FABRICATION OF POROUS CALCIUM SULPHATE BY USING YEAST AS PORE FOAMER

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FABRICATION OF POROUS CALCIUM SULPHATE BY USING YEAST AS PORE FOAMER

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LIST OF SYMBOLS

ºC	Degree Celcius
nm	Nanometer
θ	Theta
%	Percentage
Å	Angstrom

LIST OF ABBREVIATIONS

$CaSO_4$	Calcium Sulphate
Na_2SO_4	Sodium Sulphate
SEM	Scanning Electron Microscope
XRD	X-ray diffraction
FTIR	Fourier Transform Infrared Spectroscopy

FABRIKASI KALSIUM SULFAT BERLIANG MENGGUNAKAN YIS SEBAGAI PEMBENTUK LIANG

ABSTRAK

Kalsium Sulfat mempunyai sejarah klinikal yang luas daripada kebanyakan aplikasi biomaterial. Ia mengisi kekurangan tulang dengan baik dan menyerap dengan cepat dan sepenuhnya tanpa menyebabkan keradangan. Bahan asasnya sangat murah dan senang ditemui. Kalsium Sulfat boleh menyampaikan antibiotik, ubat-ubatan, dan hormon pertumbuhan. Ortopedik dan pergigian sering menggunakannyaYis adalah agen biologi yang boleh digunakan sebagai agen pembentuk liang. Objektif kajian melibatkan penghasilan kalsium sulfat berliang menggunakan peratusan yis tertentu (0% yis, 100% $CaSO_4$, 5% yis 95% $CaSO_4$, 10% yis 90% $CaSO_2$ dan 15% yis 85% $CaSO_4$) sebagai pembentuk liang serta suhu pembakaran berbeza (900ºC, 1000ºC dan 1100ºC). $CaSO_4$ akan dihasilkan melalui kaedah mendakan berair dan akan dikeringkan serta dikalsin pada suhu 500ºC. Suhu 500ºC ialah suhu optimum untuk menghasilkan $CaSO_4$ dengan ketulenan yang tinggi. Kemudian, serbuk $CaSO_4$ yang disintesis akan dicampur dan dijadikan bentuk pelet bersama yis. Kemudian, sampel yang dibakar dianalisis menggunakan kekuatan tegangan mengikut garis pusat (DTS), ujian keliangan ketara, ujian ketumpatan pukal, ujian pengecutan linear, ujian pengurangan berat, spektroskopi inframerah fourier transformasi (FTIR) untuk mengenalpasti kumpulan berangkap dan pembelauan Sinar-X (XRD) untuk menganalisis fasa yang hadir. Sampel yang dibakar pada 900 ºC, sampel 5Y/95CS menunjukkan keputusan DTS yang tertinggi iaitu 2.03MPa dengan nilai keliangan 30.25%. Kemudian, sampel 10Y/90CS dengan nilai DTS sebanyak 1.97MPa. Ini menunjukkan semakin tinggi jumlah yis, semakin rendah nilai DTS dan semakin tinggi nilai keliangan manakala berdasarkan ujian morfologi menunjukkan semakin tinggi saiz keliangn, nilai DTS akan menurun.

FABRICATION OF POROUS CALCIUM SULPHATE BY USING YEAST AS PORE FOAMER

ABSTRACT

Calcium Sulphate has a wide clinical history than most biomaterials applications. It fills bone deficiencies well and resorbs quickly and completely without causing inflammation. Its basic material is cheap and plentiful. Calcium Sulphate can deliver antibiotics, drugs, and growth hormones. Orthopedics and dentistry use it often.Yeast is a biological agent that can be used as a pore foaming agent. This study aims to fabricate porous Calcium Sulphate using different compositions of yeast (0%, 5%, 10% and 15%) that act as pore foamer with different firing temperatures (900ºC, 1000ºC and 1100ºC). $CaSO_4$ was prepared using aqueous precipitation and was calcined at 500°C. Then, the synthesized powder of $CaSO_4$ was mixed and palletized with yeast. The samples were analyzed using diametral Tensile Strength (DTS), apparent porosity test, bulk density test, linear shrinkage, weight loss, Fourier transform infrared spectroscopy (FTIR) for functional groups, and x-ray diffraction (XRD) for phase analysis. Samples fired at 900°C, with samples of 5Y/95CS show the highest DTS reading, which is 2.03MPa then, sample 10Y/90CS with DTS value of 0.84MPa It can be shown that increasing the amount of yeast may decrease the DTS reading and increase the apparent porosity. Based on the morphology analysis, yeast increases pore size, resulting in low DTS with higher apparent porosity of $CaSO_4$.

CHAPTER 1

INTRODUCTION

1.1 Introduction of the study

Calcium Sulphate ($CaSO_4$) is a class of bone healing materials that self-set. While $CaSO_4$ has great biocompatibility, surgical maneuverability, and sufficient mechanical qualities, they exhibit a sluggish rate of resorption in vivo. Moreover, $CaSO_4$ is a non-toxic, biodegradable, and non-toxic substance with unique features that is well suited for usage as a biomaterial (Thomas & Puleo, 2009)

There are six main crystal forms of $CaSO_4$, although only three are typically encountered in precipitates found in nature. The three forms are calcium sulphate dihydrate or known as gypsum ($CaSO_4.H_2O$), calcium sulphate hemihydrate or plaster of Paris (CaSO4·½H2O), and anhydrous calcium sulphate ($CaSO_4$) (Ishikawa et al., 2019).

Anhydrous $CaSO_4$ forms occur as there is no presence of water molecule (H_2O) in the $CaSO_4$ compound. There are three polymorphic forms of anhydrous $CaSO_4$. The three polymorphic forms of the anhydrous $CaSO_4$ are III-$CaSO_4$, II-$CaSO_4$, and I-$CaSO_4$. These polymorphic forms exist depending on the temperature that is being increased diromg calcinations. II-$CaSO_4$ is the target phase that is optimal in the calcium sulphate, and it is also used in biological applications because of its high stability. $CaSO_4$ is produced by the aqueous precipitation method. The precursors are $CaSO_4$ and Calcium Nitrate ($Ca(NO_3)_2.4H_2O$) will be prepared according to desired concentration and molar ratio which is Ca/S = 1/1 (Zahari et al., 2020).

$CaSO_4$ is a compound that is commonly utilized in dental and surgical treatments. There are several applications for it, including autografts, allografts, xenografts, and nonbiologically derived products (both synthetic and mineral-based). Furthermore, $CaSO_4$ has great absorbable properties, which makes it an effective space filler throughout the healing period of the wound. $CaSO_4$ has a reabsorption property that makes it to be utilized as a drug delivery system to deliver antibiotics and growth factors (Szponder et al., 2013).

$CaSO_4$ with a porous structure is utilized because it promotes cell growth and bone healing expansion Moreover, as $CaSO_4$ is used as a bone graft, the presence of pores in $CaSO_4$ promotes the growth of blood vessels and nutrient diffusion. According to Kuo et al. (2012), the presence of porosity can affect the rate of degradation of $CaSO_4$.

Therefore, yeast is introduced as a pore foaming agent due to its suitability. The English term yeast signifies foam or bubble. Yeasts are widely used in industries like food, wine, beer, and antibiotic manufacture. Particles will expand and develop into huge particle grains, according to Nasir et al. (2015), since yeast works as an agent that creates pores in the particles.

Yeast as a pore foaming agent can increase pore size and specific surface area of a compound by adsorption making yeast an ideal pore foaming agent. Moreover, Jin et al. (2020), stated that yeast undertakes anaerobic fermentation in the green body, and the pore size steadily increases as the yeast concentration rises.

1.2 Problem Statement

$CaSO_4$ with a porous structure has biomedical applications, the porous structure aids in the creation of new bone ingrowth. In addition, porosity is necessary for mechanical strength, as it must sustain the force of growing bones. According to Aarvold et al. (2013), A structure with a higher porosity indicates the development of new tissue within the pore. In addition, this structure exposes the cells to a greater area for reaction. Moreover, Yan et al. (2013), mentioned that porous $CaSO_4$ is beneficial in bone scaffolds for bone tissue engineering, and whisker composite made from porous $CaSO_4$ can increase the tensile and fatigue properties of $CaSO_4$. However, as of right now, there are only a very few limited methods that are economical and convenient to achieve porous $CaSO_4$, particularly for use in biomedical applications.

Currently, the method from Aarvold et al. (2013), utilizes the gel casting technique where the powders are mixed to form a slurry where they will be agitated together.Moreover, template-assisted colloidal processing technique also has been utilized to produce porous structure of ceramic (Sakka et al., 2005) . Meanwhile, research by Yan et al. (2013), produces porous $CaSO_4$ by mixing $CaSO_4$ hemihydrate with hydroxyapatite and sodium chloride. A study from Arsista et al. (2020), utilize sucrose granule mixed with $CaSO_4$.

In this study, porous $CaSO_4$ is produced by mixing with the yeast under different compositions and sintering temperatures. According to Menchavez & Intong, (2010), Using yeast as a biological foaming agent is preferable to using chemical foaming agents, which use a lot more chemicals. On the ceramic body, yeast can produce foam while also polymerizing to stabilize the foam. As a result, yeast will become an excellent biological agent for biomedical applications. Moreover, the utilization of a biological foaming agent which is the yeast is a flexible and straightforward method as yeast is relatively cheap and easy to obtain compared to other methods

1.3 Objective

The objectives of this study are as below :

I. To fabricate the porous $CaSO_4$ by using yeast as pore foamer

II. To evaluate the effect of different yeast compositions and different sintering temperatures on the properties of porous $CaSO_4$

1.4 Scope of Work

This research was conducted to investigate the effect of yeast as pore foaming agent to produce porous $CaSO_4$. This research is divided into four stages, as shown in Figure 1.1.

Stage I is the characterization of the raw materials, which will be conducted several analyses to verify and validate the raw materials. The raw materials are Sodium Sulphate (Na_2SO_4), Calcium Nitrate ($Ca(NO_3)_2.4H_2O$). The analysis was X-Ray Diffraction (XRD) for the phase analysis and Fourier Transform Infrared Spectroscopy (FTIR) which will be used to detect the functional group. Apart from that, Scanning Electron Microscopy (SEM) was used to analyze the change in morphology.

Stage II indicates the preparation of precursors, where Na_2SO_4 and $Ca(NO_3)_2.4H_2O$ will be mixed with a ratio of Ca/S of 1:1 to obtain the highest gain of II-$CaSO_4$ as mentioned by Zahari et al. (2020).

Stage III refers to the fabrication of porous $CaSO_4$ mixed with yeast at various compositions (0%, 5%, 10% and 15%) using stainless steel mould with a diameter of 13mm and 3 mm thickness.

Stage IV involves the characterizations of the pellet. The pellet will be sintered at temperatures 900°C, 1000°C, and 1100°C. The effect of different sintering temperatures will be analyzed to the porous structure of $CaSO_4$. Moreover, the pellet will undergo a series of tests and analyses, which are X-ray diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscope (SEM), porosity, density, and diametral tensile strength (DTS) test. Figure 1.1 shows the flowchart of the whole process of this study.

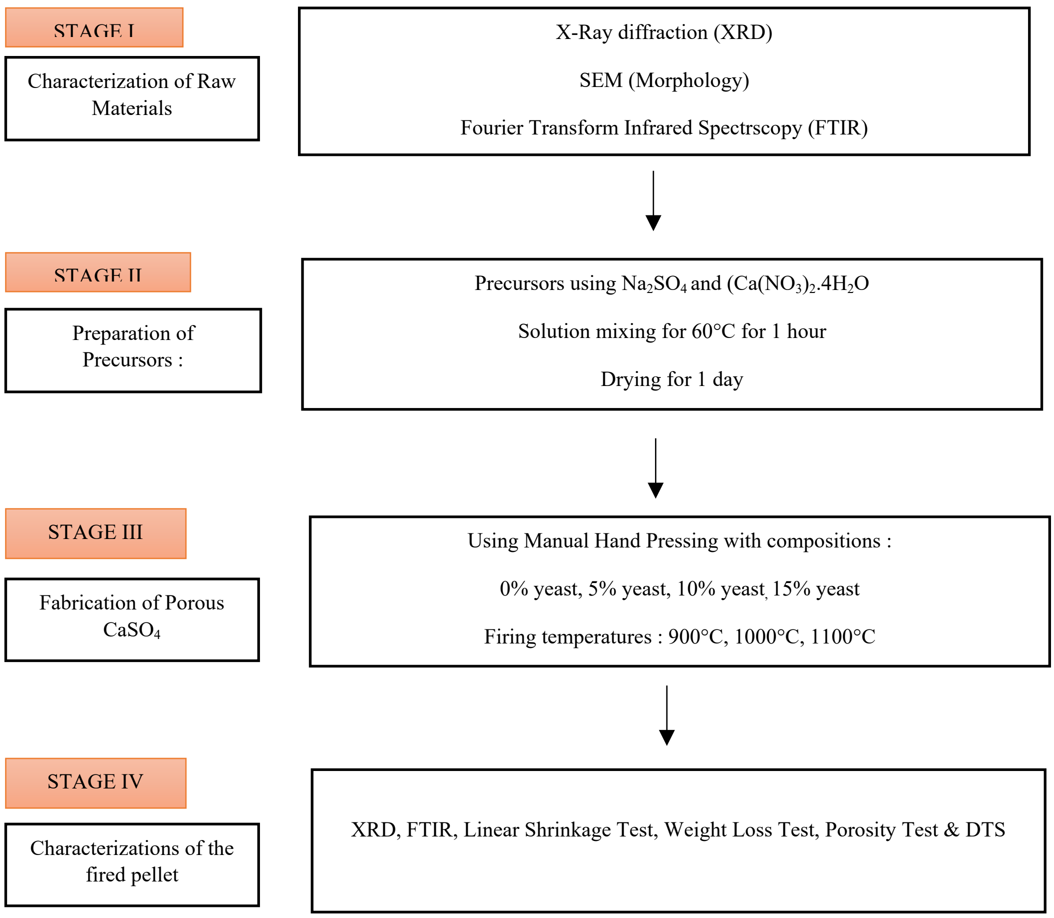

Figure 1.1: Flowcharts of the whole study

CHAPTER 2

LITERATURE REVIEW

Figure 1.1: The summarize of four stages involve in the study

2.1 Introduction

This chapter will provide an overview of the function and properties of biomaterials in their diverse applications. Aside from that, this chapter will examine the definition of biomaterials as well as specific examples of biomaterials, such as the structure and kind of bone. Then, the biological uses of Calcium Sulphate ($CaSO_4$) and the function of porous structures will be explored. In addition, this chapter will feature a brief overview of yeast's role and pore foamer.

2.2 Biomaterials

Biomaterials play an essential part in the process of restoring function and promoting healing in patients who have been sickened or injured. In the field of medicine, the term "biomaterial" refers to any substance that can sustain, augment, or replace damaged tissue or a biological function. These substances may be natural or synthetic (Song et al., 2022). The ancient Egyptians were the first known people to use biomaterials, and they did it in the form of sutures created from animal sinew. This practice stretches back to antiquity. The disciplines of medicine, biology, physics, and chemistry, in addition to more recent contributions from tissue engineering and materials science, are all brought together in the current field of biomaterials. Discoveries made over the past decade in tissue engineering, regenerative medicine, and other areas have contributed greatly to the field's rapid expansion.

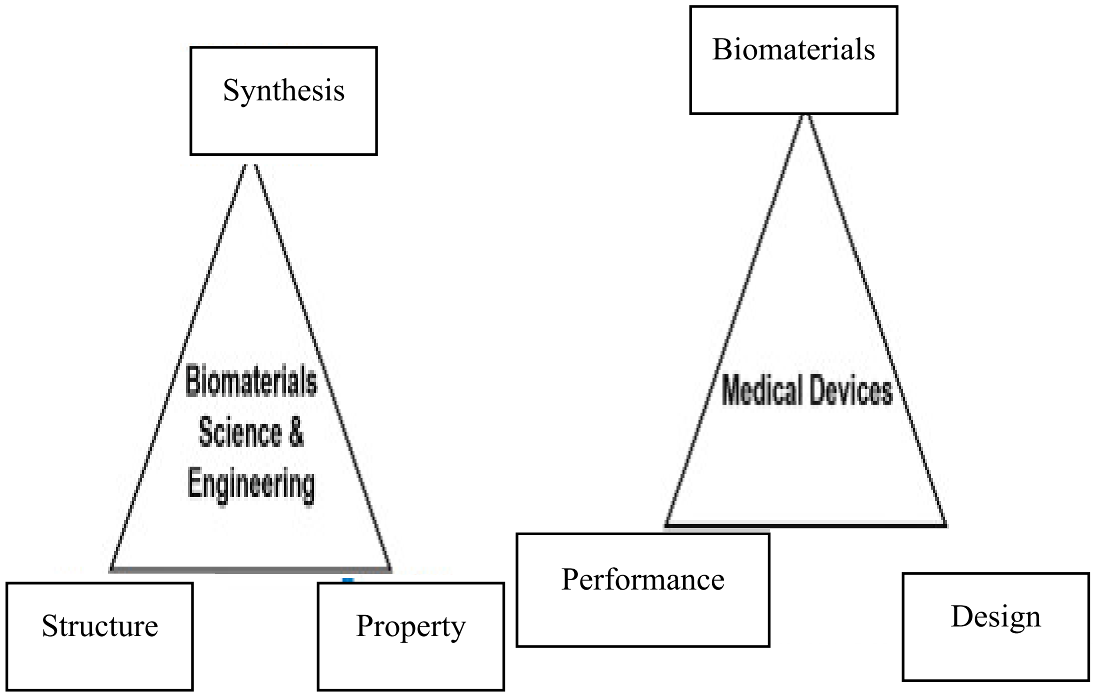

Figure 2.1: The science of biomaterials explores the links between the processing, structure, and properties of biomaterials (left). The engineering of biomaterials makes it possible for biomaterials to relate to applications by way of medical products. However, the biomaterial by itself is not sufficient; to become a product, it also requires the design to attain the desired level of functional performance (Zhang et al., 2022).

A biomaterial can be made from a wide variety of materials, including metals, ceramics, plastics, glasses, and even living cells and tissue. They are capable of being redesigned into components that are suitable for use in biomedical products and devices, such as coatings, fibers, films, foams, and textiles. These components can be machined or molded. Implanted heart valves, artificial hip joints, dental implants, and contact lenses are some examples of these types of devices. In many cases, they are biodegradable, and in other cases, they are bio-absorbable. This means that once they have served their purpose, they are gradually eliminated from the body. Biomaterials are not themselves medical items, yet they are critical elements of medical products (Song et al., 2022). Medical equipment, IVD reagents and tools, medicines, biological goods, and combination products are all medical items governed by regulatory agencies. Biomaterials must be precisely manufactured and designed in accordance with the final product specifications and application requirements in order to remove inappropriate risks and achieve desirable benefits through proven benchtop, biocompatibility and clinical performance (Song et al., 2022).

The majority of the materials that went into the construction of the body were of the single-phase variety. The vast majority of implant materials were modified versions of commercially available materials that already existed, but with increased degrees of purity. This was done to prevent the production of hazardous byproducts and to reduce corrosion. The contributions that Bill Bonfield has made to the fields of bone biomechanical, biomaterials, and multidisciplinary research are honoured in this article as a way to show our gratitude for his work. It is also a synopsis of the development of bioactive materials and the prospects for modifying the structure, texture, and surface chemistry of these materials to address five significant difficulties facing the twenty-first century (Hughes et al., 2015)

In addition, bone biomaterials are essential for bone healing as they give the essential substrate for growth and cell adhesion. Besides, the cells regenerated properties such as its shapes and functions will be the indicator for the biomaterials required (Hughes et al., 2015).

2.3 Bioceramics

Bioceramics are a category of materials used to heal or replace damaged bone tissues. Depending on the use, bioceramics can interact directly only with surrounding tissue, encouraging tissue growth or triggering new tissue regeneration (Roy et al., 2017).

Ceramic materials that also can interact with living organisms are known as bioceramics. This material is an essential component of the biomaterials category. Bioceramics are distinguished by their ability to be both bioactive and inert at the same time. In addition, the human body has a variety of applications for bioceramics. Zirconia, calcium sulphate, and hydroxyapatite are a few examples of essential biomaterials. Biocompatibility is one of the most important aspects of bioceramics. There are many different shapes and phases that bioceramics can take. There is also glass and composites, in addition to polycrystalline and crystals. The stages it goes through are determined by its application and its purpose (Abbas et al., 2021)

Recently, bioceramics are often used in dental, orthopedic implants, prostheses, and prosthetic devices. In addition, bioceramics also are used in diagnostic instruments, and tissue culture flask. Currently, few findings show that bioceramics can be used for cancer treatment. It is done by implanting bioceramic materials into the cancer cells. The unique properties of bioceramics are high chemical durability making it can transmit β-rays to the cancerous cell. For example, is hyperthermia which utilizes ferrite and magnetic materials in the cancerous area (Abbas et al., 2021)

2.4 Bone

Bone occurred naturally as the composite material as it contains two phases which are organic and mineral. It is complex mineralized living tissue with high strength and elasticity. Properties and mechanical structure determine the mechanical characteristic of the bone. There are several functions of bone in the human. Firstly, it is to give mechanical support to the inner tissue like the heart. Next is a weight-bearing organ and strength to the human skeletal system. Moreover, the bone formation process is continual where all bone tissue can spontaneously regenerate as bone remodelling can be describes the process by which the mineralized bone is degraded and replaced with new bone matrix by osteoclasts, a biochemical process that occurs over the course of an individual's lifetime (Abbas et al., 2021).

Human bone also consists of organic collagen fibers, inorganic mineralized matrix and water. 60-65%, then 20-25% of the human bone is made from organic phase. Calcium and phosphorus, in the type of an insoluble salt known as hydroxyapatite, are the primary minerals that can be found in bone tissue. Crystals of hydroxyapatite are nearby and connected to the natural protein matrix where they are found. In addition, hydroxyapatite crystals contain ions of magnesium, sodium, potassium, and citrate; however, these ions are conjugated to hydroxyapatite rather than forming their own separate crystals. Figure 2.1 shows the phases present in the human bone (Florencio-Silva et al., 2015)

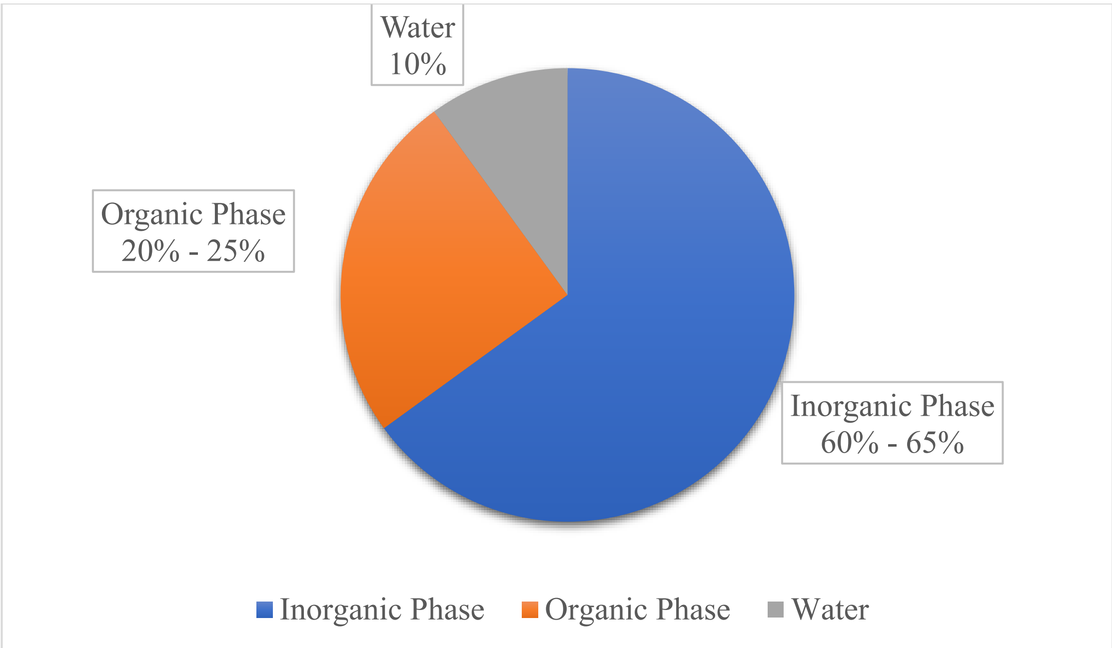

Figure 2.2: Phases Present in Human Bone (Boyan et al., 2011)

Additionally, the bone graft possesses several crucial characteristics. The first type is osteoconductive, which refers to the capacity to support bone growth during the surgical portion of the process. It is during this phase that pores, channels, and blood arteries are produced within the bone. The process of stimulating osteoprogenitor cells to develop into osteoblasts and initiate the production of new bone is referred to as osteoinductive. The ability of graft materials to make direct contact with living bone is what is meant by the term "osteointegrative," and the production of new bone by osteoblasts that are contained within the graft material is what is meant by the term "osteogenesis (Ene et al., 2021).

2.5 Bone Graft

A surgical treatment known as a bone graft is one option for treating conditions that affect the bones or joints. Bone grafting, also known as the transplantation of bone tissue, can be helpful in repairing bones that have been injured as a result of trauma or issues with the joints. In cases where there has been bone loss or a fracture, it can also be helpful in the process of rebuilding bone over an implanted device, such as a complete knee replacement. A bone transplant may be used to either fill in an area that is lacking bone or to assist in providing structural stability (Khan et al., 2005).

A bone graft can involve bone taken from the patient's own body, bone taken from a donor, or bone that is completely manufactured in a laboratory. In the event that it is accepted by the body, it has the potential to serve as a framework upon which the growth of new, live bone can occur. The treatment for bone deficiencies known as bone graft is a method known as bone graft substitution. Autografts, allografts, and xenografts are the three categories that it is possible to divide into when discussing this topic. One of the most common substances utilised in the process of bone grafting is Anhydrate. Bone grafts provide a variety of functions, including both mechanical and biologic ones. The relative importance of these functions is determined by the therapeutic outcome that is desired. For instance, enormous osteochondral grafts used in limb salvage treatments for tumours serve primarily as a mechanical support role. On the other hand, autogenous bone graft produced from the iliac crest and used in posterolateral spine fusions gives a biologic stimulus for bone regeneration. The ancient Greek physician Hippocrates is credited as being the first person to attempt the transplants of living animal tissues into humans (Khan et al., 2005).

Graft material will be determined by the kind of the injury that needs to be repaired. Allografts are frequently utilised in the repair of the hip, knee, or long bones. The arms and the legs each have long bones. The benefit is that there is no requirement for any additional surgical procedures in order to acquire the bone. Because you won't need any further incisions or surgery, it will also make it easier for you to avoid getting an infection.In contrast to organ transplants, which entai the presence of living cells allograft bone transplants use bone that has been processed to remove all living cells (Florencio-Silva et al., 2015).

Figure 2.3 : Bone grafting treatment where A and B are before treatment while C and D after grafting there can be seen slightly bone growth (Florencio-Silva et al., 2015)

As a result, the risk of rejection is significantly reduced. There is no requirement to match the blood types of the donor and the recipient while performing a bone marrow transplant because the donated bone does not contain any living marrow(Aarvold et al., 2013).

2.6 Anhydrous Calcium Sulphate

Calcium sulphate is the sulphate mineral that is found in the natural environment in the greatest abundance. On the surface of the planet, it takes the form of sedimentary deposits, which in turn affect the geochemical distribution of sulphate and calcium Additionally, it might be produced accidentally throughout certain manufacturing procedures (Ene et al., 2021)

In its natural state, calcium sulphate appears as a transparent white rock. It is possible to find it in either the anhydrous or hydrous form. The various shapes can be utilised for a variety of purposes, ranging from the production of casts for the treatment of broken limbs to the production of works of art . In addition, calcium sulphate crystals of varying sizes and morphologies, such as fibres, sheets, and particles, can be manufactured by altering the molar ratio of [Ca^{2+}] to [SO_4^{2}] in an organic solvent while maintaining room temperature. This process can be carried out at any temperature (Ene et al., 2021)

The formation of calcium sulphate crystals with different morphologies in a controlled manner is extremely important for a wide range of industrial applications due to the wide variety of purposes that these crystals serve, including as an intensifier or filler in composites, as a material for the production of paper, as a component in cements, and in the field of medicine (Ene et al., 2021).

Anhydrous Calcium Sulphate is a fine, odourless, white powder or crystalline solid with a molecular weight of 136.14 g/mol. It is stable since its melting point is 1450ºC. Additionally, $CaSO_4$ is available in a range of sizes and quantities. It differs from gypsum because to its increased specific gravity and greater hardness (Hughes et al., 2015).

Powdered calcium sulphate to have a specific appearance, it can be combine it with an indicator dye that causes the powder to change colour when exposed to water. In contrast, calcium sulphate sold in blocks is typically unrefined and has a coarse texture. Typically, this block will receive alteration prior to its intended application. It can also be recycled when it is produced as a byproduct of manufacturing processes such as waste water treatment, the production of gas and oil, desulfurization processes, and desalination. In other words, it can be made to meet certain specifications (Thomas & Puleo, 2009).

In terms of its reactivity profile, $CaSO_4$ is noncombustible and nonflammable. It only decomposes to emit poisonous sulphur oxides at extremely high temperatures (>1500°C) (Ene et al., 2021). Despite its modest reactivity, it has the potential to operate as an oxidising agent. $CaSO_4$ with diazomethane, aluminium, and phosphorus are incompatible. When $CaSO_4$ comes into contact with diazomethane, for example, an exothermic reaction leading to explosion will occur. When heated, it typically causes a strong or explosive reaction when combined with aluminium powder .

$CaSO_4$ does not dissolve in water. In contrast, soluble anhydrite (III-CaSO4) is somewhat more water-soluble than insoluble anhydrite (II-$CaSO_4$). II-CaSO4 dissolves relatively slowly (0.24g per 100g of water) and does not absorb atmospheric moisture at ambient temperature. III-$CaSO_4$ has a strong affinity for water and is utilised as a desiccant. It is capable of absorbing water to produce Plaster of Paris (Thomas & Puleo, 2009).

2.7 Application of Calcium Sulphate

Calcium sulphate is a chemical that can be found naturally in both its hydrated and its dry, crystalline forms. The hydrated form is more common. It has no discernible odour and appears most frequently in the form of a white powder; however, due to the presence of impurities, the colour may vary, for example taking on a yellowish cast. This chemical is put to use in a variety of industries, including the construction industry, where it is utilised as a pigment, as well as an element in plaster of Paris and instantly cement. As a form of calcium supplementation, calcium sulphate is utilised in the pharmaceutical and food industries (Thomas & Puleo, 2009). When heated, part of the water molecules in hydrated calcium sulphate evaporate, turning the substance into a hemihydrate instead. This form of calcium sulphate behaves differentially from the hydrated and dry forms; instead of becoming a solid, it changes into a substance similar to paste that dries out. In this context, it is possible to utilise it as plaster of Paris for artistic endeavours, and it can also be combined with cement to produce a form of cement that dries quickly.

Pigments are required for the creation of colours in paints. Calcium sulphate, when it is pure and free of impurities, has a white hue. This white colour can be achieved by mixing calcium sulphate with other pigments to make white paint. This kind of paint is used for painting works of art as well as for painting interior and outdoor surfaces.In the field of metallurgy, the application of a calcium sulphate flux can be helpful in creating a gas shielding for the welding site, which in turn improves bonding. In the field of metallurgy, the application of a calcium sulphate flux can be helpful in creating a gas shield for the welding site, which in turn improves bonding. Paper is frequently manufactured in the paper industry with a coating that confers either an increased gloss or an increased durability on the paper. Calcium sulphate is an ingredient that is used in coating papers. This coating agent increases thickness and resilience to the paper, making it more difficult to rip. Paper that has been treated with it does not acquire an additional gloss or lustre. As a result of its use as a filler, the production of paper requires a lower total quantity of the various components (Ene et al., 2021).

Additives in fertilisers can either raise or lessen the overall acidity of the fertiliser, making it more or less suited for use with particular kinds of plants and in particular situations. This component contributes to the production of an acidic fertiliser when used as an addition. Azaleas and rhododendrons are two examples of plants that flourish when provided with this kind of fertiliser. Calcium sulphate is used as an ingredient in the food industry and as a dietary supplement in the pharmaceutical industry. This less expensive type of calcium can be found in a variety of calcium supplements in the form of pills, as well as in foods like cereals and other foods that have been fortified with vitamins (Kong et al., 2012).

This results in a reduction in costs and makes the process of producing the product much simpler. This is something that the Food and Drug Administration (FDA) in the United States considers to be safe. Fluxes are chemicals that are utilised in the metalworking industry to decrease or eliminate impurities. They are necessary because to the fact that the majority of naturally occurring metals have impurities that, in order for the metal to be manufactured correctly, need to be eliminated. Calcium sulphate is utilised in the production of aluminium in the role of a flux, which aids in the purification process (Kong et al., 2012).

Because anhydrite calcium sulphate is naturally non-toxic and biocompatible, it is suitable for use in a variety of applications within the medical industry. The fact that CaSO4's rate of bone resorption is so similar to the rate at which new bone is being deposited is the primary benefit of using this compound. Because it will be resorbed and replaced with new bone throughout the healing process, it can therefore be utilised as a bone filler in surgical orthopaedic applications. $CaSO_4$ has been shown to be a successful treatment in both intramembranous and endochondral bone abnormalities, according to research carried out in the medical field

In addition to this, $CaSO_4$ is made up of osteoconductive and biocompatible elements, both of which will aid in the formation of blood vessels as well as osteogenic cells if they are present. It has been suggested that human vertebrae taken from cadavers and implanted with an injectable form of $CaSO_4$ may possess the mechanical qualities necessary for the early stabilisation of fractures (Wang et al, 2007), $CaSO_4$ has a good safety profile in both soft and hard tissue. The dissolution of $CaSO_4$ will result in the production of a pH 5.6 acidic microenvironment, which may assist in reducing the amount of bacterial activity (Byung et al, 2005). Calcium sulphate ($CaSO_4$), popularly known as "plaster of Paris," is an osteoconductive solid substance used to fill bone voids and treat cranial deformities. Calcium sulphate use in vivo is associated with the development of cancellous host bone as the graft substance is resorbed. 31 Due to its fast biodegradability, calcium sulphate is not suited for structure support clinical applications. It is used clinically in pellet form alone or in conjunction with other medicines. As calcium sulphate dissolved, it acidifies the immediate environment, resulting in antibacterial effects (Boyan et al., 2011).

The term "bone tissue engineering" refers to the process of using a scaffolding material to either act as a template or carrier for transplanted bone cells and other agents in order to promote bone production from the tissues that are around the affected area (Burg et al, 2000). The optimal substitute for bone transplant must have characteristics such as osteogenicity, biocompatibility, bioabsorption, the ability to offer structural support, ease of application in clinical settings, and an affordable price tag (Thomas & Puleo, 2009) .

$CaSO_4$ is well-known for being the bone graft alternative that offers the greatest value for the money. It is known to be an excellent void filler in the treatment of bone abnormalities in the bodies of both animals and humans. According to the findings of the medical investigations, $CaSO_4$ bone void filler is capable of providing an inert and biodegradable scaffold that allows preexisting host osteoblasts to control the deposition of new bone (Tay et al, 1999). It is applied to the bone that has recently been distracted in order to provide a direct amounts of nutrients during the bone regeneration process. This is done in order to promote the mineralization of new bone and, as a result, speed up the consolidation of the distraction zone. Within ten to twelve weeks, it also causes total resorption, which is followed by restoration with bone from the host (Hughes et al., 2015).

The $CaSO_4$ substance conforms and adheres very well to the imperfections of the bone. This is because it has a wetability quality, and also because the surface texture of the $CaSO_4$ mixture allows it to be easily adapted to uneven bone surfaces. Both of these factors contribute to this characteristic. It is simple to mix and can be applied on bone surfaces, but it does not require any sort of fixation to the bone borders that are adjacent (Ruhaimi et al., 2001). In the field of bone filler application, $CaSO_4$ can be utilised successfully either on its own or in conjunction with the other compounds such as calcium phosphate ($Ca_3(PO_4)_2$) and hydroxyapatite (HA).

Desiccant and coagulant are both possible applications for III-$CaSO_4$ when it comes to industrial operations. When it is used as a desiccant, which is a material that serves to remove water from other substances, it is frequently packaged with indicator dyes to gain the awareness when there is an occurrence of moisture intrusion. This is so that the user may take appropriate action. Because of its role as a coagulant, it can be found in certain processed foods like tofu.

In addition, $CaSO_4$ is frequently used in the production of particular paints, ceramic, and paper, where it is employed in the capacity of a filler. The $CaSO_4$ filler's job is to give the paper more body, which makes the paper more solid, brighter, and easier to write, draw, and print on (Ene et al., 2021)

$CaSO_4$ is also used as a firming agent in foods such as canned vegetables, soft-serve and regular ice cream, frostings, and gelatins; as an additive to animal feeds for providing the source of calcium and sulphate; as a paint pigment in white; and in the production of polishing powders. These are just a few of the many important applications that $CaSO_4$ has. Other applications include: providing a source of calcium and sulphate;

providing a source In addition, $CaSO_4$ has a number of applications in the metallurgical industry, such as the transformation of zinc ore into zinc metal.

2.8 Porous Ceramic

Porous ceramics find several applications as finished products and in a variety of technological innovations today. Due to their extensive uses in high-temperature filters, thermal gas separation, lightweight structural components, and thermal structural materials, porous ceramics are of great interesIt is possible to employ porous ceramics for evaporative cooling because they are sturdy, have a high thermal conductivity, are waterproof, and can persist for a long period. Extruded monoliths with parallel channels and thin walls, manufactured from a wide variety of oxide and non-oxide ceramics, as well as metal structures and foams, are capable of both moisture retention and heat exchange. Customized porosity in porous ceramics confers unique capabilities and characteristics that are typically inaccessible in traditional dense ceramics. Thus, Ceramic foam is an important part of porous ceramics. Open-cell ceramic foam is a new type of highly porous ceramics that has a three-dimensional open circulatory structure with connective pores. This gives it a high specific surface area, increasing liquid contact efficiency, and a small loss of fluid pressure. (Xu et al., 2015).

These materials have many interconnecting pores and capillary holes and a high internal specific surface energy, thus they filter and adsorb well with little fluid resistance loss. Uses include metal melt filtration, high-temperature gas purification, and catalyst support in metallurgy, chemical engineering, environmental protection, energy, and biology (Kuo et al., 2012).

Porosity, density, fluid resistance loss, and penetrability can be adjusted by processing, and alumina and cordierite are two often used materials. Cordierite boosts a product's heat resistance, whereas alumina increases its strength and thermal stability. As the need for thermal stability grows, porous silicon nitride and silicon carbide ceramics have been developed.

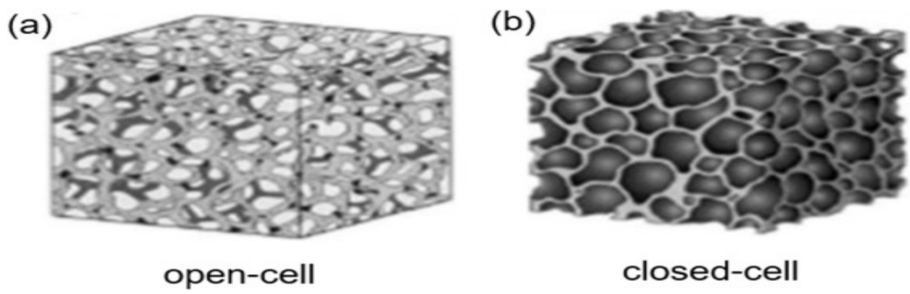

Figure 2.4: (a) Open cell and (b) closed cell structure, Open pores have solid edges and open faces,; closed pores are connected by solid faces, with no interconnectivity (Chen et al., 2021)

As their name suggests, porous ceramics are solid materials having a network of open, permeable pores that are separated and interconnected . These establish a porous microstructure consisting of solid struts that impart mechanical strength to the porous compact and empty spaces, the geometry of which typically ranges from irregular to spherical . The isolated pores within the material are not connected to the surface and are therefore inaccessible to the diffusing fluid, whereas the interconnected pores are connected to the surface and allow the permeating fluid to go from one surface to another (Kuo et al., 2012).

The diversity in pore structure and content of porous ceramics illustrates the enormous potential of these materials in a variety of applications involving significant chemical, thermal, or mechanical stresses, for which metallic or polymeric materials are unsuitable. Among other things, they act as thermally insulating materials, filters, membranes, and gas burners. To achieve optimal performance in each of these applications, the porous ceramic matrix is modified. For efficient thermal insulation, a high percentage of closed porosity is desired, but filters and membranes require a larger concentration of open porosity to enhance fluid flow. In the realm of bioceramics, ceramic implants with sufficient mechanical strength for support, porosity, and a complex structure to promote tissue integration are sought (Yan et al., 2013)

During the synthesis of porous ceramics, the swelling of starch granules imposes limitations on the management of pore size, shape, and concentration. It is desirable to control the porosity of a material through the addition of chemical foaming agents. Nonetheless, a substantial quantity of foaming agent is required for this operation. This issue has been overcome with the use of a biological foaming agent. This method combines a ceramic suspension with a biological agent (e.g., yeast), a growth substrate (e.g., sugar), and a ceramic-forming liquid binder (e.g., polysilazane). On the growth substrate, the biological agent is allowed to function, resulting in the creation of gas bubbles and foaming of the ceramic slurry (Arsista et al., 2020).

This is based on the viscosity and rate of polymerization utilised in the ceramic slurry as well as other variables that are relevant to the production process. To preserve the foam, the biological agent simultaneously acts on the growth substrate and polymerizes its binder. To start the polymerization process, heat the liquid binder until it turns into an oxide binder, which is then sprayed between the ceramic particles. The viscosity of the ceramic slurry can be substantially increased by adding both the growth substrate and the binding agent at the same time.

2.9 Yeast

Yeasts are single-celled, eukaryotic microorganisms that belong to the kingdom of fungi. Yeast has been around for hundreds of thousands of years, and there are now at least 1,500 known species. They are thought to make up about 1% of all fungi that have been named. Yeasts are single-celled organisms that developed from multicellular ancestors. Some species can change into multicellular organisms by making strings of connected budding cells called pseudohyphae or false hyphae, which give the appearance of being multicellular (Liu et al., 2018).

Yeast sizes vary a lot depending on the species and the environment. Most yeasts are 3–4 m in diameter, but some can get as big as 40 m. Most yeasts reproduce without sperm or egg, and they do this through a process called mitosis. Yeasts grow from a single cell, which is different from molds, which grow hyphae. Dimorphic fungi are those that can look different depending on the temperature or other conditions (M. Zhang et al., 2020).

Fermentation is the process by which the yeast species Saccharomyces cerevisiae turns sugars into carbon dioxide and alcohols. Since thousands of years ago, the products of this reaction have been used in baking and to make alcoholic drinks. S. cerevisiae is also one of the most studied eukaryotic microorganisms and is used as a model organism in modern cell biology research. Researchers have grown it in a lab so they can learn a lot about the biology of eukaryotic cells and, eventually, the biology of people. Other types of yeast, like Candida albicans, can cause infections in people when they get the chance. Recently, yeasts have been used in microbial fuel cells to make electricity and to make ethanol for the biofuel industry (Menchavez & Intong, 2010).

It is claimed that the process of making bread can be analogized to the foaming that occurs in ceramic slurry when yeast is present in the mixture. During this process, yeast is mixed into dough that was made from the starchy portion of crushed grains (such wheat or rye flour), such as when making bread. The yeast is responsible for breaking down some of the starch and sugar that are present in the combination, which results in the production of carbon dioxide and alcohol. This process could start at 26ºC and ferment between 30ºC and 35ºC for the best results. Above 50ºC, yeast cannot survive. The yeast will dissolve at a temperature of 105ºC (Zhang et al., 2020)

Bread is able to rise because of the presence of carbon dioxide bubbles, which create countless air holes all throughout the dough. Because oxygen is present as bread is rising, the fermentation process does not result in the production of alcohol. After being baked, the foamed mixture will have a texture that is both soft and spongy since the yeast will have died and the air pockets will have solidified. When yeast is mixed into a suspension that already contains starch, the yeast causes the starch to undergo a chemical reaction that results in the production of carbon dioxide bubbles. Because of this, heat treatment will result in the formation of pores that are permanent from the gas bubble (Menchavez & Intong, 2010).