

S.No.	Topic
1	Importance of Sugar Industry, Different raw materials for sugar manufacturing, Composition of raw materials. Manufacturing processes, Raw sugar, Crystalline white sugar, Reducing sugars.
2	Conveying of raw materials, Extraction of cane juice by milling operation, Maceration and Imbibition principles of cane juice clarification methods. Defecation procedures. Sulphitation and carbonation
3	Juice heaters - construction and juice circulation, Filters - plate and Frame filter presses. Continuous Rotary vacuum filters. Washing of filter cake, Evaporation multiple effect evaporators - construction and operation. Steam economy and capacity
4	Vacuum pan boiling - coil and calandria vacuum pans. Crystallization Nucleation and crystal growth, Equipment for crystallization. Centrifuges , Batch and continuous. Separation of Molasses. Sugar drying, packing of sugar
5	Introductory treatment of chemical control - Boiling house control - Recovery formulae (Noel Deer`s, SJM & Gundu Rao) Sugar by-products : bagasse - production of bio-gas, Fibre board, Furfural Filter mud - Extraction of cane wax, Manuxe, Molasses - Manufacture of Industrial alcohol and rectified spirit. Sugar scales and normal weight. India`s position in world sugar market

1

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Importance of Sugar Industry

The sugar industry is important because it provides food, jobs, and economic growth. It also creates by-products that have many uses.

Food

- Sugar is used in many foods, including baked goods, candy, soft drinks, and sweetened beverages

Jobs

- The sugar industry creates jobs and spurs investment in other sectors

Economic growth

- The sugar industry has played a key role in building economies around the world

By-products

- The sugar industry produces by-products like bagasse, molasses, and filter muds. These by-products have many uses, including:
 - **Bagasse**: Used as animal feed, fuel, and in the production of pulp and paper
 - **Molasses**: Used as a livestock feed, in cooking, and in the production of alcohol, vinegar, and glycerol
 - **Filter muds**: Have many uses, depending on economic considerations

Sugarcane

- Sugarcane is a major crop in many countries and is one of the most efficient plants at converting solar energy into dry matter

- Sugarcane is the second largest cash crop in India after cotton. It is a perishable, heavy raw material that cannot be transported for long distances. It is primarily used to produce sugar. However, the by-products of this process are used in various other industries as well. India is the second largest producer of sugar worldwide and is tipped to soon overtake Brazil, the number one producer. This agro-based industry is important for multiple different reasons.

- **Importance of the Sugar Industry:**

- The sugar produced in India is more than our domestic demand and is exported thereby contributing to our forex reserves and helping in growing our GDP.
- This industry is responsible for directly employing nearly 5 crores of farmers and providing indirect employment to many more.
- Sugar is not the only product created from processing sugar cane. The other by-products of this process are molasses and bagasse. These are used input for biofuel which is a cleaner and better option at a time when the world is facing climate change due to high consumption of fuel among other reasons.
- Molasses is also used as cattle feed.
- Bagasse can also be used as raw material for the paper industry.

➤ Geographic Spread of the Sugar Industry:

In India sugarcane is grown in two different regions. In northern India, it is grown in the Doab and terai region which covers the states of UP, Bihar, Haryana, and Punjab. UP is the largest producer of sugarcane in northern India.

- In the southern part of India sugarcane is grown in Maharashtra, Karnataka, Tamil Nadu, and Andhra Pradesh with Maharashtra being the largest producer. The sugar cane produced in the tropical regions of South India tends to have a higher concentration of sugar. This means that even though more sugarcane is grown in Northern India more sugar is produced from the peninsular region. Another reason for this is that it is seen that sugar mills in Maharashtra; which are owned by co-operative societies tend to be better managed and have better machinery while the mills in UP are old and often use outdated technology affecting the production of sugar.
- Sugarcane is a perishable raw commodity and cannot be transported long distances. This means that mills have to be close to the farms cultivating this crop. While the sugar and sugarcane industry is very significant of late it is facing certain problems.

■ **Challenges of the Sugar Industry:**

- Sugarcane is one of many cash crops. This means that farmers often have to choose between v crops to grow leading to volatility regarding how much sugarcane is produced every year.

5 The output of sugarcane per hectare in India is low compared to the global average.

- The conversion rate of sugar from sugarcane is very low. This coupled with the previous point mean the costs of producing sugar in India are comparatively higher than they should be.
- Since the mills have to be close to the farm and no one can be sure how much is being produced mills are small. This means that they cannot reap the benefits of economies of scale.
- We have already seen that inefficient technology is responsible for lower production than is possible, this also raises the costs involved. Since it is a seasonal crop it also leads to seasonal unemployment as farmers are idle for many months and sugar mills are also waiting for the fresh crop.
- Like most cash crops, sugarcane too is an intensive crop. It requires a lot of water and continuous cultivation in an area can degrade the quality of the land.
- Government policies have also played a critical role in this industry regulating export, prices, and the location of sugar mills as well.

Raw Materials

- The main raw materials for the sugar industry are sugarcane and sugar beets. These raw materials are processed to extract sucrose, which is the sugar that is used commercially.
- **Sugarcane**
 - Sugarcane is grown in many parts of the world, including India and Southeast Asia.
 - Sugarcane is crushed to extract the juice, which is then refined to produce sugar.
 - By-products of sugarcane processing include bagasse and molasses.
- **Sugar beets**
 - Sugar beets are another raw material used to produce sugar.
 - Beet pulp and beetroot leaves are also considered raw materials for the sugar industry.
 - By-products of sugar beet processing can be used to make biodegradable polymers.

COMPOSITION OF SUGAR

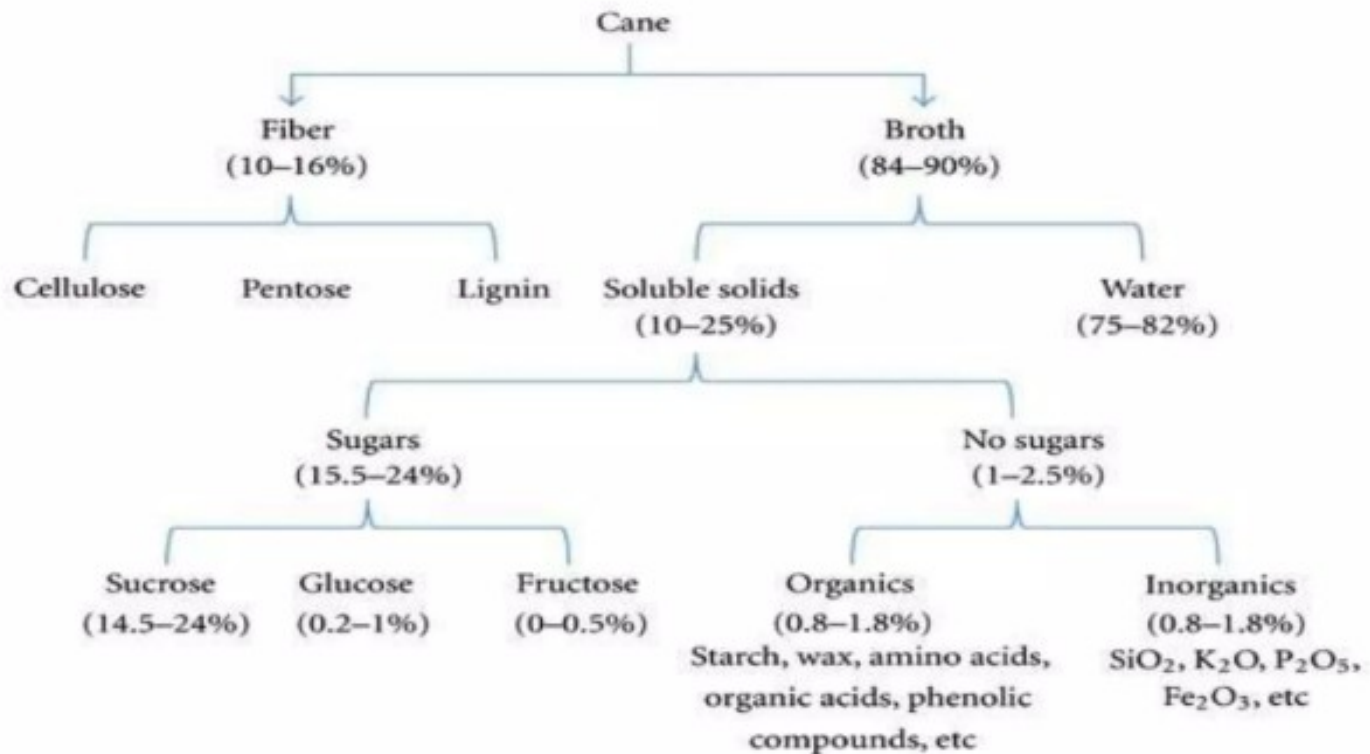
<u>Composition</u>	<u>Amount Analysed</u>
Moisture	82.91%
Ascorbic acid	3.39 mg/100ml
Reducing sugar	0.50%
Total Sugar	16.32%
Total Carbohydrate	9.23 gm/100ml
Viable bacterial count	4.56×10^6 cfu/ml
Viable yeast and mold count	2.6×10^5 cfu/ml

SUGAR CANE

- Is a grass of the genus *Saccharum*, tribe Andropogoneae that looks like bamboo and can reach 10 to 13 feet in height.
- Is cultivated in warm, moist, tropical or semitropical climates.
- Contains 75-82% water, 10-15% crystalline sugar, 0.5-1.0% reducing sugar, 10-16% fiber 1.0% ash and 1.0% organic acid specially ascorbic acid.
- The prime sugar cane growing regions, such as Mauritius, Dominican Republic, Puerto Rico, Peru, Brazil, Bolivia, Colombia, Guyana, Ecuador, Cuba, El Salvador, Jamaica, Bangladesh, India, Pakistan, Indonesia, Philippines, Malaysia, Australia, Hawaii and a great portion of United State.
- In Bangladesh sugar cane is grown in about 0.38 million acres of land.



COMPOSITION OF SUGAR CANE



SUGAR BEET

- Is a plant whose root contains a high concentration of sucrose.
- Is cultivated in temperate climates, adapts well to very cold and warmer climates.
- In the beginning only 6% sucrose was found in sugar beet but now it is increased by 28%.
- Also contains 5% fiber and 72-75% water.
- Is grown in eleven states, Europe is by far the top world producer.



11
• **Raw Sugar:** Raw sugar is the product obtained from sugarcane or sugar beet after initial processing. It is less refined compared to white sugar and has a golden-brown color due to the presence of molasses. Raw sugar can be further refined into white sugar. It contains some impurities and minerals but is generally safe for consumption in its raw form. Its flavor is more complex compared to the highly refined white sugar.

• **Crystalline White Sugar:** Crystalline white sugar, often simply referred to as granulated sugar, is the fully refined product obtained from raw sugar. It has a pure white color and consists almost entirely of sucrose. It is commonly used in cooking, baking, and as a sweetener in beverages. It is produced by removing impurities and molasses through a series of refining processes.

• **Reducing Sugars:** Reducing sugars are sugars that have a free aldehyde or ketone group capable of acting as a reducing agent. This means they can donate electrons to other molecules in certain chemical reactions. Some common reducing sugars include glucose, fructose, and lactose. They are capable of reducing other substances like copper (II) ions, which is why reducing sugars are often used in tests to detect the presence of sugar in a sample. These sugars can also participate in caramelization and Maillard reactions, contributing to browning in cooking.

Various terms

- Cane
- Primary juice
- Secondary juice
- Absolute juice
- Mixed juice
- Last mill juice

13 CANE

- Raw material is delivered to the cane carrier
- Raw material for Sugar Industry
- Absolute juice + fibre = cane
- Secondary Juice
- Diluted juice extracted from the mills in milling tandem
- Addition of water to the juice
- Absolute Juice
- Total juice extracted from the cane in milling tandem
- Absolute juice = Cane - fibre
- Mixed Juice
- Total juice extracted from the mills
- Mixer of primary juice and secondary juice
- Juice sent out from the mill house.

Mixed juice

- Total juice extracted from the mills
- Mixer of primary juice and secondary juice
- Juice sent out from the mill house.

Last mill juice

Diluted juice extracted by the last mill in milling tandem

Imbibition water added – extracted juice.

After extraction of the last mill juice the fibrous product is called as Bagasse

15

Residual Juice

- Juice left in the bagasse
- If juice left over in bagasse is more pol in bagasse is more

Clear Juice

- After clarification juice getting from the clarifier
- Removal of mud in clarifier – getting clear juice
- Settling process taken place in clarifier.
- Clear juice sent to evaporator.

Sulphured Juice

- Addition of SO_2 gas to the juice
- SO_2 gas act as bleaching agent

Un diluted juice

- With out addition of water in the juice
- Generally primary juice is undiluted juice.

Muddy juice

- Residue (mud along with juice) delivered from the clarifier
- Muddy juice sent to rotary drum vaccum filter for getting filtered juice and filter cake

Syrup

- Concentrated juice coming out from the evaporator
- 60 to 80% water evaporated in evaporator
- Addition of SO_2 gas in sulphitation tank to the syrup then sent to pans

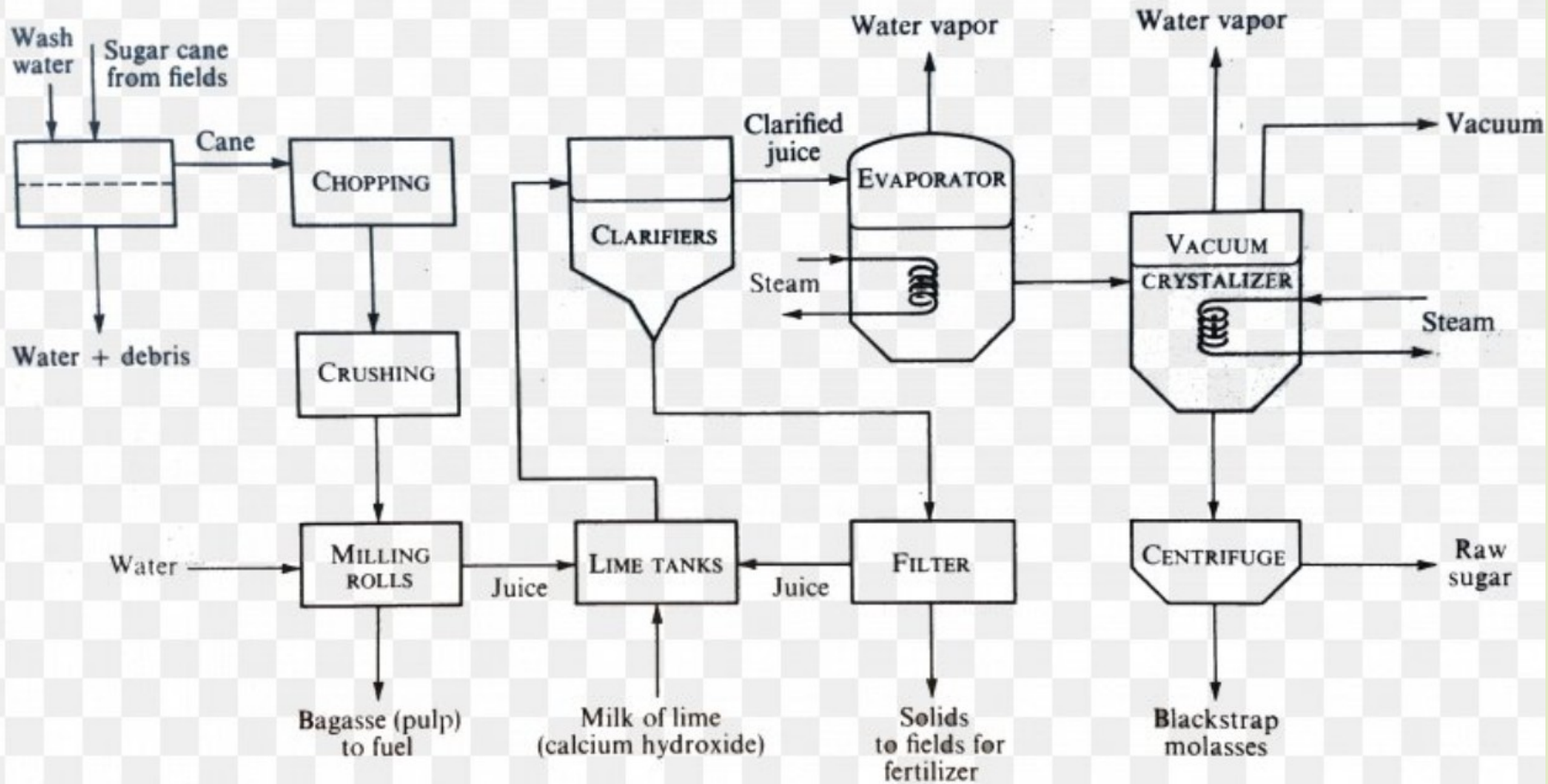


Figure 1-1 Processing steps for producing raw sugar from sugar cane.

Various terms :

- Masecuite
- Molasses
- Filter cake
- Press cake
- Imbibition
- Maceration
- Bagasse

Massecuite

- Mixture of sugar crystals and mother liquor (Molasses)
- Different types of massecuites named as Am/c, Bm/c, Cm/c

- **Molasses**

- Effluent obtained from the centrifugals
- Different types of molasses obtained
- A-heavy, B-heavy, C-heavy, A-light, B-light, and C-light molasses

- **Filter cake**

Residue delivered from the vacuum filter

It is used as a fertilizer

Used as cattle feed with the combination of molasses

19

Press Cake

Residue delivered from the filter press

Used as manure and fertilizer

Used as cattle feed

- The **types of massecuites** are classified as follows:
- **A-massecuite**: Hot cured. (Massecuite leaving a vacuum pan is supersaturated and hot, in the range 63 to 67 °C.)
- **B-massecuite**: Cooled to a temperature around 52-54°C.
- C-massecuite: Cooled to 40-42°C and then re-heated to 50-52°C. These classifications are important for the crystallization process in sugar production, as they dictate the conditions and methods used for processing

Maceration and **Imbibition** are two important principles used in the clarification of **cane juice** during sugar production. Both of these methods play a role in enhancing the efficiency of juice extraction and ensuring the quality of the final sugar product by helping to separate impurities from the juice.

Imbibition

- “ Addition of water in the mills to the bagasse” bed before last mill
- Addition of hot water before the last mill
- **The process in which water or juice is applied to bagasse to enhance the extraction of juice in the next mill**
- Better extraction of juice
- Hot water temperature should be below 70c

Advantages of hot water

22

- Hot water ruptures some cells
- Sanitary and enzymatic reactions
- Efficient juice extraction

Advantages of cold water imbibition

- Reducing gums, waxes and pectin's
- Good for clarification

Types of imbibition

Two types of imbibition

1.simple

2.compound

Generally compound imbibition is followed in sugar factory

Imbibition water temperature should be around 65⁰c to 75⁰c.

In the **sugar industry**, **imbibition** refers to the process of adding water (or a dilute solution) to sugarcane or sugar beet during the **extraction** of juice. This process helps to enhance the efficiency of juice extraction by ensuring maximum sugar recovery from the raw material.

- **Simple Imbibition in Sugar Industry:**

The process of adding water alone to the bagasse is known as simple imbibition.

Hot water addition between 3 and 4 mill

- **Imbibition Process in Cane Crushing:**

- During the extraction of juice from **sugarcane**, **water** (called "imbibition water") is added to the crushed cane. The cane is first crushed by mills to release its juice, but to increase the amount of juice extracted, water is sprinkled or sprayed onto the cane fibers.
- The water helps to **wash out** the remaining sugar from the crushed fibers, aiding in the separation of sugar from the cane stalks.
- The water used in imbibition helps to **dissolve** the remaining sugar and makes it easier to extract the juice, improving the overall yield.

Imbibition in the Extraction of Sugar Beet Juice:

Similarly, in the case of **sugar beets**, the beet slices (cossettes) are soaked in water to **extract sugar**. This is part of the **diffusion process**, where water is used to dissolve and carry away the sugar from the beet slices.

The water is typically heated to help dissolve the sugar more efficiently and is circulated through the beet slices, extracting the sugars into the liquid.

- **Why Imbibition is Important in Sugar Production:**
- **Improved Juice Yield:** Imbibition increases the extraction of juice from the raw material, leading to a higher yield of sugar from the cane or beet.
- **Efficient Use of Water:** The imbibition water is typically reused in the process, reducing the need for large amounts of fresh water.
- **Reduction of Waste:** By ensuring that more sugar is extracted from the plant material, imbibition reduces the amount of sugar left behind in the waste byproducts (bagasse from sugarcane or pulp from sugar beets).

Compound Imbibition:

Water is added to the bagasse going to the last mill. The juice from last mill is added to the bagasse coming to the penultimate mill and the juice from the penultimate mill is sent to the preceding mill and so on. Depending upon the number of stages this is also known as double, triple, quadruple compound imbibition and so on.

- **Compound imbibition** is a more advanced form of the imbibition process, where two or more different solutions or liquids are involved in the absorption process, as opposed to simple imbibition where only one liquid (typically water) is absorbed.
- In **compound imbibition**, the substance that absorbs the liquid may interact with or absorb a **combination of liquids**, such as water and a dissolved solute, or two immiscible liquids. This leads to a more complex interaction between the absorbing material and the liquids.
- **Key Features of Compound Imbibition:**
- **Multiple Liquids:** In compound imbibition, at least two different liquids or solutions are involved in the absorption process. For example, water might be absorbed together with a sugar solution, or different solvents might be absorbed simultaneously (additive for sanitation i.e., to prevent sucrose loss quaternary ammonium compounds or dithiocarbamates are added) .
- **Complex Interaction:** The materials that absorb the liquids might interact with them chemically or physically. This can result in a variety of effects, including changes in the volume or structure of the material being imbibed, or in the properties of the absorbed liquids.

➤ Application in Industrial Processes:

28

➤ **Sugar Industry:** In sugarcane or sugar beet processing, compound imbibition might involve the use of water combined with dilute juice or other solvents to extract sugar more effectively from the plant material. This is part of the diffusion process, where both water and dissolved sugars are involved in the imbibition.

➤ **Wastewater Treatment:** In wastewater treatment, materials like activated carbon can undergo compound imbibition when they absorb not just water, but also dissolved contaminants or chemicals from the water.

➤ Example in the Sugar Industry:

- In sugar production, especially in the **extraction of sugar from sugarcane or sugar beets**, **compound imbibition** occurs when water is added to the crushed or sliced plant material in stages, sometimes along with dilute juice. This allows the plant's sugar to be more efficiently extracted into the liquid phase. The combination of water and dilute juice helps the plant material absorb and release more sugar by altering the conditions in which the sugar is dissolved.
- In such a case, the combination of different solutions can optimize the efficiency of sugar extraction and improve the overall yield from the raw materials.

Maceration

29 **Maceration** refers to the process of softening or breaking down the sugarcane cell walls to facilitate the extraction of juice, especially soaking (24hrs) in the presence of water or other solvents. Its slower than imbibition

Crushing and Grinding: In the context of cane juice clarification, maceration typically involves the **crushing** or **grinding** of the sugarcane to release the juice. This process helps break down the fiber structure, allowing the sugarcane juice to flow out more easily

- **Water and Heat Application:** Maceration can be improved by adding water (imbibition) or applying heat. Water softens the cane fibers, making it easier to extract the juice during crushing, while heat can help break down tougher cell walls, releasing the sugar more effectively
- Raw sugar is produced from juice in sugar cane crushed by a series of mills. To improve the extraction a liquid bath is applied to the cane between mills. This liquid bath, commonly called maceration, consists of water and some of the produced juice. Although the extraction is improved with higher water content in the maceration, the total juice output is restricted by the storage capacity of the plant. The aim of maceration control is to manipulate the added water within the process limits placed by the storage capacity whilst optimizing sugar extraction Steeping of bagasse in excess water
- Generally it is followed in diffusers

Defacation

- In sugar process industry for clarification purpose generally followed juice defecation or juice sulphitation process. For raw sugar or organic sugar making process followed juice defection and for planitation white sugar manufacturing followed juice sulphitation process.
- The cane juice received from mill is turbid liquid with varies colours from light gray to green. It contains many soluble and insoluble impurities. The impurities in cane juice is coming from cane origin itself. The main aim of clarification is to remove these non-sugar impurities of raw juices.
- The *defecation* process simply defined as to neutralize the raw juice (After extraction of the juice from sugar cane by milling or diffuser technology) by milk of lime(MOL).
- In defecation process used food grade Phosphoric Acid(as per requirement) , Lime & heat

■ **The characteristics of defecation process can be highlighted as follows :**

- Changing the acidic nature to slightly alkaline juice by adding proper amount of milk of lime (MOL).
- Heating of the juice above its boiling point.
- Settling of lime & heated juice.
- Filtration of muddy juice with suitable filters.

■ **Different methods in Juice Defecation process :**

- Cold liming
- Hot liming
- Fractional liming
- Fractional liming and double heating.

■ **Cold liming :**

- Before 1920 it was standard practice to lime the unheated juice. This method was called cold liming.

- The juice coming from the mills generally at a pH in the neighborhood of 5 to 5.5. It is usually limed to a pH of 7.2, but may be taken as high as 7.8. It is usually limed to a pH of 7.2, but may be taken as high as 7.8. Then pumped to the heaters in order to bring the juice to just above its boiling point during its passage, i.e., to 101 to 102 °C minimum after it will divert to settler/clarifier.
- When this method was followed a serious complication frequently occurred. The growth of dextran gel, often called frog – spawn which blocked pipes and pumps. The name of the bacteria responsible is **Leuconostoc mesenteroides**. It is specially virulent in alkaline juices.
- **Hot Liming:**
- Better clarification is often obtained by pumping the juice first to a heater heated by vapour bleed from the evaporator body of the multiple effects, so as to obtain a temperature of about 70 to 75 ° C, and then proceeding to add the lime to the same pH value 7.2 to 7.5 and finally heating further up to boiling point 102 to 103 ° C than juice allowed to settle.
- This method prevented the growth of frog- spawn. In this process heating prior to liming held advantage of coagulation the colloids like albumin etc, but it was difficult to keep the pH of the limed juice constant. Heating at the natural pH of 5.2 – 5.5 however involves some risk of inversion of sucrose

➤ **Fractional Liming:**

- Raw juice is limed to a pH 6.0-6.4, heated to 101 to 102 ° C then limed again to a pH of 7.6-7.8 and than juice allowed to settle.

➤ **Fractional Liming & Double Heating:**

- Lime is added in two stages. First to a pH 6.2 to 6.4 with heating then to 7.6 to 8.2 with further heating.

Bagasse

- “ Insoluble matter (fibre) in the cane.
- After extraction of juice the residue coming out from the last mill
- Generally used as a fuel in boilers

Sugar Industry can be divided into.

1) Mill House.

2) Boiling House.

Mill House

36

- 1) Cane Carriers
- 2) Cane Kicker
- 3) Cane Leveler
- 4) Cane Cutter
- 5) Cane Shredder
- 6) Mills

Cane Carrier

- ▶ Carries the cane
- ▶ Distant location to mill house
- ▶ Like a conveyor.

Cane Kicker

- It kicks the cane
- It eliminates choking
- To maintain a uniform level
- It increases crushing without effecting milling efficiency

Cane leveller

39

- It is placed over the cane carrier to evenly distribute and flatten the cane bed before milling
- It breaks down the cane but levels/uniforms the cane in cane carrier.
- Leveller comprises a set of knives which cut the whole cane
- The pitch between the two knives kept three inches apart
- The clearance between leveller and cane carrier is 5" – 10"

Cane cutter

40

- It cuts the cane into pieces.
- It comprises knives of similar design of cane leveller
- The pitch between the two knives is 1.5 in
- The clearance between tip of the knife and cane carrier surface is 3" – 5"

Cane shredder

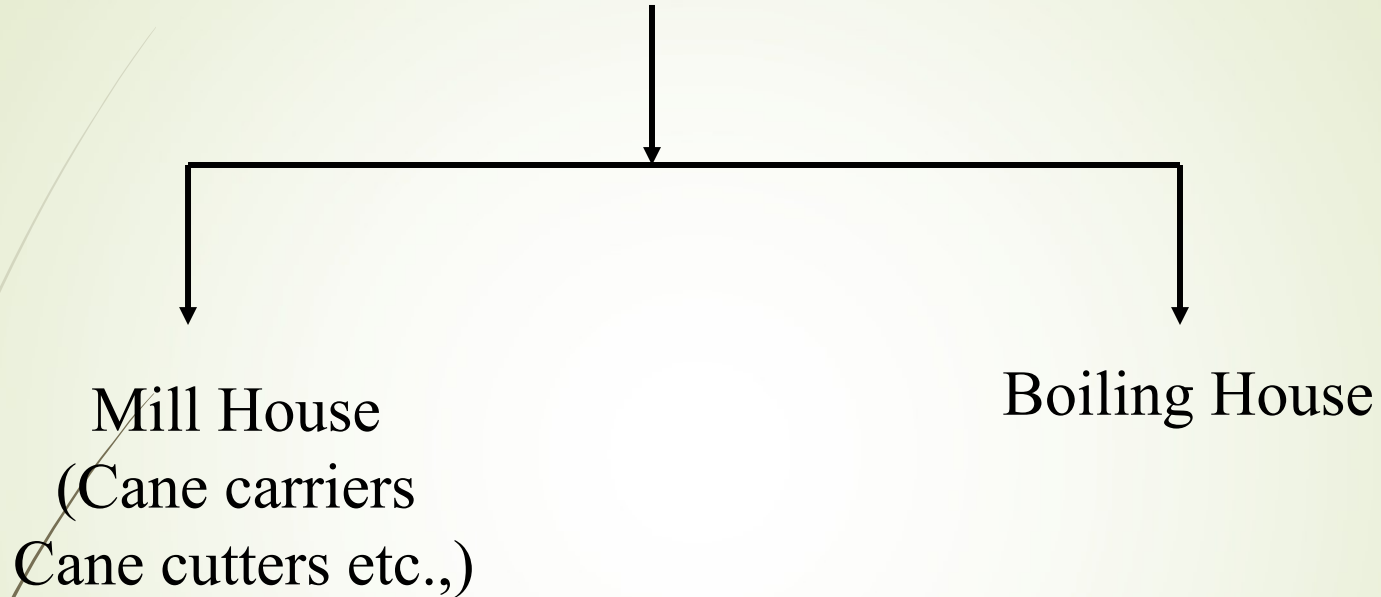
41

- Ruptured the cane.
 - Inside the shredder, there are rotating blades or knives (often made of high-strength steel) that cut the sugarcane stalks into smaller pieces. The blades rotate at high speeds to shred the cane into finer pieces.
 - Improves the preparation of cane and preparatory index
 - Capacity increased without effecting extraction
 - It is generally driven by electric motor through flexible coupling
- the **Preparatory Index** (sometimes referred to as the **Preparation Index**) is a measure used to evaluate the effectiveness of the preparation processes, especially those involved in the initial steps of sugarcane or sugar beet processing. It is an index used to assess the **efficiency of the cane preparation**, which includes activities like shredding, milling, and juice extraction. $PI = \frac{\text{Brix\% in cold water extract of prepared cane}}{\text{Brix\% in cold water extract of fully disintegrated cane}}$ (85 – 90%) 1 degree brix = 1 gram of sucrose per 100 gm of Juice
- The **Preparatory Index** helps to determine how well the cane or beet has been prepared for the subsequent extraction and refining processes, with the goal of optimizing sugar recovery.

Mills

- Extraction of juice from the cane.
- Getting mixed juice.
- Milling tandem consists of 4 to 5 mills
- Three rollers present in each mill
- Good preparation of cane results in better extraction

Sugar Industry can be divided



Boiling House

44

1. Juice weighing scale.
2. Juice heaters
3. L & S Tank.
4. Clarifier.
5. Evaporator
6. Sulphitation Tank

7. Pans
8. Crystallizer
9. Centrifugal
10. Hopper
11. Grader

Juice weighing scale

- Weighment of mixed juice.
- Generally it is a 3 to 5 ton capacity
- Mixed juice weighment and counting of weighing tank

Juice Heater

- Heating of the juice.
- It is a heat exchanger
- Horizontal and vertical types of juice heaters
- Mixed Juice heats upto 70°C
- L & S juice heats upto 100°C – 105°C

48 L & S Tank

- ▶ Mixing tank
- ▶ Mixing of lime, SO_2 with mixed juice.
- ▶ To maintain PH 6.8 to 7.2
- ▶ SO_2 gas for neutralizing and bleaching the juice
- ▶ Lime used for PH and settling agent

Clarifier

- ▀ Clarification of the juice
- ▀ Removal of mud
- ▀ Getting clear juice

Evaporator

- Evaporates water in juice
- Concentrated juice.
- Brix will be raised from 15° to 60° brix
- 60 to 80 % of water in the juice will be evaporated

Sulphitation tank.

- Addition of SO_2 gas.
- SO_2 Gas for bleaching purpose

Pans

- Crystals preparation
- Massecuite preparation.
- Preparation of A, B & C massecuites
- Massecuite is a mixture of sugar crystals and mother liquor

Crystallizers

- Growth of the crystals
- Storage purpose.
- Air cooled, water cooled, vacuum crystallizers

Centrifugals

- ▶ Separation of crystals and molasses
- ▶ Single curing and double curing
- ▶ Heavy molasses and light molasses are obtained
- ▶ B-seed ,C-seed, A-sugar are generated

Hopper

- ▶ Getting dry sugar
- ▶ Removal of slumps.
- ▶ Removal of conglomerates
- ▶ Removal of moisture

Grader

- ▀ Sieves the sugar crystals
- ▀ Uniform size of sugar crystals
- ▀ Grading of Sugar

Sugar conveying systems

Sugar conveying systems are crucial components in the sugar industry, designed to efficiently move raw materials, intermediate products, and finished sugar between different stages of the production process. These systems are used to transport sugarcane, sugar beet, bagasse, raw sugar, refined sugar, and other by-products in both the mill and refinery operations.

Types of Sugar Conveying Systems:

Belt Conveyors:

- **Description:** Belt conveyors use a continuous loop of a belt to transport materials from one point to another. They are often used for moving raw sugarcane, crushed cane, or even refined sugar in bags or bulk.
- **Advantages:** Simple to operate, suitable for both horizontal and inclined conveying, and easy to maintain. They are widely used in sugar mills and refineries for bulk material handling.

• **Bucket Elevators:**

- **Description:** Bucket elevators use a series of buckets attached to a vertical belt or chain to lift materials vertically. These are commonly used in the sugar industry for transporting raw sugar, refined sugar, or bagasse to higher levels.

- **Advantages:** Highly efficient for vertical lifting, prevents material spillage, and minimizes dust generation.

• **Screw Conveyors (Auger Conveyors):**

- **Description:** These conveyors use a rotating screw inside a tube or trough to move materials. They are commonly used for transporting granular or powdered materials, such as raw sugar or sugar crystals.

- **Advantages:** Compact design, works well with sticky or viscous materials, and is effective for short distances or when precise material control is needed.

•Pneumatic Conveying Systems:

59

•Pneumatic conveying system is the ideal solution for safely and reliably moving sugar. Pneumatic Conveying is the process of using compressed air to move bulk materials through pipelines or hoses from Point A to Point B. With the right system, it is an extremely efficient way to cover distances from a few to hundreds of meters as it will help you to avoid blockages, high energy bills and reduce loading and unloading times to a minimum. A correctly sized blower or compressor is key in achieving an efficient conveying process.

•**Advantages:** Can transport materials over long distances and through multiple bends, reduces the risk of contamination, and can be automated easily. Common in both mills and refineries.

•Chain Conveyors:

•**Description:** Chain conveyors consist of a series of interconnected chains that carry material on a flat surface or in an enclosed channel. These are used to transport heavier materials such as bagasse or raw sugar.

•**Advantages:** Suitable for heavier materials, durable, and less prone to wear compared to belt conveyors.

- **Roller Conveyors:**

- **Description:** Roller conveyors use rotating rollers to move materials along a flat or inclined surface. They are particularly useful for transporting bags or boxes of sugar in the packaging area.

- **Advantages:** Easy to use for handling packaged sugar, often used for palletized or boxed sugar products.

- **Vibratory Conveyors:**

- **Description:** These systems use vibration to move materials along a conveyor bed. They are especially useful for handling materials like sugar crystals, which require gentle handling to avoid breakage or loss of quality.

- **Advantages:** Minimal mechanical parts, gentle handling of sensitive materials, and low maintenance.

Functions and Uses of Sugar Conveying Systems:

Transporting Raw Materials:

- In sugar mills, conveyors are used to transport sugarcane or sugar beets from the harvesting area to the milling or extraction section.
- Conveyor systems can also move bagasse (the fibrous residue from crushed sugarcane) to a boiler for energy generation.

■ Moving Intermediate Products:

- After juice extraction, conveyors help transport the juice, which will undergo further processing. Additionally, conveyors are used to move the **massecuite** (a mixture of sugar crystals and molasses) during the crystallization stage.
- Bagged sugar or loose raw sugar can be moved using conveyors to the packing or storage areas.

- **Handling Refined Sugar:**

62 In sugar refineries, conveyors transport **refined sugar** from the crystallization process to packaging and storage.

- Systems are designed to handle various forms of sugar (granulated, powdered, or cubed) without damaging the product.

- **Efficient Packaging and Loading:**

- In the final stages of sugar processing, conveyors are used to move packaged sugar into storage or shipping areas. This allows for efficient bulk handling, palletizing, and loading into trucks or containers.

- **Dust Control:**

- Many sugar conveyors are designed with **dust collection systems** to minimize sugar dust in the air. This is particularly important in environments where sugar crystals or powder are being transported, as excessive dust can be hazardous and lead to loss of product quality.

Key considerations

- **Capacity and Speed:** The conveying system should be designed based on the required throughput of the facility. Speed adjustments are important to align with the processing rate and optimize production efficiency.
- **Product Protection:** Some sugar products, especially fine or powdered sugars, need gentle handling to avoid damage or loss of quality. Conveyors must be selected and designed to minimize the risk of sugar breaking or contamination.
- **Hygiene and Cleanliness:** The sugar industry requires high hygiene standards, so conveying systems should be easy to clean and maintain. Materials must be non-corrosive and resistant to sugar build-up.
- **Energy Efficiency:** Since conveyors run continuously in many sugar mills and refineries, selecting energy-efficient equipment helps reduce operational costs and environmental impact.
- **Automation:** Many modern sugar conveying systems are automated, integrating sensors, controls, and monitoring systems to ensure smooth, uninterrupted operation and to reduce the need for manual intervention.

Clarification

64

Clarification in the context of **cane juice** refers to the process of removing impurities and unwanted substances from the extracted juice after it has been squeezed from the sugarcane. The goal of clarification is to produce a clean, clear juice that can be further processed to extract sugar. The process involves several physical and chemical steps to remove suspended solids, organic materials, pigments, and other non-sugar components that could negatively affect the quality of the final sugar product.

- **Importance of Cane Juice Clarification:**
- **Improves the purity of juice:** It ensures that the juice is free from undesirable substances that could affect the quality of sugar.
- **Prepares juice for further processing:** Clarification is necessary before the juice undergoes evaporation, crystallization, and refining, which are sensitive to impurities.
- **Enhances sugar yield:** By removing impurities, the sugar crystals that are eventually produced are purer, leading to better-quality sugar.

Steps in Cane Juice Clarification:

Juice Collection:

- After the juice has been extracted from the sugarcane via milling or other extraction methods, the juice contains not only dissolved sugar but also suspended impurities, fibers, proteins, organic acids, and colorants (such as polyphenols and pigments).

■ Heating:

- The juice is often **heated** to a temperature between 80°C and 90°C (176°F to 194°F). This process helps to coagulate the impurities, which makes them easier to remove.
- Heating also helps in reducing the acidity of the juice and enhances the reaction with lime (if used as part of the clarification process).

■ Lime Treatment:

- **Lime (calcium hydroxide)** is commonly added to the juice to neutralize any free acids (like organic acids). Lime helps to raise the pH of the juice, making the coagulation of impurities more efficient.
- The **lime treatment** forms insoluble compounds that combine with the impurities (e.g., proteins, polyphenols) to form **flocculants**. These flocculants settle to the bottom of the juice.

• **Coagulation and Precipitation:**

- When lime is added, it reacts with the juice, causing the **formation of calcium salts** and other compounds that bind to the impurities in the juice.
- The impurities, including suspended solids and proteins, form **coagulated particles** that aggregate (clump together) and settle at the bottom of the juice.

• **Settling or Flotation:**

- After lime treatment and heating, the juice is allowed to **settle** in large tanks called **settling tanks** or **clarifiers**. The coagulated impurities, now in the form of flocs, sink to the bottom as a sludge.
- Alternatively, **flotation** can be used where bubbles are introduced to the juice to float the impurities to the surface for removal. This method is especially useful when fine particles are present.

• **Filtration:**

- After settling, the clarified juice (which is now clearer and contains fewer suspended particles) is filtered to remove any remaining impurities. **Vacuum filters, pressure filters, or fine mesh screens** are often used in the filtration process.
- The result is clean, clarified juice that is ready for further processing, such as **evaporation** to concentrate the juice and **crystallization** to form sugar.

Decanting:

- The remaining thick sludge, which consists of the impurities, is **decanted** or removed. This sludge is typically sent to a treatment facility or used in other industrial processes like the production of compost or as a source of energy (through combustion).

► Factors Influencing Cane Juice Clarification:

67

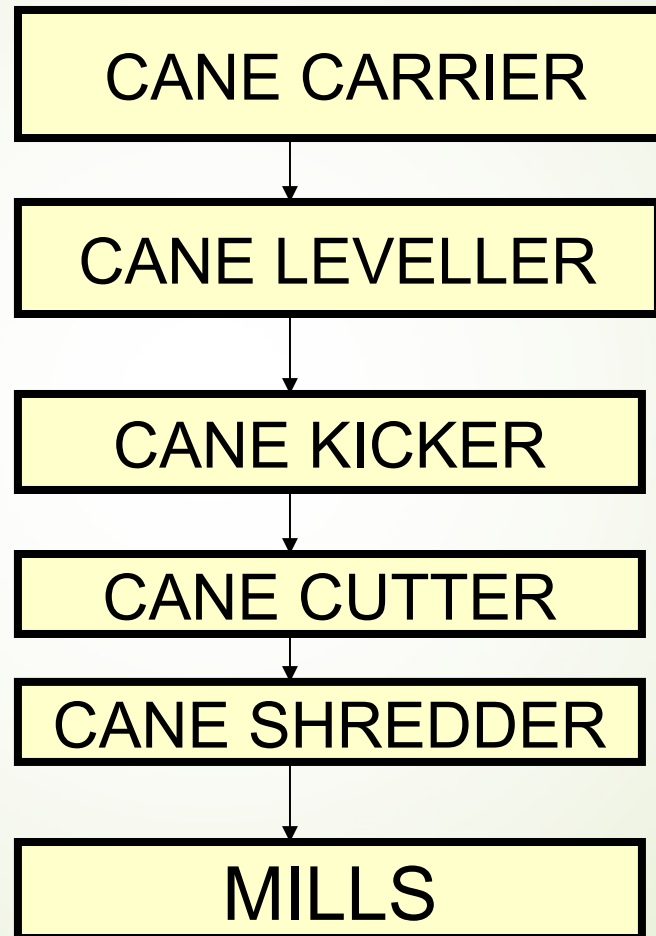
- **pH Level:** The addition of lime adjusts the pH level of the juice. The correct pH level is crucial for optimal coagulation and impurity removal. If the pH is too high or too low, clarification may not be as effective.
- **Temperature:** The temperature of the juice during clarification affects the efficiency of coagulation and the settling process. Higher temperatures generally improve the coagulation of impurities, but care must be taken not to overheat the juice, as excessive heat can break down sugar molecules and reduce yield.
- **Lime Dosage:** The amount of lime used in the clarification process must be carefully controlled. Too much lime can lead to the formation of excess sludge, while too little may result in incomplete neutralization of acids.
- **Juice Composition:** The composition of the juice, including its sugar content, acidity, and the amount of impurities, also affects the clarification process. Different juice qualities may require adjustments to the clarification parameters.

- **Advantages of Cane Juice Clarification:**
- **Improved Quality:** Clarified juice has fewer impurities, which leads to better quality sugar crystals and prevents the formation of unwanted color and off-flavors in the final product.
- **Increased Sugar Recovery:** By removing non-sugars and impurities early in the process, sugar extraction is more efficient, leading to higher sugar yields.
- **Cleaner Final Product:** A clear juice results in cleaner, more refined sugar and reduces the need for extensive refining processes.

CLARIFICATION TECHNIQUES

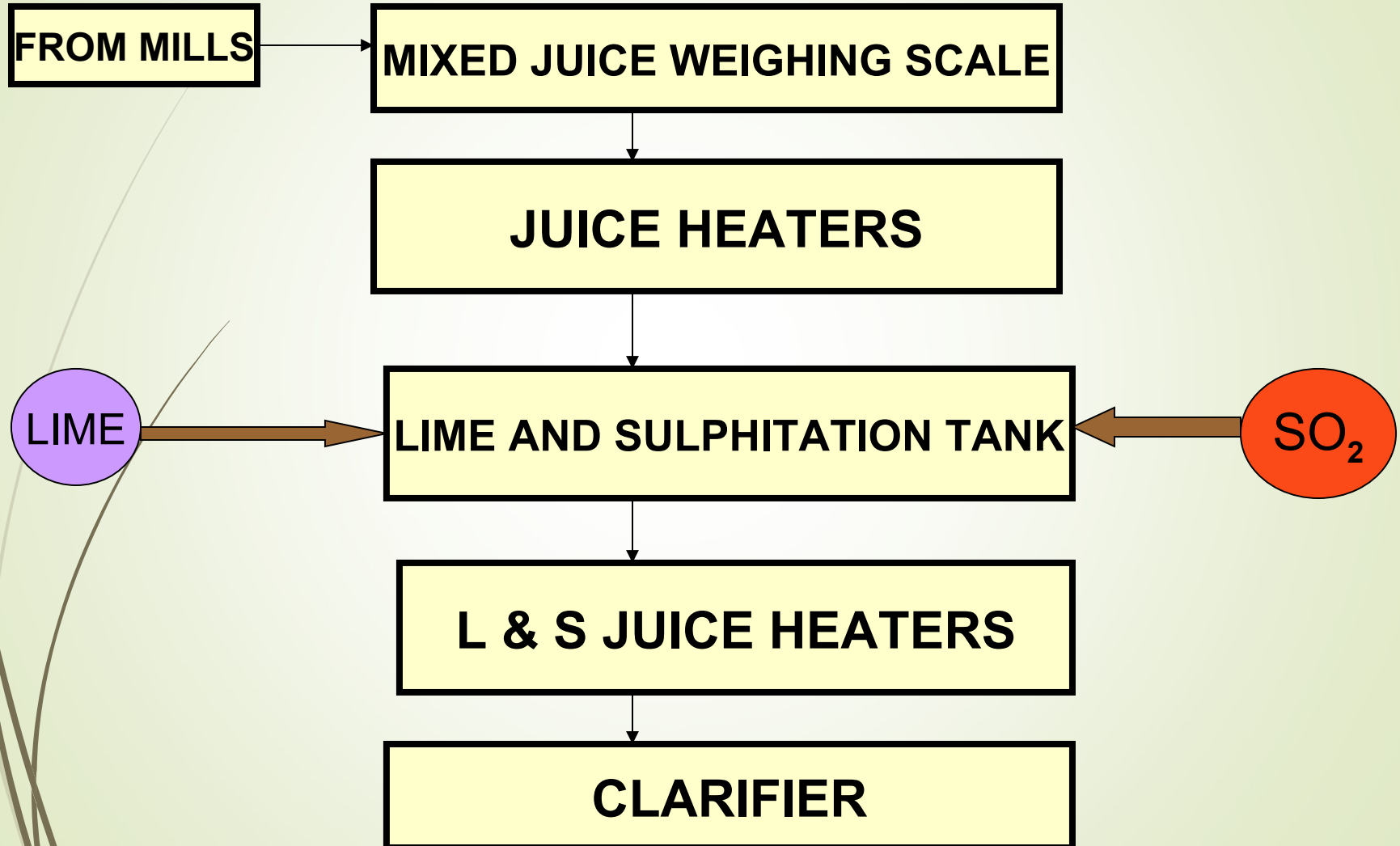
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DOUBLE SULPHITATION FLOW CHART



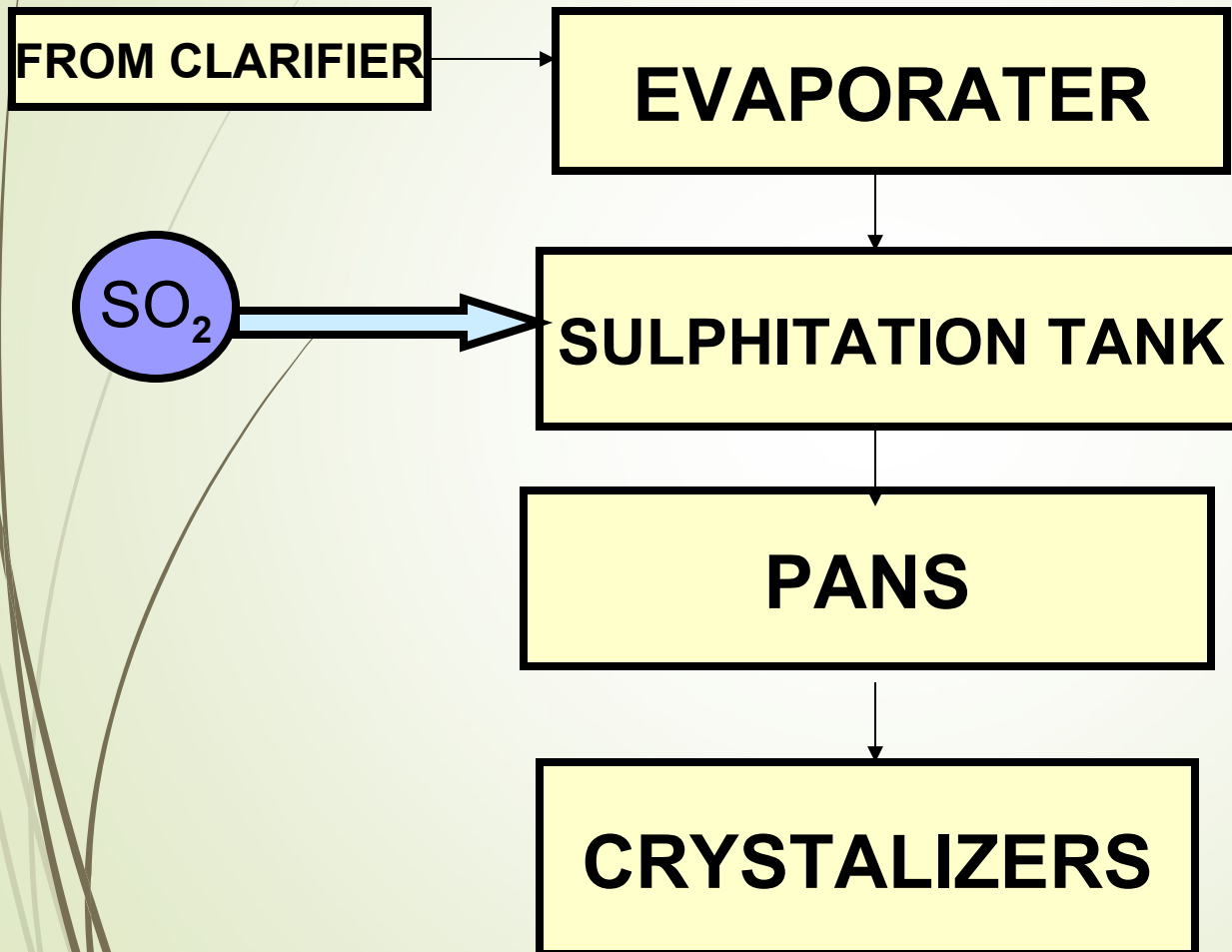
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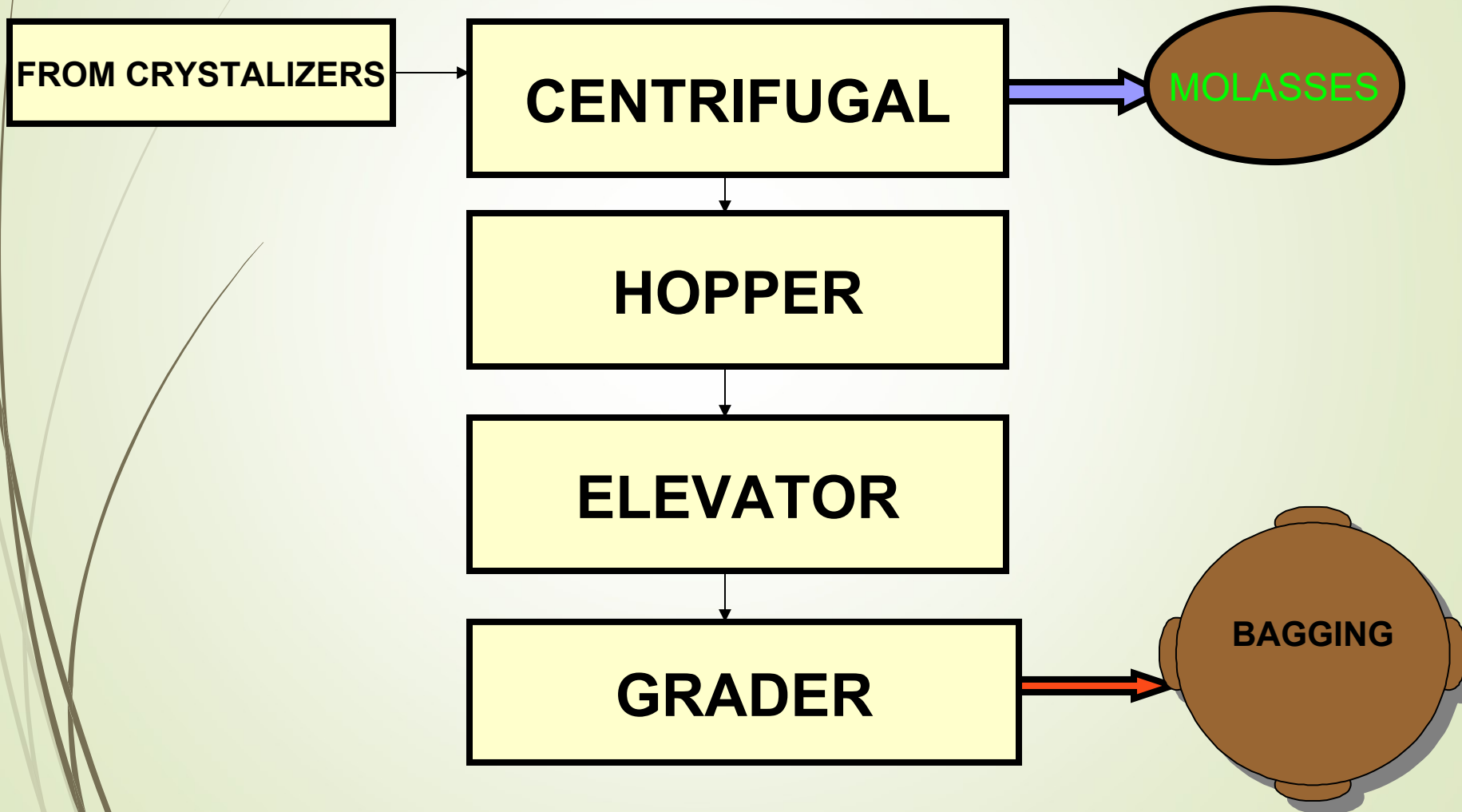
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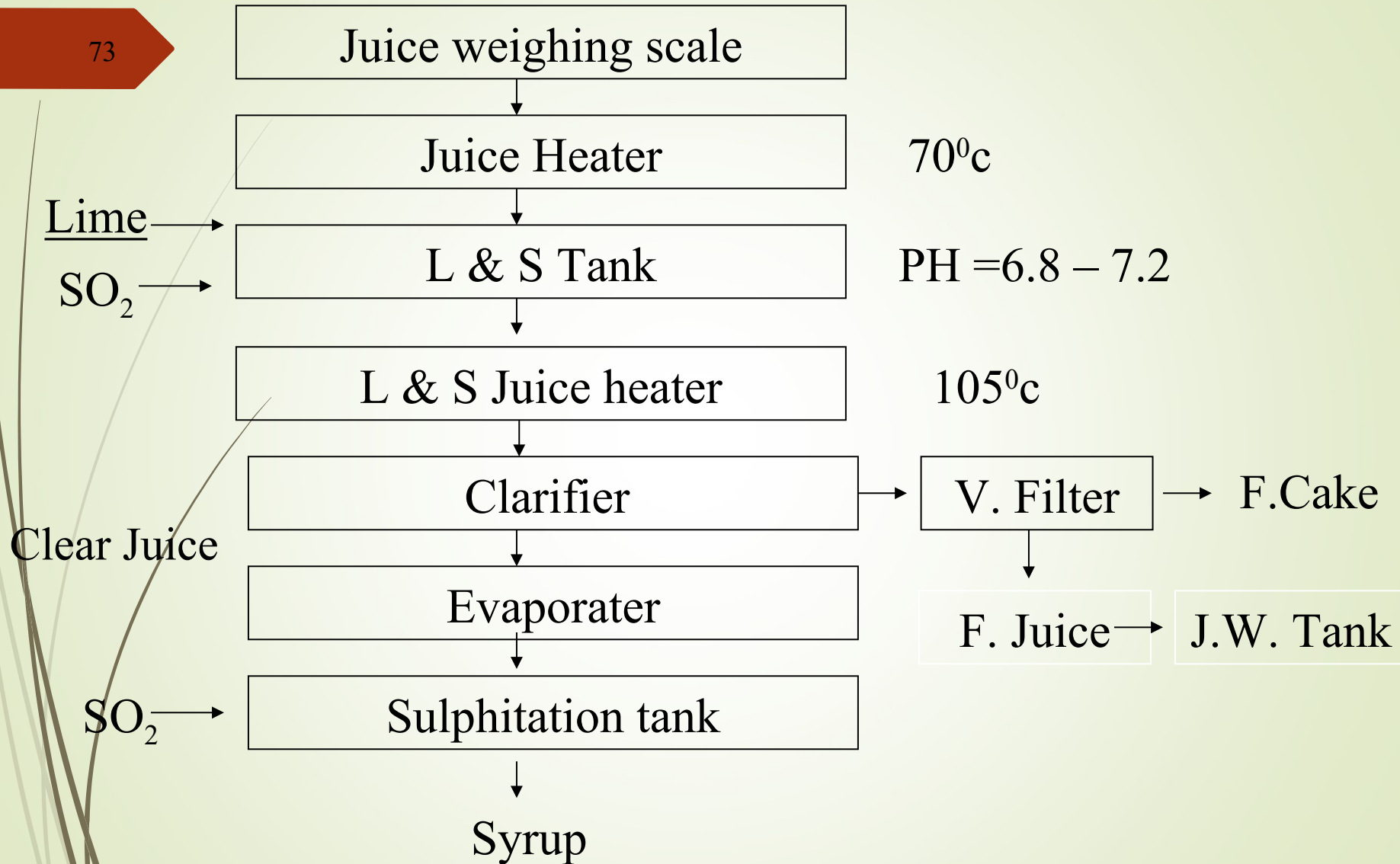
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72



Clarification section

73



REACTION OF SULPHITATION

- The solution of Ca(OH)_2 will dissociate completely as.
- $\text{Ca(OH)}_2 \leftrightarrow \text{Ca}^{++} + 2\text{OH}^-$ (Dissociation Of Ca(OH)_2)
 $\text{Ca}^{++} + 2\text{OH}^{--} \rightarrow \text{Ca(OH)}_2$
- The pH of the lime solution is above 12.6 at 30 °C, when SO_2 gas is passed liquid H_2SO_3 (Sulphurous acid) is formed.
- $\text{SO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{SO}_3$
- The sulphurous acid get dissociated at high initial pH into H^+ & SO_3^- ions.
- $\text{H}_2\text{SO}_3 \leftrightarrow 2\text{H}^+ + \text{SO}_3^-$
- Immediately the product of (Ca^{++}) and (SO_3^-) which exceed the solubility product of CaSO_3 & more CaSO_3 precipitate will result.
- $\text{Ca}^{++} + \text{SO}_3^- \leftrightarrow \text{CaSO}_3$
- Mean while the OH^- ion from Ca(OH)_2 molecule will react with H^+ ions & with H_2SO_3 to form undissociated water molecule.

Sulphatation is another method used in the sugar industry for clarifying **cane juice** during the production of sugar. It involves the addition of **sulphur dioxide (SO_2)** to the cane juice, which helps to neutralize acids and remove impurities, particularly colorants and non-sugar components. Sulphatation is widely used in **sugar mills** that want to maintain a high level of efficiency and sugar purity, but it is not as common as other clarification methods like **lime clarification** or **carbonation**.

How Sulphatation Works:

1. Addition of Sulphur Dioxide:

1. **Sulphur dioxide (SO_2)** is added to the raw cane juice, typically when the juice is still hot after initial extraction. This is usually done by dissolving **sulfur dioxide gas** directly into the juice.

2. Reaction with Impurities: The **sulphur dioxide** reacts with **organic impurities** (like **polyphenols** and **proteins**) and **non-sugars** present in the juice. The reaction causes these impurities to form **sulphites** or **sulfur-containing compounds** that are less soluble in the juice and can be easily removed.

3. Formation of Sulfite Compounds: Sulphur dioxide reacts with certain organic acids in the juice, especially those with **phenolic compounds**, to form **sulfite compounds**. These sulfite compounds, being insoluble, precipitate out of the juice.

4. Impurity Precipitation: The reaction between sulphur dioxide and impurities leads to the formation of coagulated particles that can settle at the bottom of the juice, much like in carbonation or lime clarification.

5. Clarification of Juice:

1. After **settling**, the clarified juice is separated from the sludge containing the coagulated impurities. The clarified juice can then proceed to the next stages of processing (evaporation, crystallization) for sugar recovery

6. Sludge Removal:

1. The precipitated sludge is removed, and the clarified juice is sent to the next processing steps. This sludge contains the removed impurities, including **sulphite salts** and coagulated organic matter.

Key Reactions in Sulphatation:

•Sulphur Dioxide with Organic Acids:

- SO_2 reacts with organic acids like **acetic acid** or **formic acid** in the juice, neutralizing them and preventing them from affecting the crystallization process.

•Sulphur Dioxide with Phenolic Compounds:

- **Phenolic compounds** (which cause browning in the juice) react with sulphur dioxide to form **sulfite complexes**. This prevents the formation of dark-colored products during crystallization, ensuring a **lighter-colored sugar**.

Advantages of Sulphatation in Sugar Production:

Effective Color Removal:

Sulphatation is particularly effective in removing colorants and **polyphenolic compounds**, which can cause **darkness** in sugar and affect its final appearance. This results in **whiter sugar** after crystallization.

Improved Juice Clarity:

The process helps in reducing the **turbidity** of the cane juice by removing suspended solids and dissolved impurities. This improves the **clarity** of the juice and enhances the purity of the sugar extracted.

1.Prevention of Maillard Reaction:

1.The **Maillard reaction** (a reaction between reducing sugars and amino acids that can lead to browning) is minimized due to the removal of reactive compounds like **phenols** .

2.Reduction of Non-Sugars:

1.The sulphatation process helps in the removal of certain **non-sugars** (such as **organic acids**) that can interfere with sugar crystallization.

3.Increased Sugar Yield:

1.By removing impurities that could interfere with sugar recovery, sulphatation can improve the **efficiency of sugar extraction**, leading to higher **sugar yields**.

Disadvantages of Sulphatation:

1. Sulphur Odor:

1. The addition of **sulphur dioxide** to the juice can lead to a **strong sulfuric odor**, which can be unpleasant. This is a common issue when sulphatation is used, although modern technology can help control the release of these odors.

2. Environmental Concerns:

1. Sulphur dioxide is a **gas** that must be carefully handled to avoid air pollution. Excessive release of sulfur compounds into the environment can lead to **acid rain** and other environmental issues.

3. Sulphur Dioxide Costs:

1. The use of **sulphur dioxide** as a clarification agent adds to the cost of sugar production. The purchase and handling of sulphur dioxide require special equipment and safety measures, which can increase operational costs.

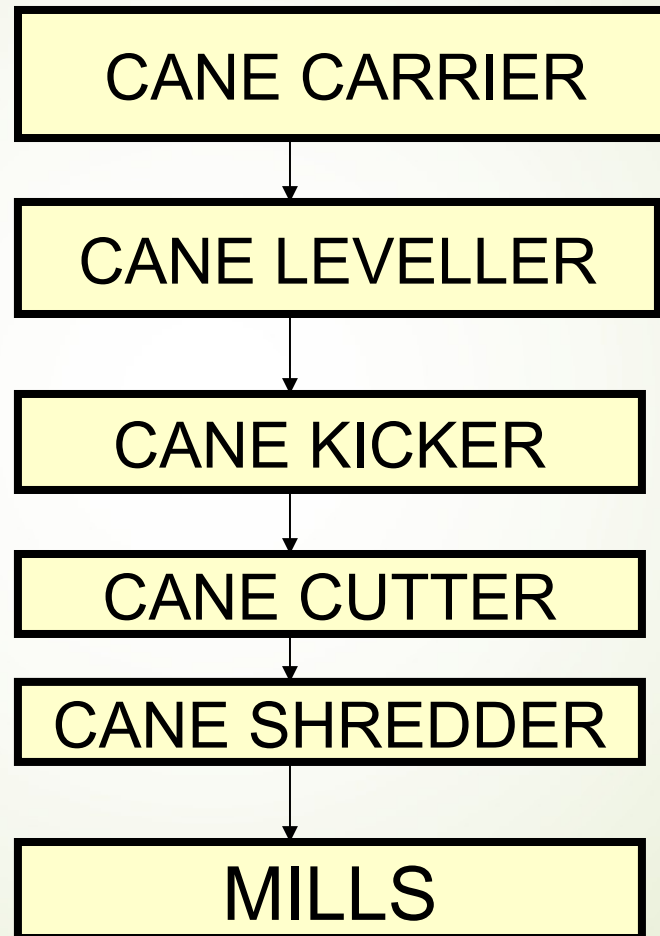
4. Complexity in Handling:

1. **Sulphur dioxide** requires specialized handling and storage systems. The gas must be stored in pressurized tanks, and safety measures must be in place to prevent accidental leaks or exposure.

5. Sludge Disposal:

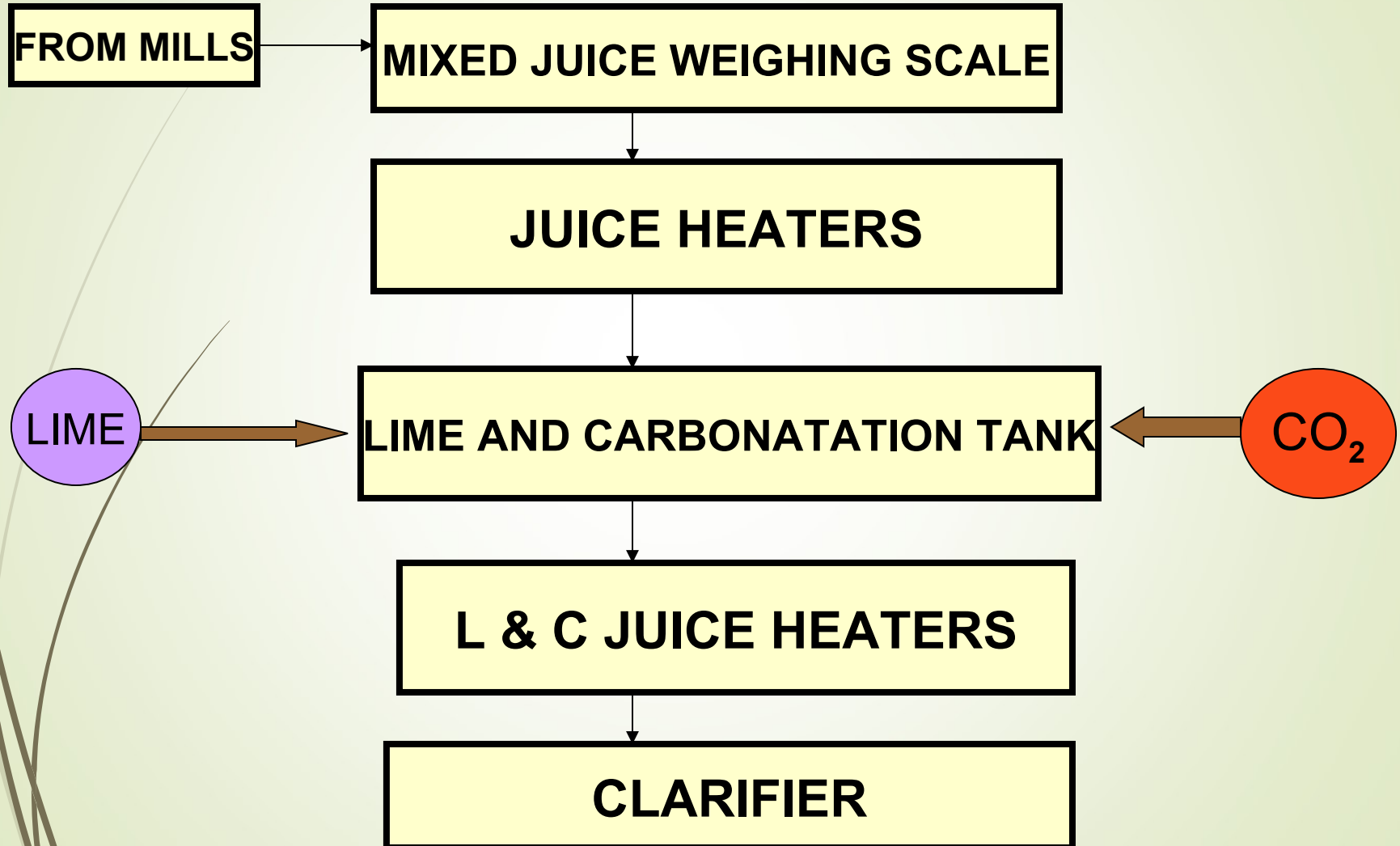
1. The sludge formed during sulphatation contains **sulfite compounds** and other impurities, which may need special treatment before disposal. This can add to the operational costs of the sugar mill.

DOUBLE CARBONATATION FLOW CHART



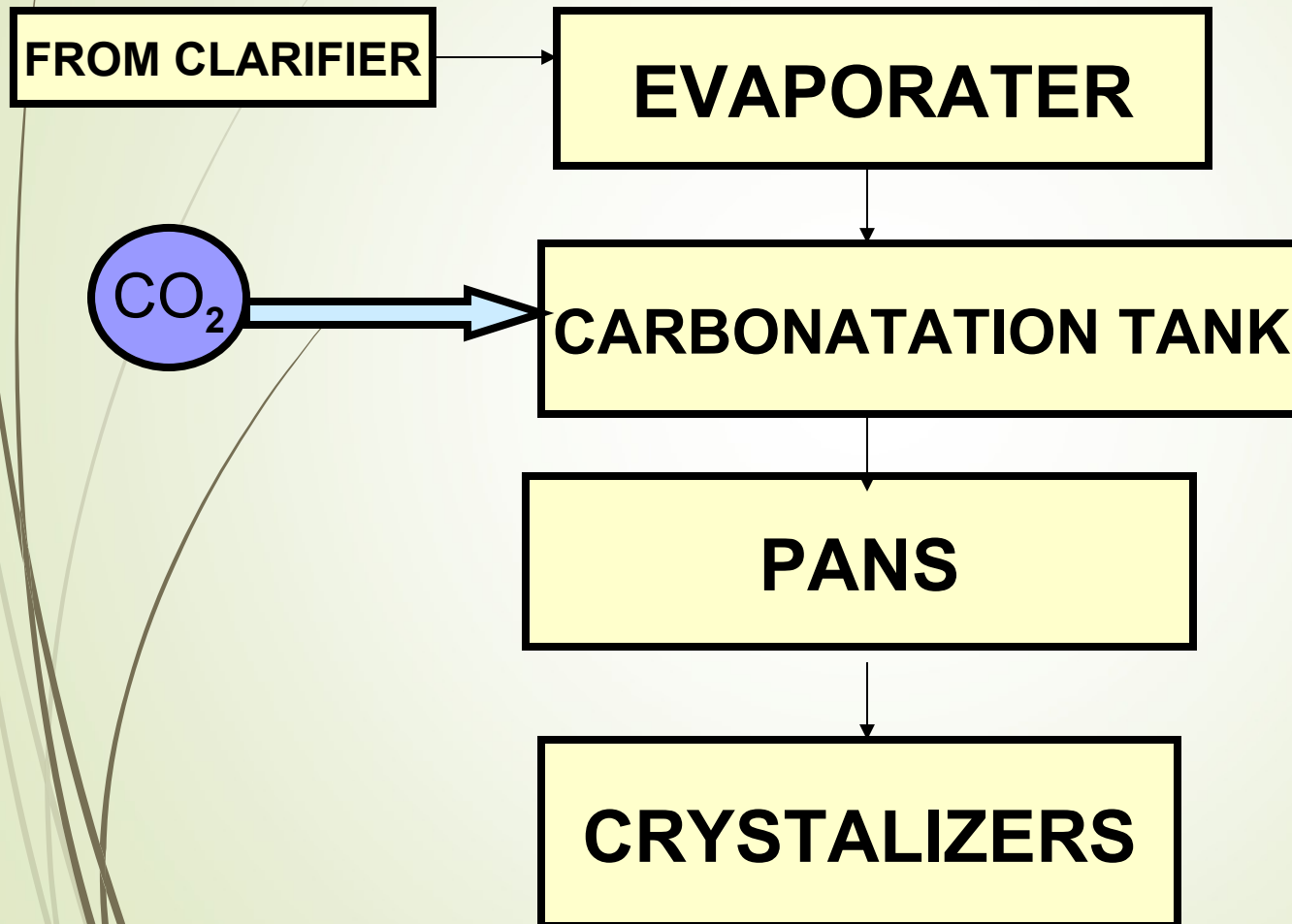
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80

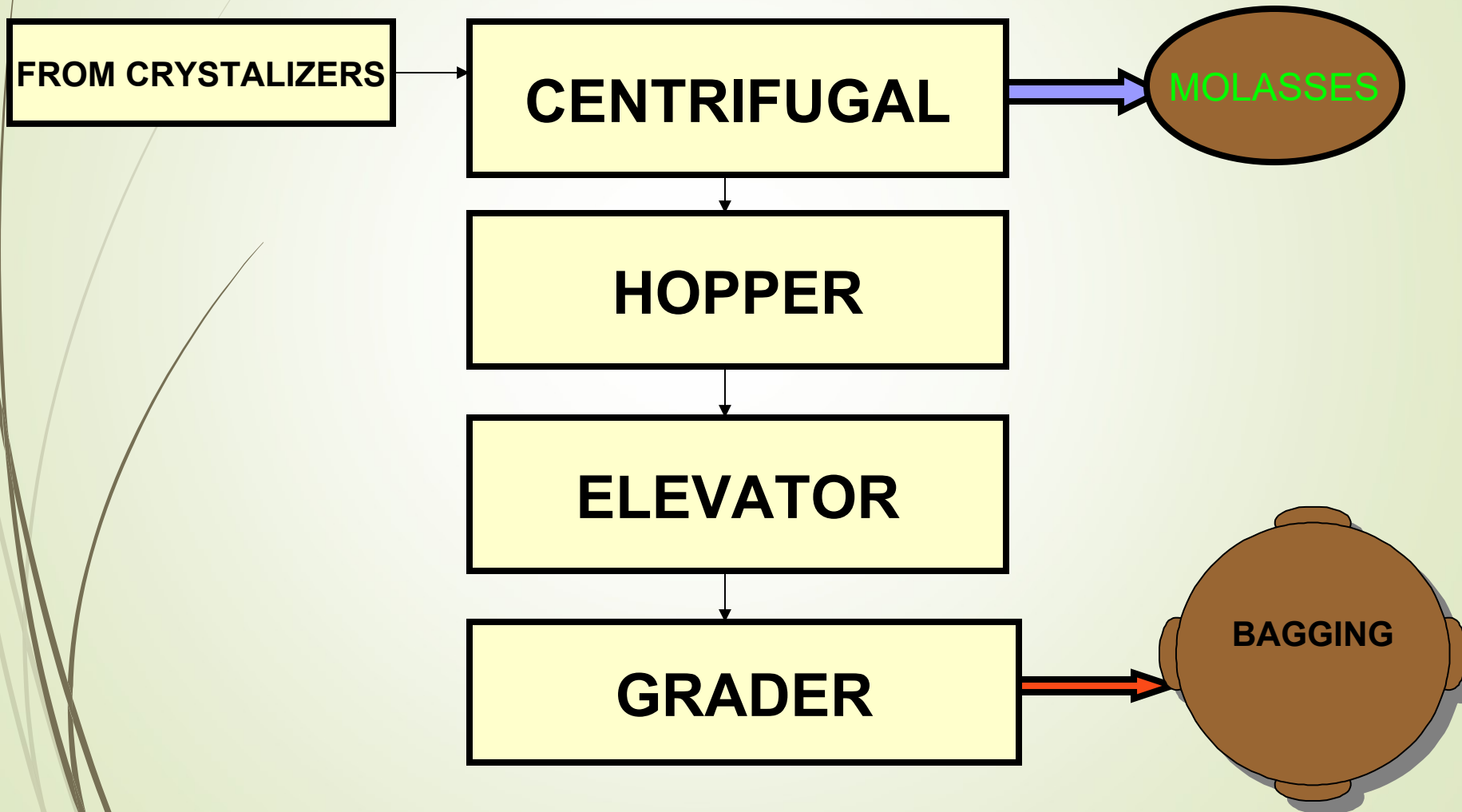


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81



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- **Carbonation** in the sugar industry is a key process used for **clarifying cane juice** and **removing impurities** during the production of sugar. It is an alternative to lime clarification, utilizing carbon dioxide (CO_2) to help neutralize acids and facilitate the separation of impurities from the juice. This method is widely employed in sugar mills to enhance the quality of the juice before it undergoes other processing like evaporation and crystallization.

➤ **How Carbonation Works in Cane Juice Clarification:**

➤ **Carbon Dioxide Introduction:**

- Carbon dioxide (CO_2) is bubbled through the hot **raw cane juice** to neutralize acids present in the juice. The CO_2 reacts with the juice, leading to the formation of **calcium carbonate (CaCO_3)**.
- This reaction also helps in the removal of **suspended solids**, **organic acids**, and other impurities from the juice.

➤ **Reaction with Organic Acids:**

- Cane juice contains **organic acids** such as **acetic acid** and **formic acid**. When CO_2 is bubbled through the juice, it reacts with these acids, neutralizing them and forming **calcium salts**.
- This neutralization reduces the overall acidity of the juice and promotes the coagulation of **impurities**.

Calcium Carbonate Precipitation:

- The CO_2 forms **calcium carbonate** (CaCO_3), which is an insoluble compound. These calcium carbonate particles, along with the coagulated impurities, precipitate out of the juice and settle at the bottom as sludge.

Clarified Juice:

84

The remaining juice, after carbonation and settling, is **clearer** and contains fewer impurities. It is then separated from the sludge and can be sent for further processing, such as evaporation, concentration, and crystallization.

Sludge Removal:

- The **calcium carbonate** sludge, along with the removed impurities, is either removed through **filtration** or allowed to settle in a **settling tank**. The clean, clarified juice is collected for further refining.

Steps in Carbonation Process:

Heating: The raw cane juice is **heated** to a temperature between 85°C and 95°C (185°F to 203°F), which helps in better CO_2 absorption and facilitates the coagulation process.

CO_2 Injection: Carbon dioxide is **bubbled** through the juice using a system of diffusers or pipes, ensuring that the gas is evenly distributed throughout the juice.

Precipitation and Settling: The CO_2 reacts with the juice to form **calcium carbonate**, and other impurities form precipitates. The juice is then allowed to **settle** in a clarifier or settling tank.

➤ Advantages of Carbonation in the Sugar Industry:

➤ Improved Juice Quality:

- Carbonation results in **clearer juice**, with fewer suspended particles, reducing the chance of impurities interfering with later stages of sugar production, such as crystallization.

85

Reduced Chemical Use:

- Unlike lime clarification, which requires the addition of **lime ($\text{Ca}(\text{OH})_2$)** and often **phosphoric acid**, carbonation uses only **carbon dioxide**, making it an environmentally friendly alternative that reduces the use of chemicals.

➤ Higher Sugar Recovery:

- The **better clarification** achieved through carbonation improves the efficiency of subsequent sugar recovery processes, such as **evaporation** and **crystallization**, by ensuring fewer impurities are carried into those steps.

➤ Lower Lime Requirement:

- As carbonation replaces lime in the clarification step, it lowers the cost of lime purchase and reduces the environmental impact related to lime handling and disposal.

➤ Improved Color and Purity:

- The clarification process helps to remove **colored substances** like **polyphenols** and other **organic impurities**, which might otherwise affect the color and purity of the final sugar product.

■ **Less Sludge Disposal:**

- The sludge generated by carbonation is typically less **alkaline** compared to that produced by lime clarification. This makes it easier and less costly to handle, treat, and dispose of.

Disadvantages and Considerations:

86 **CO₂ Supply:**

- The carbonation process requires a continuous and reliable source of **carbon dioxide**. This means the sugar mill must have access to CO₂ gas, which may involve extra costs or logistical challenges.

■ **Capital Investment:**

- Setting up the necessary carbonation equipment, such as CO₂ injectors, diffusers, and clarifiers, can require significant capital investment.

■ **Specific Juice Conditions:**

- Carbonation works best when the juice has an appropriate **pH** and temperature range. If the pH is too high or too low, the carbonation process may be less efficient, and the juice may need to be pre-adjusted before carbonation.

■ **Impurity Removal Efficiency:**

- While carbonation is effective for many impurities, it may not remove all forms of soluble non-sugars or very fine suspended solids. Sometimes additional treatments, like **polymer flocculation** or **filtration**, may be needed.

Clarification section

87

