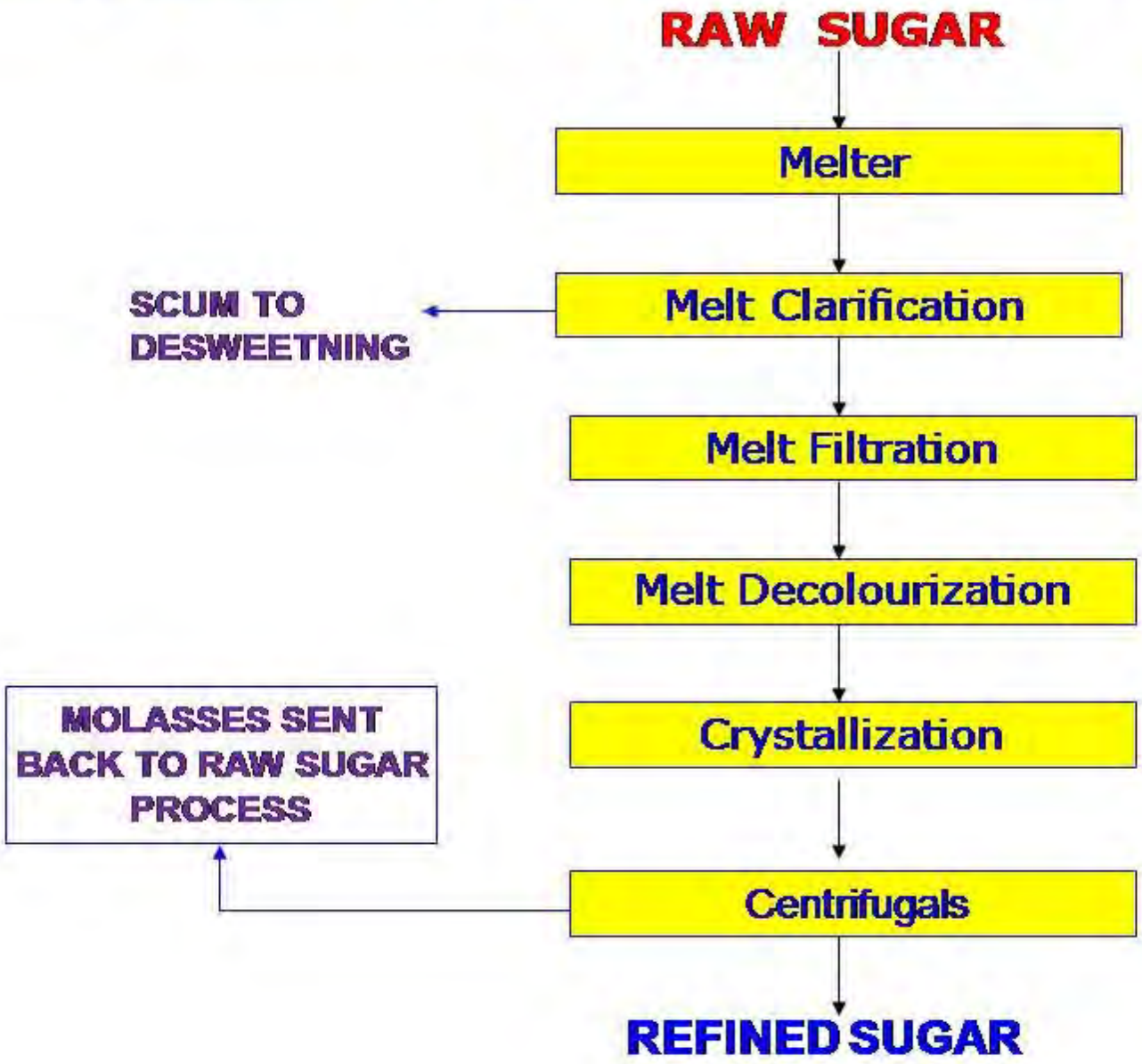
Sugar refining

The purpose of the refinery is to remove impurities from sugar crystals. The refinery accepts raw sugar as its feed material. The sugar is dissolved (melted) and the colour is removed by various clarification processes.

The final refining steps include melting the brown or raw sugar, decoloring by passing through carbon filters, recrystallizing in vacuum boiling pans, and drying by centrifuging.

Simple Flow chat for refined sugar process



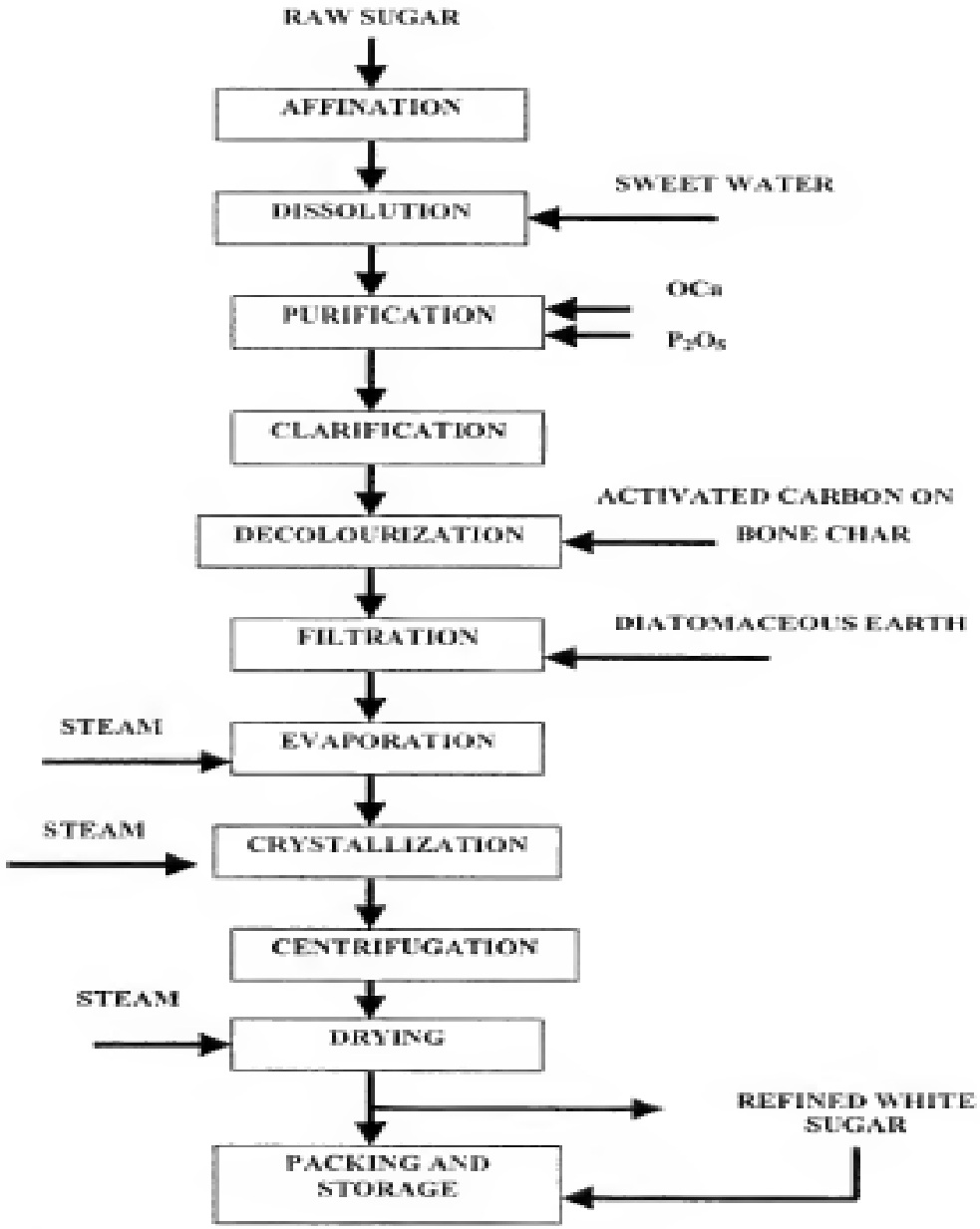


Figure 7 - Flowchart for the production of white refined sugar by phosflotation and the use of activated carbon or bone char

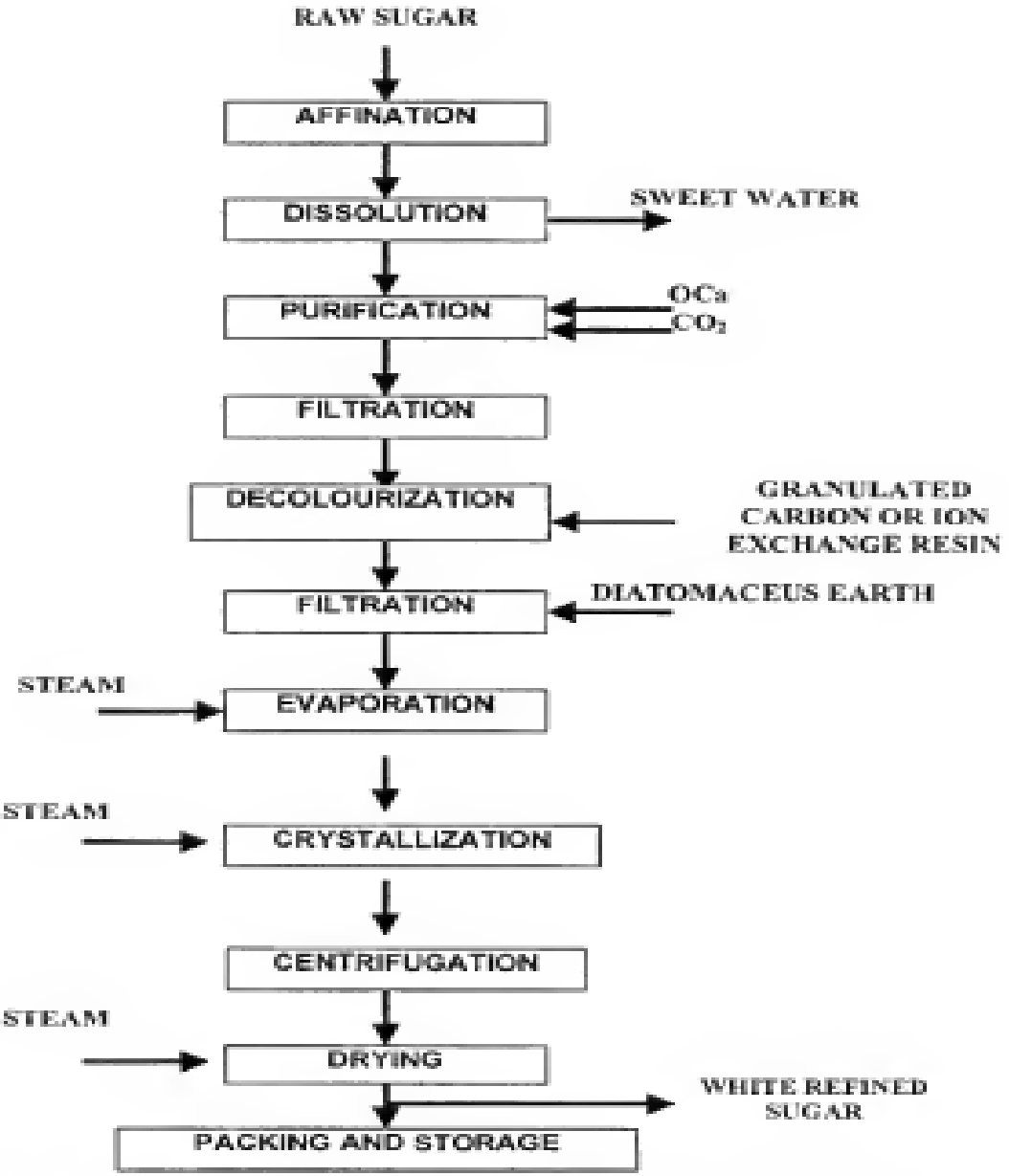


Figure 8 – Flowchart for the production of white refined sugar by carbonation and ion exchange resin or granulated carbon (Delgado, *et al.*, 1990)

Refining Process

Affination

The first stage of processing the raw sugar is to soften and then remove the layer of mother liquor surrounding the crystals with a process called "affination". The raw sugar is mixed with a warm, concentrated syrup of slightly higher purity than the syrup layer so that it will not dissolve the crystals. The resulting magma is centrifuged to separate the crystals from the syrup thus removing the greater part of the impurities from the input sugar and leaving the crystals ready for dissolving before further treatment.

The liquor which results from dissolving the washed crystals still contains some colour, fine particles, gums and resins and other non-sugars.

The Affination process comprises a U-mixer, hot magma mingler, centrifugal and sugar melter. In the U-mixer raw sugar is stirred with a measured amount of water before transfer to the mingler for heating and slurrying

Carbonatation

The first stage of processing the liquor is aimed at removing the solids which make the liquor turbid. Coincidentally some of the colour is removed too. One of the two common processing techniques is known as carbonatation where small clumps of chalk are grown in the juice. The clumps, as they form, collect a lot of the non-sugars so that by filtering out the chalk one also takes out the non-sugars. Once this is done, the sugar liquor is now ready for decolourisation. The other technique, phosphatation, is chemically similar but uses phosphate rather than carbonate formation.

Dissolved sugar from the melter is reacted under carefully controlled conditions of ph and temperature, with milk of lime (CaO) and Carbon Dioxide (CO_2) to form a calcium carbonate ($CaCO_3$) precipitate.

FILTRATION

Carbonated liquor (solution) is pumped through a series of leaf filters which retain the calcium precipitate in the filter and discharge a clear but coloured sugar solution

Decolourisation

There are also two common methods of colour removal in refineries, both relying on absorption techniques with the liquor being pumped through columns of medium. One option open to the refiner is to use granular activated carbon [GAC] which removes most colour but little else. The carbon is regenerated in a hot kiln where the colour is burnt off from the carbon. The other option is to use an ion exchange resin which removes less colour than GAC but also removes some of the inorganics present. The resin is regenerated chemically which gives rise to large quantities of unpleasant liquid effluents.

The clear, lightly coloured liquor is now ready for crystallisation except that it is a little too dilute for optimum energy consumption in the refinery. It is therefore evaporated prior to going to the crystallisation pan.

ION EXCHANGE

The clear but tan coloured sugar solution is pumped through a series of columns containing an ion exchange resin which absorbs the remaining colour to produce a clear and colourless solution known as fine liquor.

EVAPORATION

Water is evaporated from the fine liquor in specially designed equipment to concentrate the sugar solution into a stream known as thick liquor.

VACUUM PAN & CRYSTALLIZER

Thick liquor is transferred to boiling vessels known as pans where under controlled vacuum the liquor is boiled at low temperature to further concentrate the solution. As water evaporates and the liquor concentrates, sugar crystals begin to form, their growth being controlled by careful adjustment of the boiling conditions.

CENTRIFUGAL

Massecuite from the crystallizers is processed through centrifugals where the spinning action separates the sugar crystals from the remaining liquid solution (molasses).

SUGAR HANDLING & PACKAGING

The wet crystals are discharged through a rotating drum into which hot air is continuously blown to remove moisture and dry the crystals. At the exit of the dryer the crystals are cooled and passed through a sieve to grade the crystal size. Any dust formed during this process is removed by vacuum and the sugar then conveyed to the packing area for final packing into 50kgs bags.

Bagasse	**The fibrous residue of sugar cane which remains after the crushing operation.**
Boiling	**The evaporation of moisture from the juice at temperatures of between 90 and 116ºC.**
Brix	**The term 'degrees Brix' (or more usually ºBrix) is the sugar 'technologists' measure of the concentration of dissolved solids in solution.**
Clarification	**Removal of impurities from the juice.**
Extraction	**The removal of juice from the cane by crushing.**
Factory	**This term is used throughout to indicate a sugar processing plant regardless of its type, processing capacity or physical size.**
Invert sugar	**High temperatures and acid conditions can cause chemical decomposition of the sucrose resulting in simpler sugars such as glucose and fructose forming. These sugars are known as invert sugars and are not desirable in the final product.**
Massecuite	**The concentrated cane juice obtained after boiling, also known as rab or final syrup.**
Molasses	**A syrup by-product from the manufacture of sugar, containing sucrose, invert sugars, moisture, ash and other insoluble matter.**

Open Pan (OP)	**Describes sugar produced by boiling juice in open pans at atmospheric pressure.**
OPS	**Open Pan Sulphitation (OPS) is a method for production of white granular sugar, developed in India.**
Recovery	**The proportion of sugar produced by weight of cane processed, usually expressed as a percentage. For example, 10% recovery means that for every 100kg of cane processed 10kg of sugar is produced.**
Strike	**The removal of massecuite from the boiling operation at the required concentration.**
Sucrose	**An organic chemical of the carbohydrate family, found in the sap of most green plants. Ordinary white crystal sugar is almost (99.9%) pure sucrose while some of the non-crystalline sugars may contain less; for example syrup and jaggery which contain as little as 50 and 80% sucrose respectively.**

TCD	**Tonnes of Cane per Day refers to the amount of cane a processing plant crushes each day and not the amount of sugar produced. Most sugar processing plants are sized according to this figure which is based on a 24 hour day. However, many small-scale factories, and some large ones, only operate for part of a day and in some cases for only part of the year. Therefore care must be taken when analysing TCD figures as they only represent a factory's capacity and do not necessarily reflect the actual throughput**
Vacuum Pan	**Vacuum (VP) pan describes a particular type of technology used to boil or evaporate the sugar cane juice. It was developed by the large-scale industry to improve efficiency but some small-scale VP factories are in operation, especially in India**

Yields

The yield of gur from sugar cane depends mostly on the quality of the cane and the efficiency of the extraction of juice. The table below gives some extreme values.

	High quality cane	Poor quality cane
Juice per 100kg of cane	50kg	40kg
% sugar in juice	22	17
Raw sugar per 100kg of cane	10kg	7kg

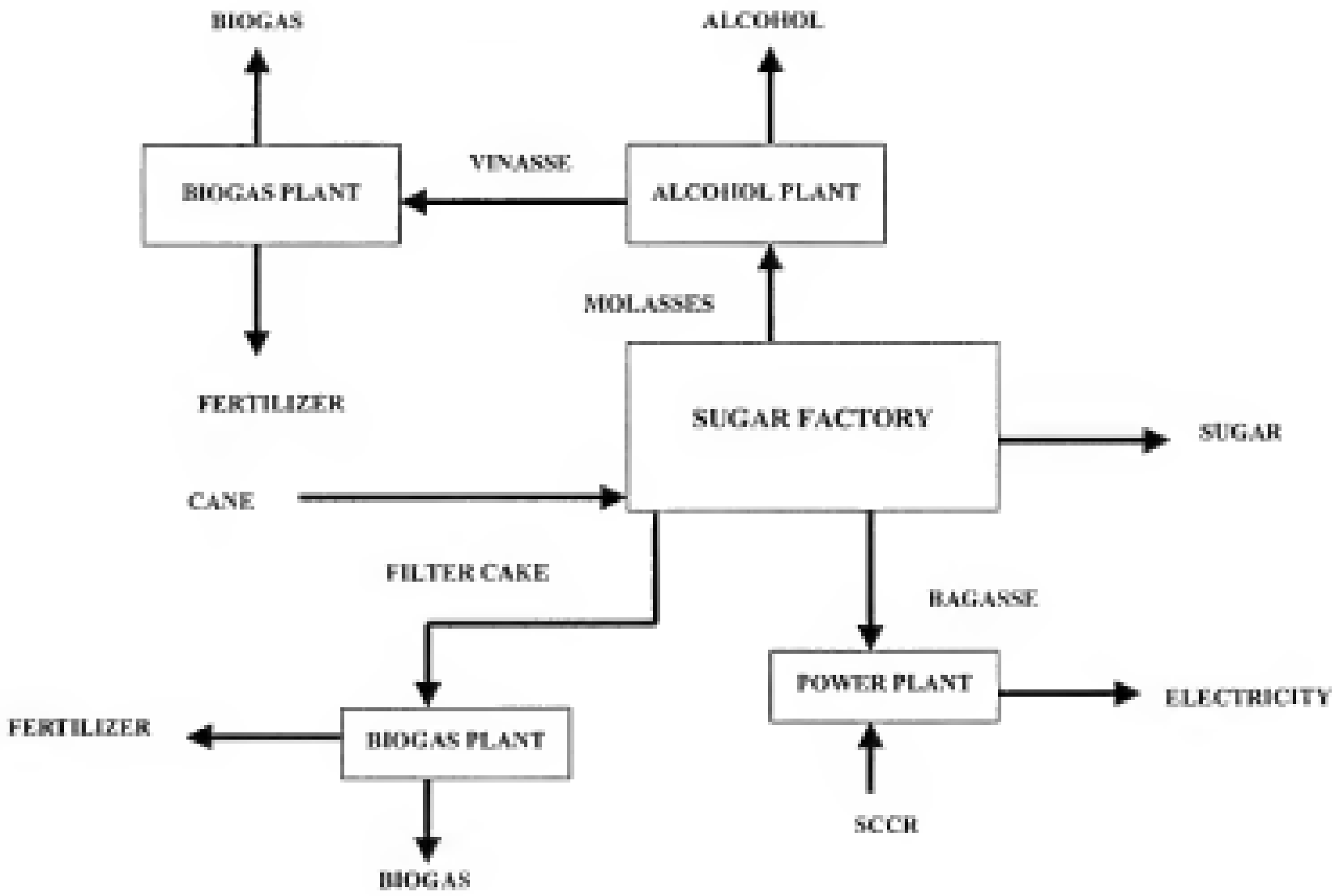


Figure 25 – Residues from raw sugar production and their uses

Types of cane sugar

Processed sugar comes in two forms: non-crystalline and crystalline of which there are two basic types; centrifuged and non-centrifuged. The different forms of sugar are produced in many different countries and often have different names, therefore for clarity the different types are described as follows:

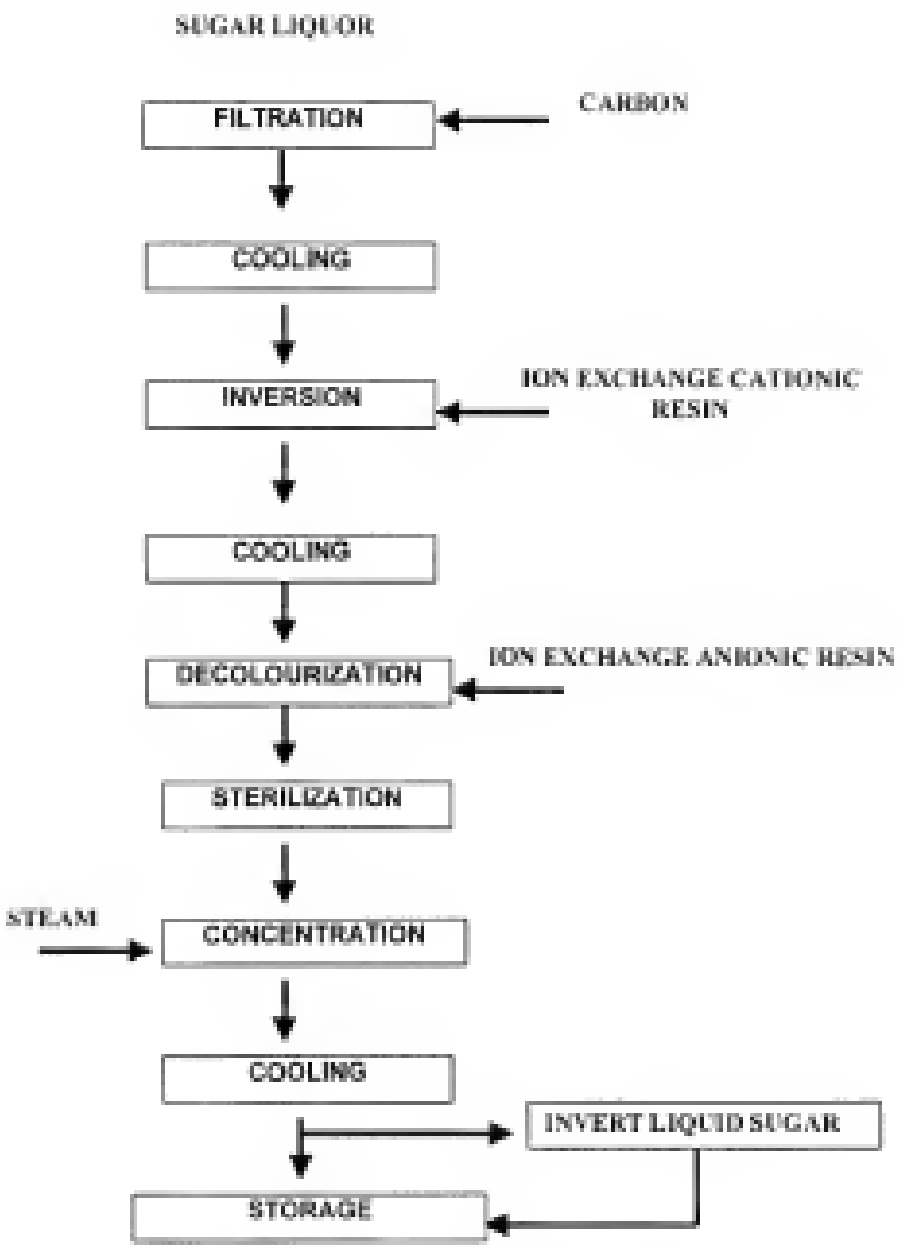


Figure 11 - Flowchart for the production of invert liquid sugar

Non-crystalline sugars
Syrups

A non-crystalline liquid of high viscosity (thickness) concentrated from whole cane juice. It can vary from golden brown to dark brown and contains; up to 50% sucrose, high levels (up to 20%) of invert sugars, up to 20% moisture and the remainder is made up of other insoluble matter (ash, proteins, bagasse etc).

Crystalline sugars

These can be divided into two types: non-centrifugal sugars and centrifugal sugars. Non- centrifugal sugars are basic lump sugars where the molasses and crystals have not been separated. Centrifugal sugars are free flowing granular sugars where the molasses and crystals have been separated to some degree

Non-centrifugal sugars
Lump sugars

Lump sugars are produced in many countries around the world and are known by a range of names: jaggery in Africa, gur in India and Bangladesh, desi in Pakistan, chancaca in Peru; other names include panela, piloncillo, and rapedura.

These sugars are a concentrated product of the cane juice and are produced in many countries for direct consumption. They vary from yellowish brown to dark brown (almost black sometimes) in colour and contain up to 80% sucrose with the remainder made up from moisture, invert sugars and other insoluble matter such as ash, proteins and bagasse fines in varying proportions.

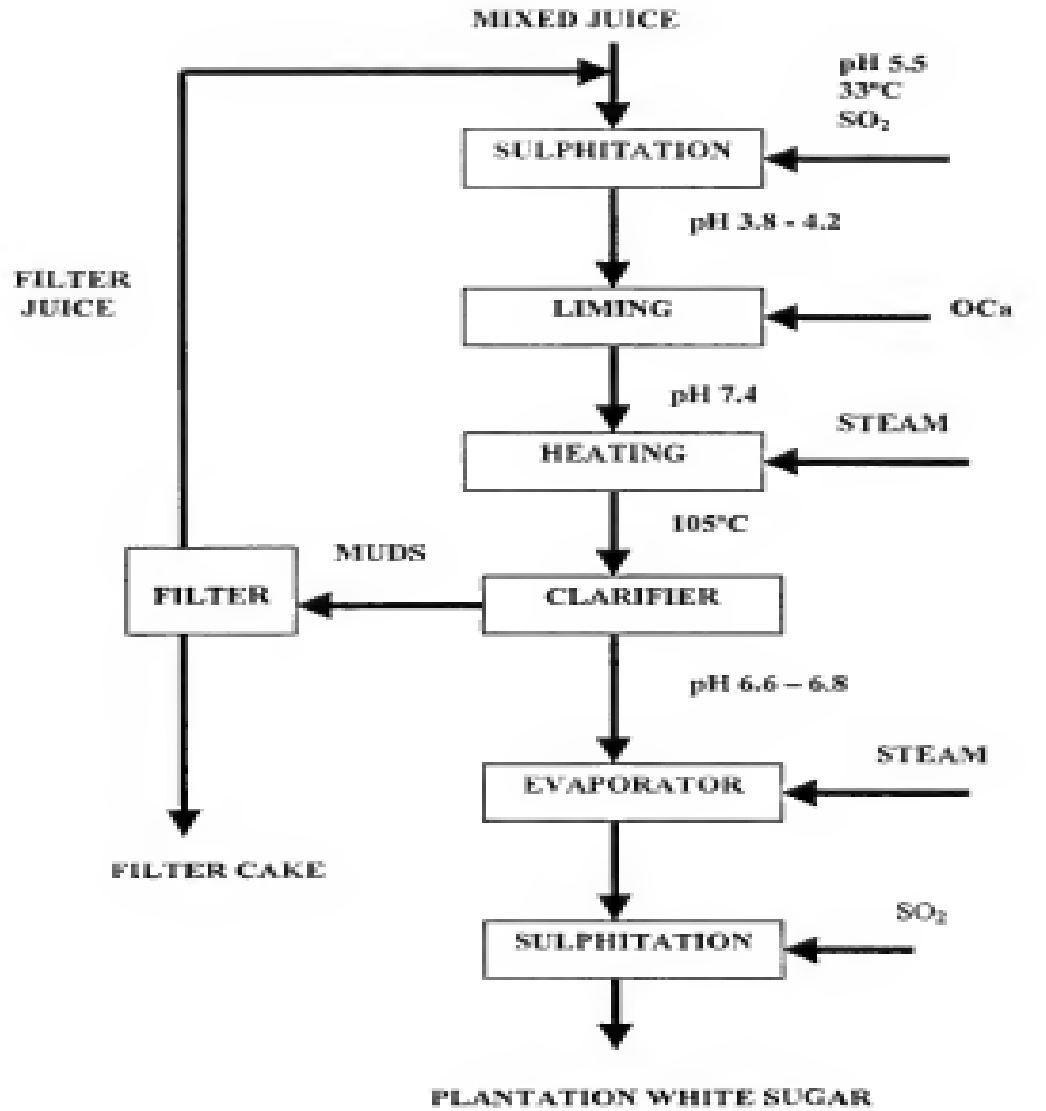


Figure 5 - Schematic of the production of plantation white sugar by sulphitation of the mixed juice using the cold acid process (Source: University of Natal, South Africa, 1996)

White granular sugars

Free flowing white granular sugars are often referred to as plantation white. These sugars are traditionally produced in large-scale VP factories. It is possible for the medium-scale sector to develop small-scale or mini VP plants for the production of good quality white sugar.

Brown granular sugars

There are two categories of granular brown sugar: those produced directly from the cane juice at the place of origin and those that are produced during the refining of raw sugar. The first type includes demerara, muscovado and turbinado sugars. The second types are coated brown or 'soft' sugars and manufactured demerara.

Those produced directly from the cane juice at the place of origin can be made using medium- scale open pan production methods. The refined brown sugars, however, tend to be produced in modern large-scale VP sugar factories.

Lump sugar and syrup production

There are four stages of production

- **Extraction of juice from the cane**
- **Clarification of the juice**
- **Boiling of the juice**
- **Moulding and packaging**

Boiling

For syrup production the juice is boiled until the required concentration is reached and the strike is made at around 105ºC when most of the moisture has been boiled off and just before crystallisation occurs. If the juice is over-boiled then crystals may be present which may cause discoloration. If under-boiled, too much moisture will remain in the syrup which may, with time, cause cloudiness and shorten its shelf life. For lump sugars the juice is boiled for longer and the strike is made at between 116 and 120ºC.

In all cases the furnaces use sun dried bagasse as fuel. The bigger factories often have a surplus at the end of operations while smaller units have to operate their furnaces with much greater cane to ensure that they do not use all the bagasse before boiling is completed.

Moulding and packaging

For syrup production the juice is poured or ladled from the boiling pan into containers where it is allowed to cool. For lump sugar production, the massecuite is poured into cooling trays where it is stirred to promote even cooling and crystallisation. Upon setting, the lump sugar is cut or moulded into shapes to suit the local market and customer requirements. Alternatively, before the massecuite solidifies it can be poured into pots or moulds to produce various shapes.

In Bangladesh where small temporary factories are common the pan is removed from the furnace allowing cooling and crystallisation to occur within the pan while a new pan with fresh juice is placed on the furnace.