F. DIAGNOSIS AND TREATMENT OF DISEASES BY USING METALLIC NANOPARTICLES-A REVIEW.

[56]. Mughal, S., Abbas, F., Tahir, M., Ayub, A., Javed, H., Mamtaz, M., & Iram, H. (2019). Role of Silver Nanoparticles in Colorimetric Detection of Biomolecules. doi:10.7537/marsbnj050419.04

[57]. Perveiz, S., Hassan, S. M., Mughal, S. S., Pando, A., Rafiq, A., & Shabbir, N. Structural, Morphological and Biotoxicity Studies of Biosynthesized CaO Nanoparticles Via Cuminum Cyminum.

[58]. SHABBIR, N., HASSAN, S. M., MUGHAL, S. S., PERVEIZ, S., MUNIR, M., MUSHTAQ, M., & KHAN, M. K. Peppermint oil, its useful, and adverse effects on human health: a review.

[59]. Perveiz, S., Hassan, S. M., Mughal, S. S., Ullah, H., Shabbir, N., Munir, M., ... & Farman, M. A Review on Heavy metal contamination in water and the Strategies for the Reduction of Pollution Load of Commercial and Industrial Areas of Pakistan.

[60]. Hafeez, M., Hassan, S. M., Mughal, S. S., & Mushtaq, M. Evaluation of Biological Characteristics of Abelmoschus esculentus.

[61]. Hassan, S. M., Mubeen, N., Hassan, S. K., Ibrahim, A., Hassan, H., Mughal, S. S.,. & Haider, G. MORINGA Oleifera, A MULTIFUNCTIONAL PLANT: A REVIEW STUDY.

[62]. Mushtaq, M., S.M. Hassan, and S.S. Mughal, Synthesis, Characterization and Biological Approach of Nano Oxides of Calcium by Piper nigrum. American Journal of Chemical Engineering, 2022. 10(4): p. 79-88.

[63]. Khushi, A., Hassan, S. M., & Mughal, S. S. Antimicrobial and Structural Investigation of Green Synthesized ZnO Nanostructures from Bougainvillea glabra Leaves Extract.

[64]. Khan, Aysha, Syeda Mona Hassan, and Shahzad Sharif Mughal. "Biological Evaluation of a Herbal Plant: Cichrorium intybus." *Science and Technology* 6.2 (2022): 26-38.

[65]. Muneeza Munir, Syeda Mona Hassan, Shahzad Sharif Mughal, Alvina Rafiq, Evaluation of Biological Approaches of Green Synthesized MgO Nanoparticles by *Syzygium aromaticum*, *International Journal of Atmospheric and Oceanic Sciences*. Volume 6, Issue 2, December 2022 , pp. 44-53. doi: 10.11648/j.ijaos.20220602.12

[66]. Lashari, Aamna, Syeda Mona Hassan, and Shahzad Sharif Mughal. "Biosynthesis, Characterization and Biological Applications of BaO Nanoparticles using Linum usitatissimum." *American Journal of Applied Scientific Research* 8.3 (2022): 58-68.

[67]. Kostyukovsky, M., Rafaeli, A., Gileadi, C., Demchenko, N., & Shaaya, E. (2002). Activation of octopaminergic receptors by essential oil constituents isolated from aromatic plants: possible mode of action against insect pests. *Pest Management Science: formerly Pesticide Science, 58*(11), 1101-1106.

[68]. Lin, S.-Y., Wu, M.-T., Cho, Y.-I., & Chen, H.-H. (2015). The effectiveness of a popular science promotion program on nanotechnology for elementary school students in I-Lan City. *Research in Science & Technological Education, 33*(1), 22-37.

[69]. Luitel, D. R., Rokaya, M. B., Timsina, B., & Münzbergová, Z. (2014). Medicinal plants used by the Tamang community in the Makawanpur district of central Nepal. *Journal of Ethnobiology and Ethnomedicine, 10*(1), 1-11.

[70]. Luo, X., Morrin, A., Killard, A. J., & Smyth, M. R. (2006). Application of nanoparticles in electrochemical sensors and biosensors. *Electroanalysis: An International Journal Devoted to Fundamental and Practical Aspects of Electroanalysis, 18*(4), 319-326.

[71]. Majumdar, D., Singha, A., Mondal, P. K., & Kundu, S. (2013). DNA-mediated wirelike clusters of silver nanoparticles: an ultrasensitive SERS substrate. *ACS applied materials & interfaces, 5*(16), 7798-7807.

[72]. McNeil, S. E. (2005). Nanotechnology for the biologist. *Journal of leukocyte biology, 78*(3), 585-594.

[73]. Nikalje, A. P. (2015). Nanotechnology and its applications in medicine. *Med chem, 5*(2), 081-089.

[74]. Ozin, G. A. (1992). Nanochemistry: synthesis in diminishing dimensions. *Advanced Materials, 4*(10), 612-649.

[75]. Park, I.-K., Kim, J., Lee, S.-G., & Shin, S.-C. (2007). Nematicidal activity of plant essential oils and components from ajowan (Trachyspermum ammi), allspice (Pimenta dioica) and litsea (Litsea cubeba) essential oils against pine wood nematode (Bursaphelenchus xylophilus). *Journal of nematology, 39*(3), 275.

[76]. Park, J., Joo, J., Kwon, S. G., Jang, Y., & Hyeon, T. (2007). Synthesis of monodisperse spherical nanocrystals. *Angewandte Chemie International Edition, 46*(25), 4630-4660.

[77]. Prabhakar, R., & Samadder, S. (2018). Low cost and easy synthesis of aluminium oxide nanoparticles for arsenite removal from groundwater: a complete batch study. *Journal of Molecular Liquids, 250*, 192-201.

[78]. Qi, M., Zhang, K., Li, S., Wu, J., Pham-Huy, C., Diao, X., . . . He, H. (2016). Superparamagnetic Fe 3 O 4 nanoparticles: synthesis by a solvothermal process and functionalization for a magnetic targeted curcumin delivery system. *New Journal of Chemistry, 40*(5), 4480-4491.

[79]. Raffi, M., Rumaiz, A. K., Hasan, M., & Shah, S. I. (2007). Studies of the growth parameters for silver nanoparticle synthesis by inert gas condensation. *Journal of Materials Research, 22*(12), 3378-3384.

[80]. Rahman, P., & Green, M. (2009). The synthesis of rare earth fluoride based nanoparticles. *Nanoscale, 1*(2), 214-224.

[81]. Rajput, N. (2015). Methods of preparation of nanoparticles-a review. *International Journal of Advances in Engineering & Technology, 7*(6), 1806.

[82]. Ramaswamy, S., Sengottuvelu, S., Sherief, S. H., Jaikumar, S., Saravanan, R., Prasadkumar, C., & Sivakumar, T. (2010). TRACHYSPERMUM AMMI FRUIT. *International Journal of Pharma and Bio Sciences, 1*, 1.

[83]. Rao, C. N. R., Müller, A., & Cheetham, A. K. (2006). *The chemistry of nanomaterials: synthesis, properties and applications*: John Wiley & Sons.

[84]. Roco, M. (1999). Nanoparticles and nanotechnology research. *Journal of nanoparticle research, 1*(1), 1.

[85]. Salah, N., Habib, S. S., Khan, Z. H., Memic, A., Azam, A., Alarfaj, E., . . . Al-Hamedi, S. (2011). High-energy ball milling technique for ZnO nanoparticles as antibacterial material. *International journal of nanomedicine, 6*, 863.

[86]. Schmidt, V., Wittemann, J. V., Senz, S., & Gösele, U. (2009). Silicon nanowires: a review on aspects of their growth and their electrical properties. *Advanced Materials, 21*(25-26), 2681-2702.

[87]. Seth, S., Mondal, N., Patra, S., & Samanta, A. (2016). Fluorescence blinking and photoactivation of all-inorganic perovskite nanocrystals CsPbBr3 and CsPbBr2I. *The journal of physical chemistry letters, 7*(2), 266-271.

[88]. Sharifi, S., Behzadi, S., Laurent, S., Forrest, M. L., Stroeve, P., & Mahmoudi, M. (2012). Toxicity of nanomaterials. *Chemical Society Reviews, 41*(6), 2323-2343.

[89]. Singh, G., Maurya, S., Catalan, C., & De Lampasona, M. (2004). Chemical constituents, antifungal and antioxidative effects of ajwain essential oil and its acetone extract. *Journal of agricultural and food chemistry, 52*(11), 3292-3296.

[90]. Solanki, J. N., & Murthy, Z. V. P. (2011). Controlled size silver nanoparticles synthesis with water-in-oil microemulsion method: a topical review. *Industrial & engineering chemistry research, 50*(22), 12311-12323.

[91]. Srivastava, K. (1988). Extract of a spice—Omum (Trachyspermum ammi)-shows antiaggregatory effects and alters arachidonic acid metabolism in human platelets. *Prostaglandins, Leukotrienes and Essential Fatty Acids, 33*(1), 1-6.

[92]. Sun, Y., Mayers, B. T., & Xia, Y. (2002). Template-engaged replacement reaction: a one-step approach to the large-scale synthesis of metal nanostructures with hollow interiors. *Nano Letters, 2*(5), 481-485.

[93]. Suryanarayana, C., & Koch, C. (2000). Nanocrystalline materials–Current research and future directions. *Hyperfine interactions, 130*(1), 5-44.

[94]. Taylor, A., Jones, G., & Pearl, T. P. (2008). Bumpy, sticky, and shaky: nanoscale science and the curriculum. *Science Scope, 31*(7), 28-35.

[95]. Teo, W. E., & Ramakrishna, S. (2006). A review on electrospinning design and nanofibre assemblies. *Nanotechnology, 17*(14), R89.

[96]. Tretter, T. R., Jones, M. G., Andre, T., Negishi, A., & Minogue, J. (2006). Conceptual boundaries and distances: Students' and experts' concepts of the scale of scientific phenomena. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 43*(3), 282-319.

[97]. Vallejos, S., Stoycheva, T., Umek, P., Navio, C., Snyders, R., Bittencourt, C., . . . Correig, X. (2011). Au nanoparticle-functionalised WO 3 nanoneedles and their application in high sensitivity gas sensor devices. *Chemical Communications, 47*(1), 565-567.

[98]. Wang, X., Ruditskiy, A., & Xia, Y. (2016). Rational design and synthesis of noble-metal nanoframes for catalytic and photonic applications. *National Science Review, 3*(4), 520-533.

[99]. Wang, X., Song, J., & Wang, Z. L. (2007). Nanowire and nanobelt arrays of zinc oxide from synthesis to properties and to novel devices. *Journal of Materials Chemistry, 17*(8), 711-720.

[100]. Ward, M., Brydson, R., & Cochrane, R. (2006). *Mn nanoparticles produced by inert gas condensation.* Paper presented at the Journal of Physics: Conference Series.

[101]. Wesley, S. J., Raja, P., Raj, A. A., & Tiroutchelvamae, D. (2014). Review on-nanotechnology applications in food packaging and safety. *International Journal of Engineering Research, 3*(11), 645-651.

[102]. Xia, Y., Li, W., Cobley, C. M., Chen, J., Xia, X., Zhang, Q., . . . Brown, P. K. (2011). Gold nanocages: from synthesis to theranostic applications. *Accounts of chemical research, 44*(10), 914-924.

[103]. Xing, T., Sunarso, J., Yang, W., Yin, Y., Glushenkov, A. M., Li, L. H., . . . Chen, Y. (2013). Ball milling: a green mechanochemical approach for synthesis of nitrogen doped carbon nanoparticles. *Nanoscale, 5*(17), 7970-7976.

[104]. Zha, J., & Roggendorf, H. (1991). Sol–gel science, the physics and chemistry of sol–gel processing, Ed. by CJ Brinker and GW Scherer, Academic Press, Boston 1990, xiv, 908 pp., bound—ISBN 0-12-134970-5: Wiley Online Library.

[105]. Zhang, X., Yan, S., Tyagi, R., & Surampalli, R. (2011). Synthesis of nanoparticles by microorganisms and their application in enhancing microbiological reaction rates. *Chemosphere, 82*(4), 489-494.

[106]. Zinchenko, A., Miwa, Y., Lopatina, L. I., Sergeyev, V. G., & Murata, S. (2014). DNA hydrogel as a template for synthesis of ultrasmall gold nanoparticles for catalytic applications. *ACS applied materials & interfaces, 6*(5), 3226-3232.