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REVIEW ON DIFFERENT PARAMETERS AND USES OF BONE ASH

S. Sahithi[1], L. Manasa[2], G. Anusha[3], Dr. S.V. Krishna[4], Dr. V. Tejeswara Rao[5*]

[1,2,3] M.Sc. (Final) Analytical chemistry, MVR Degree and PG College, Visakhapatnam

[4*]Vice Principal, MVR Degree and PG College, Visakhapatnam.

[4*]Associate professor, Department of chemistry, MVR Degree and PG College, Visakhapatnam.

Abstract:

Bones are rigid organs that form part of the endoskeleton of vertebrates. They function to move, support, and protect the various organs of the body, produce red and white blood cells and store minerals. Bone tissue is a type of dense connective tissue. Because bones come in a variety of shapes and have a complex internal and external structure, they are lightweight, yet strong and hard, in addition to fulfilling their many other functions. Bone ash is a white material produced by the calcination of bones. Typical bone ash consists of about 55.82% calcium oxide, 42.39% phosphorus pentoxide, and 1.79% water. The exact composition of these compounds varies depending upon the type of bones being used, but generally the formula for bone ash is $Ca_5(OH)(PO_4)_3$. Bone ash usually has a density around 3.10 g/mL and a melting point of 1670 °C (3038 °F). Most bones retain their cellular structure through calcination.

Keywords: Bone ash, calcium phosphate, recycle, Bone tissue, organic fertilizer

Introduction:

Burnt bones have been recovered from numerous Ancient Greek sanctuaries dating from the Late Bronze Age up to the Hellenistic period. The burnt bones are often calcined with a white or blueish colour, allowing archaeologists to identify them as sacrificial remains. At the sanctuary to Artemis in Eretria a round altar of fieldstones filled with soil was found, dating to the 8th century BC. The upper surface was covered with clay and animal bones were burned on top, then apparently swept off the surface with terracotta, metal objects, and pottery and trampled until the altar was eventually subsumed by the ritual debris. Some scholars have attributed these altars to chthonian rituals, but this is disputed [1]. Xenocrates of Aphrodisias reported its use as a medicinal ingredient, although cannibalism was, according to Galen, prohibited under the laws of the Roman Empire [2].

Bone ash has the following intrinsic properties:

• Has excellent non-wetting properties

• Is chemically inert and free of organic matter

• Has high resistance to heat transfer (natural thermal insulator)

In painting grounds, it makes a durable surface while adding some tooth especially for egg and casein tempera, distemper, encaustic and oil painting. Use in chalk and gesso grounds to increase absorbency and add texture. Bone ash is used in Cennino's recipe for silverpoint grounds. Add to oil colors and mediums to create textural and bodying qualities to oil paint without affecting the color. Bone ash has little color in drying oil, so it can be added to oil paint without affecting the color temperature.

Since the 1990s, the use of synthetic alternatives to bone ash, which are based on dicalcium phosphate and tricalcium phosphate, has increased. Significant amounts of bone China are produced using these synthetic alternatives rather than bone ash [3]. Bone ash can be used alone as an organic fertilizer or it can be treated with sulfuric acid to form a "single superphosphate" fertilizer which is more water soluble

$$Ca_3(PO_4)_2 + 2\ H_2SO_4 + 5\ H_2O \rightarrow 2\ CaSO_4 \cdot 2H_2O + Ca(H_2PO_4)_2 \cdot H_2O$$

Similarly, phosphoric acid can be used to form triple superphosphate, a more concentrated phosphorus fertilizer which excludes the gypsum content found in single superphosphate [4].

$$Ca_3(PO_4)_2 + 4\ H_3PO_4 \rightarrow 3\ Ca(H_2PO_4)_2$$

Real bone ash is obtained by calcining bone up to approximately 1100°C and then cooling and milling. This material is still manufactured today since some of its important properties are due to the unique cellular structure of bones that is preserved through calcination. Real bone ash has excellent non-wetting properties, it is chemically inert and free of organic matters and has very high heat transfer resistance.

Bone ash has traditionally been added to porcelain to achieve a high degree of translucency (thus the name 'bone china'). The manufacture of bone china is difficult to master because the clays are non-plastic, ware is unstable in the kiln, and it is difficult to burn consistently to the body's narrow firing range. Today the availability of super-white kaolins, low iron feldspars and processed bentonites, smectites and hectorites makes it possible for almost anyone to make very white, translucent and strong porcelains even at cone 6.

Bone ash is not common in glazes. When employed it can cause the slurry to flocculate and thicken (and produce a very thick layer on the ware surface which cracks during drying). People often react to this by adding more water, producing a glaze that shrinks even more on drying and eventually thickens again. A better way is to add a little deflocculant to the glaze slurry (like Darvan). Up to 1-2% bone ash can be used in enamels for opacification (more will usually cause pinholes). In glazes, as with enamels, too much or too high a temperature will cause blistering. In this use the phosphorus' influence toward a stiff melt generally checks the fluxing action of the calcia. Bone ash or calcium phosphate are used to opacify opal glass (1-3%) because the P_2O_5 content forms colourless compounds with iron impurities.

Composition:-

Bone ash Bone china is a type of porcelain that is composed of bone ash, feldspathic material, and **kaolin**. It has been defined as "ware with a translucent body" containing a minimum of 30% of phosphate derived from animal bone and calculated calcium phosphate.

USES:-

- Bone ash is used in machine shops for various purposes. Examples include polishing compounds, protective powder coatings for metal tools, and as a sealant for seams and cracks. As a powder coating, bone ash has many unique characteristics. First of all, the powder has high thermal stability, so it maintains its form in extremely high temperatures

Phosphorus (**P**) is a mineral of crucial importance for all living organisms. It is needed for bone mineralization, energy metabolism, and other metabolic processes in the body. Due to globally limited availability of rock P resources and environmental impact of P contained in excreta, but also for economic reasons, it is desirable to minimize mineral P supplementation of poultry feed. *Myo*-inositol 1,2,3,4,5,6-hexakis(dihydrogen phosphate) ($InsP_6$), the main storage form of P in plant seeds, is only partially available for non-ruminants [5-6]. For this reason, poultry diets are commonly supplemented with mineral P, phytase or both.

Our aging populations are on the increase. Some experts predict that osteoporosis patients will soon occupy 30% of hospital beds. Statistics show that 20% of patients suffering from an osteoporotic hip fracture do not survive the first year after surgery, all this showing that there is a tremendous need for better therapies for diseased and damaged bone [7]. Human bone consists for about 70% of Calcium phosphate (CaP) mineral; therefore, CaPs are the probable materials of choice to repair damaged bone.

Fish bones can also be used as a raw material for the production of calcium phosphate. In one method [8] The biological apatite (calcium phosphate particles) was produced by heat treatment of fish bones, placed in salt solution, stirring at a temperature of 75 °C, and reacting with $CaCl_2 \cdot 2H_2O$ followed by filtration. Approximately 41.76 % yield of calcium phosphate was obtained.

Egg shells have been used as a source for calcium phosphate through the hydrothermal synthesis route where the yield was 21%. Oyster shells, carbonized fowl droppings, fly ash, coribcula shells are some of the sources tried for extracting calcium phosphate [9-11]. Calcium phosphates were prepared using corbicula shells and phosphoric acid [12] at high temperature. 90% yield of calcium carbonate was obtained through this process Calcium phosphates were prepared from sea urchin shells and artificial phosphorus waste fluid (Atsushi,2016). The calcined shells were dissolved in hydrochloric acid solution, and then filtered. This sea urchin shell extract was mixed with the artificial phosphorus waste fluid prepared from sodium dihydrogen phosphate. It was then adjusted to pH 7 using sodium hydroxide solution. The obtained precipitate contained the organic colouring material from sea urchin shell calcined at lower temperature. The main component of the precipitate was $CaHPO_4.2H_2O$. The product yield of calcium phosphate which got around 55%.

Other Bone Ash Applications

Bone ash is used in the porcelain industry, especially for the manufacturing of bone china, but due to its outstanding characteristics, it is also most suitable for casting of refined copper, copper alloy and aluminium. Bone ash in the aluminium industry forms a substantial part of Direct Chill casting of ingots and billets. Bone ash has a direct influence in improving the casting quality, because of the intrinsic benefits described above.

Bone ash can be used as a protective coating on:

- Ladles, launders, troughs, tundishes, etc., made from fused silica
- Ceramic fiber, calcium silicate, castable, etc.
- All metal equipment and tools exposed to molten metal such as metal ladles, sow moulds, ingot moulds, metal troughs, etc.
- Floor areas around mould stations, furnaces and ladles.

Bone

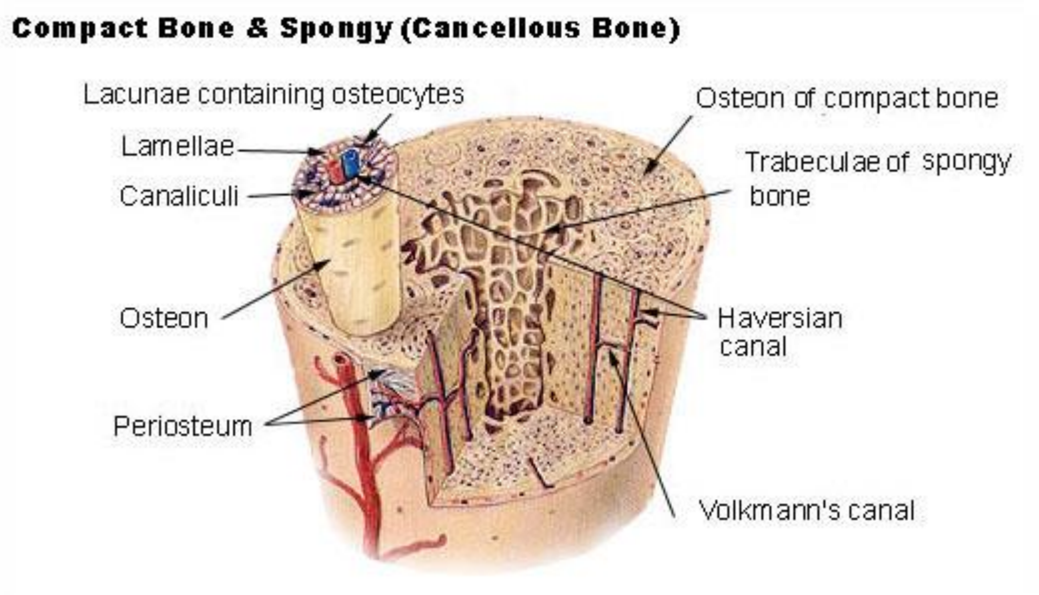
Bones are rigid organs that form part of the endoskeleton of vertebrates. They function to move, support, and protect the various organs of the body, produce red and white blood cells and store minerals. Bone tissue is a type of dense connective tissue. Because bones come in a variety of shapes and have a complex internal and external structure they are lightweight, yet strong and hard, in addition to fulfilling their many other functions. One of the types of tissue that makes up bone is the mineralized osseous tissue, also called bone tissue, that gives it rigidity and a honeycomb-like three-dimensional internal structure. Other types of tissue found in bones include marrow, endosteum and periosteum, nerves, blood vessels and cartilage. There are 206 bones in the adult human body and 270 in an infant.

Structure of Bone Tissue

There are two types of bone tissue: compact and spongy. The names imply that the two types differ in density, or how tightly the tissue is packed together. There are three types of cells that contribute to bone homeostasis. Osteoblasts are bone-forming cell, osteoclasts resorb or break down bone, and osteocytes are mature bone cells. Equilibrium between osteoblasts and osteoclasts maintains bone tissue.

Compact Bone

Compact bone consists of closely packed osteons or haversian systems. The osteon consists of a central canal called the osteonic (haversian) canal, which is surrounded by concentric rings (lamellae) of matrix. Between the rings of matrix, the bone cells (osteocytes) are located in spaces called lacunae. Small channels (canaliculi) radiate from the lacunae to the osteonic (haversian) canal to provide passageways through the hard matrix. In compact bone, the haversian systems are packed tightly together to form what appears to be a solid mass. The osteonic canals contain blood vessels that are parallel to the long axis of the bone. These blood vessels interconnect, by way of perforating canals, with vessels on the surface of the bone.



Spongy (Cancellous) Bone

Spongy (cancellous) bone is lighter and less dense than compact bone. Spongy bone consists of plates (trabeculae) and bars of bone adjacent to small, irregular cavities that contain red bone marrow. The canaliculi connect to the adjacent cavities, instead of a central haversian canal, to receive their blood supply. It may appear that the trabeculae are arranged in a haphazard manner, but they are organized to provide maximum strength similar to braces that are used to support a building. The trabeculae of spongy bone follow the lines of stress and can realign if the direction of stress changes.

Functions Bones have eleven main functions:

Mechanical:-

- **Protection** — Bones can serve to protect internal organs, such as the skull protecting the brain or the ribs protecting the heart and lungs.
- **Shape** — Bones provide a frame to keep the body supported.
- **Movement** — Bones, skeletal muscles, tendons, ligaments and joints function together to generate and transfer forces so that individual body parts or the whole body can be manipulated in three-dimensional space. The interaction between bone and muscle is studied in biomechanics.
- **Sound transduction** — Bones are important in the mechanical aspect of overshadowed hearing.

Synthetic:-

- **Blood production** — The marrow, located within the medullary cavity of long bones and interstices of cancellous bone, produces blood cells in a process called haematopoiesis.

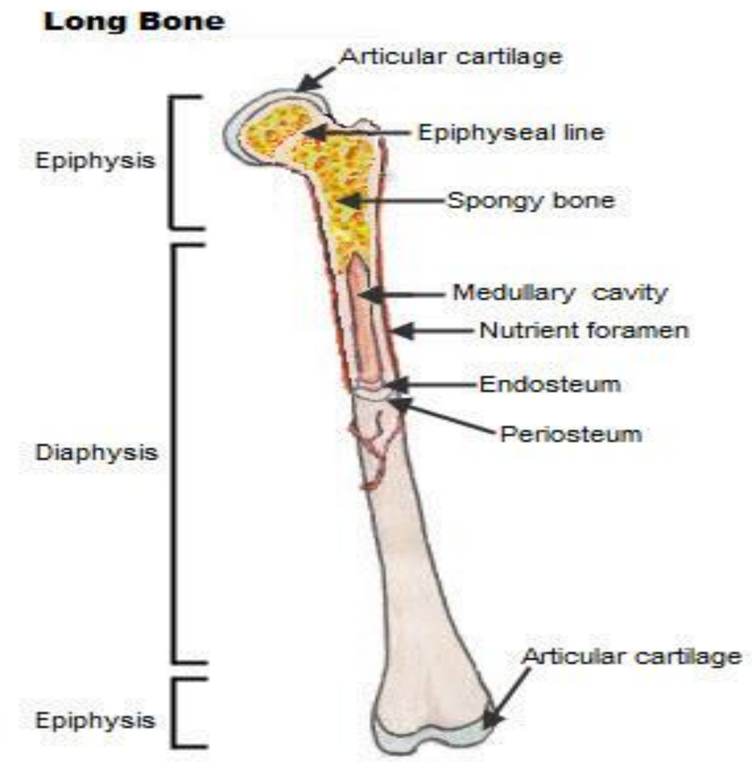
Metabolic:-

- **Mineral storage** — Bones act as reserves of minerals important for the body, most notably calcium and phosphorus.

- **Growth factor storage** — Mineralized bone matrix stores important growth factors such as insulinlike growth factors, transforming growth factor, bone morphogenetic proteins and others.
- **Fat Storage** — The yellow bone marrow acts as a storage reserve of fatty acids.
- **Acid-base balance** — Bone buffers the blood against excessive pH changes by absorbing or releasing alkaline salts.
- **Detoxification** — Bone tissues can also store heavy metals and other foreign elements, removing them from the blood and reducing their effects on other tissues. These can later be gradually released for excretion.
- **Endocrine organ** - Bone controls phosphate metabolism by releasing fibroblast growth factor - 23 (FGF-23), which acts on kidneys to reduce phosphate re absorption.

TYPES OF BONES:-

A. Long Bones



The bones of the body come in a variety of sizes and shapes. The four principal types of bones are long, short, flat and irregular. Bones that are longer than they are wide are called long bones. They consist of a long shaft with two bulky ends or extremities. They are primarily compact bone but may have a large amount of spongy bone at the ends or extremities. Long bones include bones of the thigh, leg, arm, and forearm.

B. Short Bones

Short bones are roughly cube shaped with vertical and horizontal dimensions approximately equal. They consist primarily of spongy bone, which is covered by a thin layer of compact bone. Short bones include the bones of the wrist and ankle.

C. Flat Bones`

Flat bones are thin, flattened, and usually curved. Most of the bones of the cranium are flat bones.

D. Irregular Bones

Bones that are not in any of the above three categories are classified as irregular bones. They are primarily spongy bone that is covered with a thin layer of compact bone. The vertebrae and some of the bones in the skull are irregular bones.

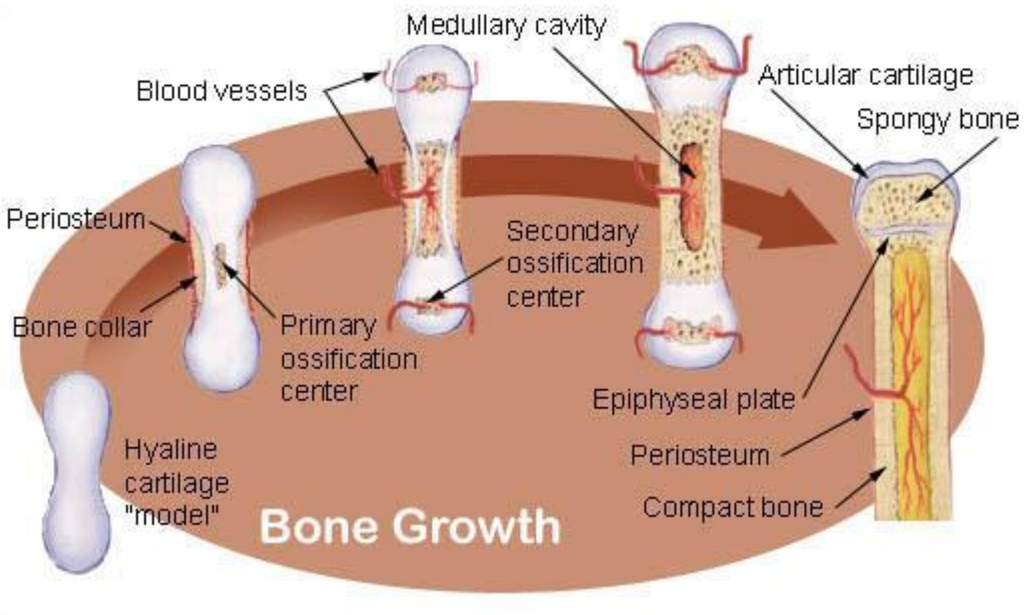
All bones have surface markings and characteristics that make a specific bone unique. There are holes, depressions, smooth facets, lines, projections and other markings. These usually represent passageways for vessels and nerves, points of articulation with other bones or points of attachment for tendons and ligaments.

E. Sesamoid Bones

A **sesamoid bone** is a small, round bone that forms in tendons (sesamo- = "sesame" and -oid = "resembling"). **Tendons** are a dense connective tissue that connect bones to muscles and sesamoid bones form where a great deal of pressure is generated in a joint. The sesamoid bones protect tendons by helping them overcome excessive forces but also allow tendons and their attached muscles to be more effective. Sesamoid bones vary in number and placement from person to person but are typically found in tendons associated with the feet, hands, and knees. The patellae (singular = patella) are the only sesamoid bones found in common with every person.

Bone Growth

Bones grow in length at the epiphyseal plate by a process that is similar to endochondral ossification. The cartilage in the region of the epiphyseal plate next to the epiphysis continues to grow by mitosis. The chondrocytes, in the region next to the diaphysis, age and degenerate. Osteoblasts move in and ossify the matrix to form bone. This process continues throughout childhood and the adolescent years until the cartilage growth slows and finally stops. When cartilage growth ceases, usually in the early twenties, the epiphyseal plate completely ossifies so that only a thin epiphyseal line remains and the bones can no longer grow in length. Bone growth is under the influence of growth hormone from the anterior pituitary gland and sex hormones from the ovaries and testes.



Even though bones stop growing in length in early adulthood, they can continue to increase in thickness or diameter throughout life in response to stress from increased muscle activity or to weight. The increase in diameter is called appositional growth. Osteoblasts in the periosteum form compact bone around the external bone surface. At the same time, osteoclasts in the endosteum break down bone on the internal bone surface, around the medullary cavity. These two processes together increase the diameter of the bone and, at the same time, keep the bone from becoming excessively heavy and bulky.

BONE CANCER

Bone cancer can begin in any bone in the body, but it most commonly affects the pelvis or the long bones in the arms and legs. Bone cancer is rare, making up less than 1 percent of all cancers. In fact, noncancerous bone tumors are much more common than cancerous ones.

The term "bone cancer" doesn't include cancers that begin elsewhere in the body and spread (metastasize) to the bone. Instead, those cancers are named for where they began, such as breast cancer that has metastasized to the bone.

Some types of bone cancer occur primarily in children, while others affect mostly adults. Surgical removal is the most common treatment, but chemotherapy and radiation therapy also may be utilized. The decision to use surgery, chemotherapy or radiation therapy is based on the type of bone cancer being treated.

Types

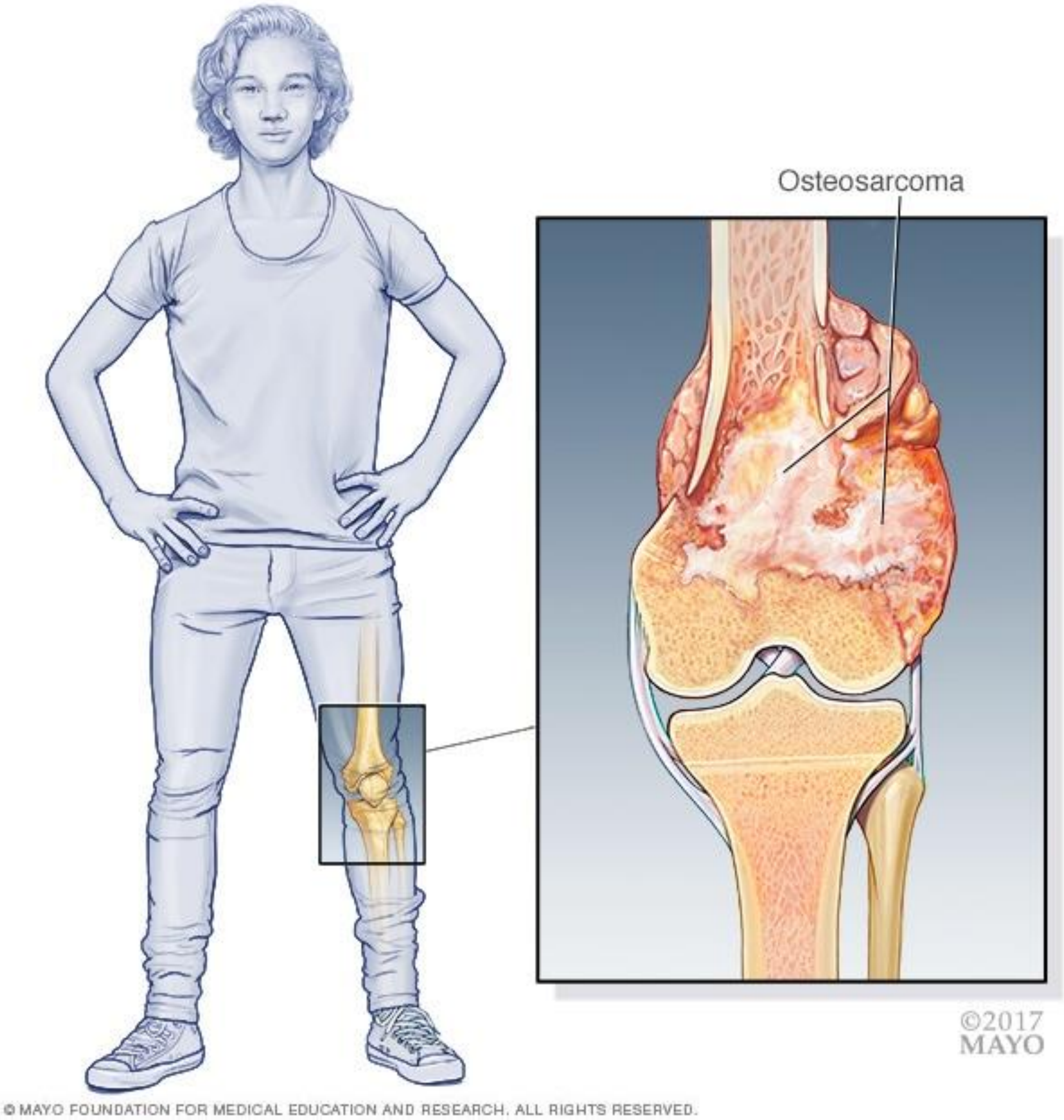
1. Chondrosarcoma
2. Ewing sarcoma
3. Osteosarcoma

Signs and symptoms of bone cancer include:

- Bone pain
- Swelling and tenderness near the affected area
- Weakened bone, leading to fracture
- Fatigue
- Unintended weight loss

Causes

The cause of most bone cancers is unknown. A small number of bone cancers have been linked to hereditary factors, while others are related to previous radiation exposure.



ANALYSIS OF ASH:-

Analysis of ash is to measure the amount of mineral present in the sample. Determination of the ash content of foods is important for a number of reasons.

- *Nutritional labeling:*-The concentration and type of minerals present must often be stipulated on the label of a food.
- *Quality:*-The quality of many foods depends on the concentration and type of minerals they contain, including their taste, appearance, texture and stability.
- *Microbiological stability:*- High mineral contents are sometimes used to retard the growth of certain microorganisms.
- *Nutrition:*-Some minerals are essential to a healthy diet (*e.g.,* calcium, phosphorous, potassium and sodium) whereas others can be toxic (*e.g.,* lead, mercury, cadmium and aluminum).
- *Processing:*- It is often important to know the mineral content of foods during processing because this affects the physicochemical properties of food.

Determination of Ash Content:-

Ash is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents, which provides a measure of the total amount of minerals within a bone

.Analytical techniques for providing information about the total mineral content are based on the fact that the minerals can be distinguished from all the other components within a food in some measurable way. The most widely used methods are based on the fact that minerals are not destroyed by heating, and that they have a low volatility compared to other food components.The three main types of analytical procedure used to determine the ash content of foods are based on this principle: dry ashing, wet ashing and low temperature plasma dry ashing. The method chosen for a particular analysis depends on the reason for carrying out the analysis, the type of food analyzed and the equipment available. Ashing may also be used as the first step in preparing samples for analysis of specific minerals, by atomic spectroscopy or the various traditional methods described below.

Ash contents of fresh foods rarely exceed 5%, although some processed foods can have ash contents as high as 12%, *e.g.,* dried beef.

SAMPLE PREPARATION:-

As with all ash analysis procedures it is crucial to carefully select a sample whose composition represents that of the food being analyzed and to ensure that its composition does not change significantly prior to analysis. Typically, samples of 1-10g are used in the analysis of ash content. Solid foods are finely ground and then carefully mixed to facilitate the choice of a representative sample. Before carrying out an ash analysis, samples that are high in moisture are often dried to prevent spattering during ashing. High fat samples are usually defatted by solvent extraction, as this facilitates the release of the moisture and prevents spattering. Other possible problems include contamination of samples by minerals in grinders, glassware or crucibles which come into contact with the sample during the analysis. For the same reason, it is recommended to use deionized water when preparing samples.

Dry Ashing:-

Dry ashing procedures use a high temperature muffle furnace capable of maintaining temperatures of between 500 and 600 ^{o}C. Water and other volatile materials are vaporized and organic substances are burned in the presence of the oxygen in air to CO_2, H_2O and N_2. Most minerals are converted to oxides, sulfates, phosphates, chlorides or silicates. Although most minerals have fairly low volatility at these high temperatures, some are volatile and may be partially lost, *e.g.*, iron, lead and mercury. If an analysis is being carried out to determine the concentration of one of these substances then it is advisable to use an alternative ashing method that uses lower temperatures.

The food sample is weighed before and after ashing to determine the concentration of ash present. The ash content can be expressed on either a *dry* or *wet* basis:

$$\% \text{ Ash (dry basis)} = \frac{M_{ASH}}{M_{DRY}} \times 100$$

$$\% \text{ Ash (wet basis)} = \frac{M_{ASH}}{M_{WET}} \times 100$$

where M_{ASH} refers to the mass of the ashed sample, and M_{DRY} and M_{ASH} refer to the original masses of the dried and wet samples.

There are a number of different types of crucible available for ashing food samples, including quartz, Pyrex, porcelain, steel and platinum. Selection of an appropriate crucible depends on the sample being analyzed and the furnace temperature used. The most widely used crucibles are made from porcelain because it is relatively inexpensive to purchase, can be used up to high temperatures (< 1200^{o}C) and are easy to clean. Porcelain crucibles are resistent to acids but can be corroded by alkaline samples, and therefore different types of crucible should be used to analyze this type of sample. In addition, porcelain crucibles are prone to cracking if they experience rapid temperature changes. A number of dry ashing methods have been officially recognized for the determination of the ash content of various foods (AOAC Official Methods of Analysis). Typically, a sample is held at 500-600 °C for 24 hours.

- ***Advantages**:* Safe, few reagents are required, many samples can be analyzed simultaneously, not labor intensive, and ash can be analyzed for specific mineral content.
- ***Disadvantages**:* Long time required (12-24 hours), muffle furnaces are quite costly to run due to electrical costs, loss of volatile minerals at high temperatures, *e.g.*, Cu, Fe, Pb, Hg, Ni, Zn.

Recently, analytical instruments have been developed to dry ash samples based on microwave heating. These devices can be programmed to initially remove most of the moisture (using a relatively low heat) and then convert the sample to ash (using a relatively high heat). Microwave instruments greatly reduce the time required to carry out an ash analysis, with the analysis time often being less than an hour. The major disadvantage is that it is not possible to simultaneously analyze as many samples as in a muffle furnace.

Wet Ashing:-

Wet ashing is primarily used in the preparation of samples for subsequent analysis of specific minerals .It breaks down and removes the organic matrix surrounding the minerals so that they are left in an aqueous solution.A dried ground food sample is usually weighed into a flask containing strong acids and oxidizing agents (*e.g.,* nitric, perchloric and/or sulfuric acids) and then heated. Heating is continued until the organic matter is completely digested, leaving only the mineral oxides in solution. The temperature and time used depends on the type of acids and oxidizing agents used. Typically, a digestion takes from 10 minutes to a few hours at temperatures of about 350°C. The resulting solution can then be analyzed for specific minerals.

- ***Advantages**:* Little loss of volatile minerals occurs because of the lower temperatures used, more rapid than dry ashing.
- ***Disadvantages**:* Labor intensive, requires a special fume-cupboard if perchloric acid is used because of its hazardous nature, low sample throughput.

Determination of Water Soluble and Insoluble Ash:-

As well as the total ash content, it is sometimes useful to determine the ratio of water soluble to water-insoluble ash as this gives a useful indication of the quality of certain foods, *e.g.*, the fruit content of preserves and jellies. Ash is diluted with distilled water then heated to nearly boiling, and the resulting solution is filtered. The amount of soluble ash is determined by drying the filtrate, and the insoluble ash is determined by rinsing, drying and ashixng the filter paper.

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