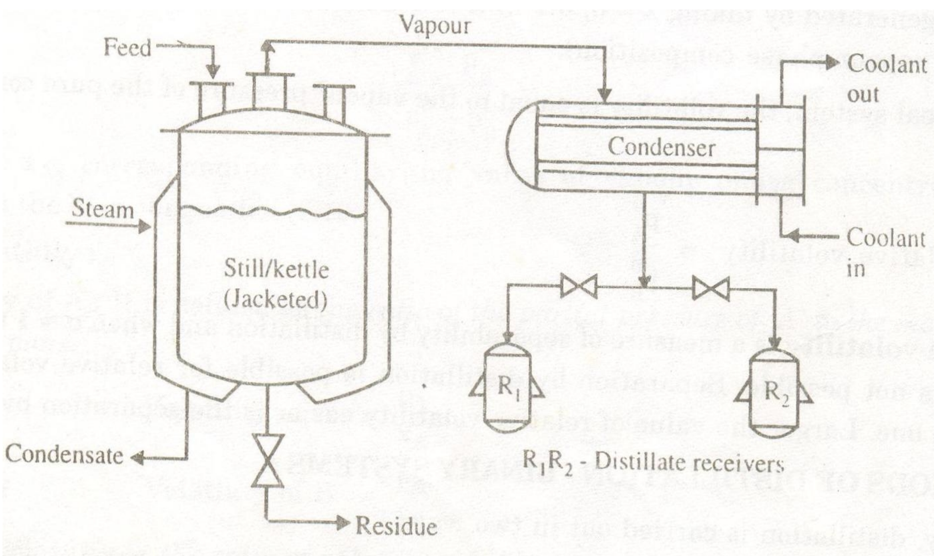
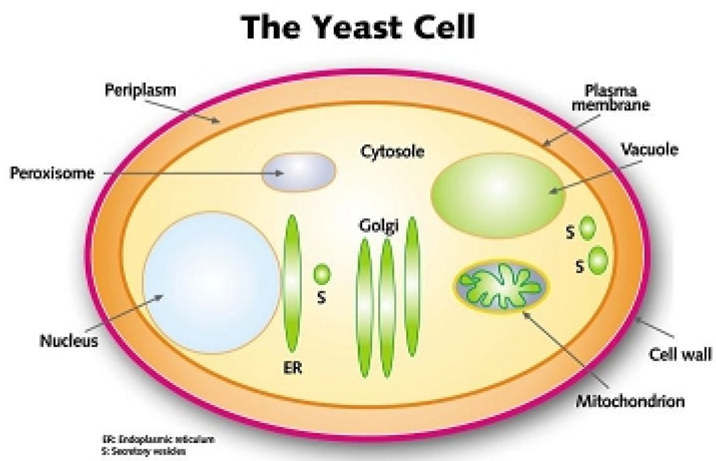
SUMMER-15 EXAMINATION

Model Answer

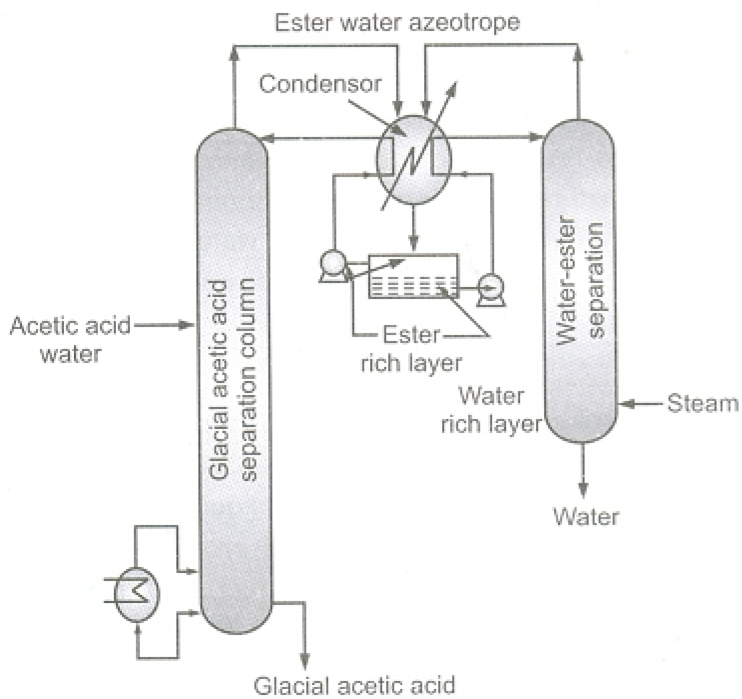
Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q No.	Answer	marks	Total marks
1.a	**Distillation:** It is the unit operation in which a mixture of two miscible liquids is separated based on their difference in boiling point using thermalenergy. Types of distillation: 1.Simple/Differential distillation 2. Flash/ Equilibrium distillation 3. Fractional distillation/ Rectification	1 3	4
1.b	**Schematic diagram of distillation apparatus**  **Simple/Differential distillation**	4	4
1.c	**Yeast:** It is a one celled fungus that converts sugar and starch into carbon dioxide and alcohol Eg: beer yeast, dry yeast, wine yeast **Bacteria:** They are microscopic organisms whose single cell have neither a membrane enclosed nucleus nor other membrane enclosed organelles like mitochondria and chloroplast.	1 1 1	4

	Eg: cocci, bacilli, spirilla	1	
1.d	**Morphology of yeast:** It is the description of – 1. the shape, size and internal structure of the yeast cells 2. changes during the reproduction of vegetative cells and the position of the newly formed cells to their parent 3. the changes the cells undergo when forming resting cells, ballistospores or asco spores 4. the size, shape, surface of spores, their number per ascus and mode of germination  	4	4
1.e	**Use of enzyme in manufacturing malt alcohol:** 1.In metabolizing the malt into alcohol and carbon dioxide. 2. By adding small amount of protease enzyme, helps in yeast growth and reduce fermentation time. 3. During distillation process, it may be necessary to reduce viscosity of the fermentation broth. To facilitate this beta glucanase/ pentosanase enzymes are added.	4	4
1.f	**Raw materials for Rum and whisky:**	4	4

	1. Fermented Sugarcane juice 2. Fermented sugarcane molasses 3. Sugarcane byproducts		
1.g	**Contents of waste from alcohol industry:** 1. Ash 2. Calcium oxide 3. Potash(as K_2O) 4. Sodium salt 5. Iron 6. Acid insolubles 7. Phosphorus 8. Nitrogen	4	4
2.a	**(i)Azeotropic distillation :** An azeotrope is a liquid mixture with an equilibrium vapour of same composition as the liquid. The dew point and bubble point are identical at azeotropic composition and mixture vapourises at single temperature , so azeotropes are called constant boiling mixture. Azeotrope can not be separated by distillation because the dew point and bubble point are identical. The constituents of binary azeotrope are separated completely by 1) Adding third component to the binary mixture 2) By changing system pressure. The third component added to the binary azeotrope usually form a low boiling azeotrope with one of the feed constituents and withdrawn as distillate. The third component added is called as entrainer of azeotrope breaker. The process of distillation where the third component is added to the binary azeotrope to effect the complete separation is called azeotropic distillation.	4	8

	In azeotropic distillation of acetic acid-water mixture, n butyl acetate is used as the entrainer. Addition of entrainer will result in the formation of a minimum boiling azeotrope with water. The azeotropic mixture therefore will be distilled over as vapour product from the high boiling acetic acid, which leaves as bottomproduct.  OR example of ethanol-water mixture **(ii)Advantages:** 1. Used to separate closed boiling liquid mixtures. 2. Thermal energy requirement is less	2 2	
2.b	**(i) Liqefaction:** It is the first step in processing starch containing grains to alcohol. Here the grain flour is mixed with water and heated to break down the starch molecule	2	8

	into shorter dextrin molecules using enzymes. **(ii)Process of pretreatment of enzyme** Firstly, there is a liquefaction process. A starch suspension containing 30-40% dry matter is first gelatinised and liquefied. By using heat-stable bacterial alpha amylase, 'maltodextrin' is obtained which contains mainly different oligosaccharides and dextrins. Maltodextrins are only slightly sweet and they usually undergo further conversion. In most starch conversion plants, starch liquefaction takes place in a jet-cooking process. The heat stable alpha amylase is added to the starch slurry after pH adjustment, and the slurry is pumped through a jet cooker. Live steam is injected here to raise the temperature to 105^{o}C, and the slurry is then passed through a series of holding tubes for 5-7 minutes, which is necessary to gelatinise the starch fully. Then the temperature of the partially liquefied starch is reduced to 90-100^{o}C by flashing, and the enzyme is allowed to react further at this temperature for 1-2 hours until the required DE (Dextrose Equivalent) is obtained. (iii) **Significance:** 1.Increased output 2.To enhance hydrolysis of cellulose	4 2	
2.c	**(i)Yeast acidification:** Yeast can grow at low pH, but 4.6 is generally considered the level that will prevent the growth and toxin production for pathogens. pH is considered primarily a means of growth inhibition and not a method for destruction of existing pathogens. A pH of 4.6 is used as a divider	5	8

	between high acid and low acid foods. Some foods that are naturally low acid are processed in a way that makes them a high acid food. This is called acidification. Acidification is the direct addition of acid to a low acid food (pH less than 4.6). These foods are called acidified foods. There are a variety of organic acids that are used- acetic, lactic or citric. Selection of acid depends on the desired attributes of the finished products. Acidification (ii**) Significance:** 1. To improve the quality of food.(desired taste, texture) 2. helps in non refrigerated storage. 3. helps in preventing the growth and toxin production for pathogens.	3	
3.a	**Material of construction of yeast vessel:** 1.Plastics: Light, inexpensive, not resistant to heat and chemicals, low thermal conductivity. 2. Ceramics: Inert, easily worked, inexpensive, fragile and only suitable for small scale domestic brewing. 3. Stainless steel (most preferred) : Strong, very durable, expensive, excellent cleaning properties, corrosion resistant, high thermal conductivity. 4. copper: strong, easily cleaned, very expensive, very high thermal conductivity. 5. Concrete: Durable, can be formed in to any shape, relatively heavy but can be used for large vessels, requires inert lining material. 6. Aluminium: Light, durable, easily worked, can be used as lining material or as main fabric of vessels, susceptible to attack by alkalies, subjected to electro chemical corrosion.	4	8

	Maintenance of yeast vessel: 1. Valves should be checked and gaskets changed at regular intervals. 2. Filter insert is to be replaced every 2-3 years. 3. Before any operations, lines are flushed with water and steam sterilized. 4. Temperature and pH indicators should be checked.	4	
3.b	**Manufacture of Vodka** **Raw materials:** 1.Vegetable or grains: Potato,corn,wheat 2.Water 3.Malt meal 4. Yeast- Sacchasomyces Cereviscal 5. Flavourings- herbs,grasses, spices,fruit essence **Process:** ***1. Mash preparation*** The grain or vegetables are loaded into an automatic mash tub. The tub is fitted with agitators that break down the grain as the tub rotates. Aground malt meal is added to promote the conversion of starches to sugar. ***2. Sterilization and inoculation*** Preventing the growth of bacteria is very important in the manufacture of distilled spirits. First, the mash is sterilized by heating it to the boiling point. Then, it is injected with lactic-acid bacteria to raise the acidity level needed for fermentation. When the desired acidity level is reached, the mash is inoculated once again. ***3. Fermentation*** The mash is poured into large stainless-steel vats. Yeast is added and the vats are closed.Over the next two to four days, enzymes in the yeast convert the	5	8

sugars in the mash to ethyl alcohol.

4. Distillation and rectification

The liquid ethyl alcohol is pumped to stills, stainless steel columns made up of vaporization chambers stacked on top of each other. The alcohol is continuously cycled up and down, and heated with steam, until the vapors are released and condensed. This process also removes impurities. The vapors rise into the upper chambers (still heads) where they are concentrated. The extracted materials flow into the lower chambers and are discarded. Some of the grain residue may be sold as livestock feed.

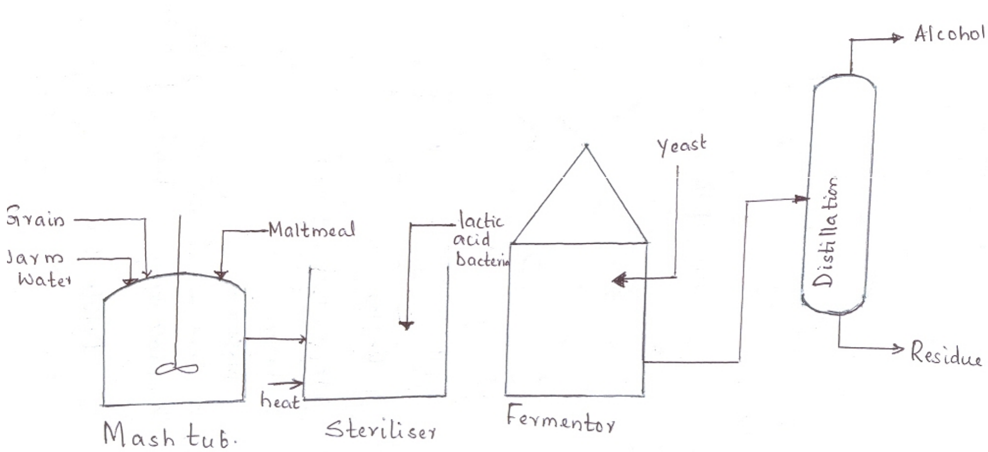
5. Water added

The concentrated vapors, or fine spirits, contain 95-100% alcohol. This translates to 190 proof. In order to make it drinkable, water is added to the spirits to decrease the alcohol percentage to 40, and the proof to 80.

6. Bottling

Alcoholic beverages are stored in glass bottles because glass is non-reactive.

Flow diagram:



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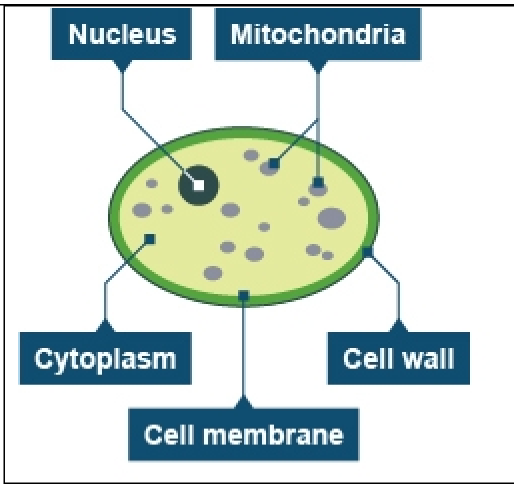
3.c	(i) **Toxological Effects of effluent from alcohol industry:** 1.Effluent from alcohol industry causes severe land pollution(foul smell and dark colour) 2. Distillery effluent causes decrease in dissolved oxygen and prove dangerous to aquatic life. 3.If the effluent from the alcohol industry is used for irrigation, high BOD water results in crop failure 4.Seapage of coloured liquids can adversely affect ground water as well as land quality. 5. Soil condition will be deteriorated in course of time. (ii) **Chemicals used to treat effluent from alcohol:** Lime, HCl, oxidizing agents like$KMnO_4$,microorganisms	5 3	8
4.a	**Government stipulated conditions for alcohol industry wastewater:** Effluent standards: BOD-100mg / l for land disposal 30 mg / l for disposal in streams pH – between 5.5 and 9 Total dissolved solids: 2100 mg / l Oil and grease: less than 10 mg / l Sodium : < 60% Ammoniacal nitrogen: < 50 mg/l Disposal of molasses in the environment is to be done only after prior approval of the concerned state water pollution control board. Fermented sludge should be allowed to mix with the spent wash. this sludge should be dewatered, dried, and used as manure or cattle feed. Necessary treatment to bring BOD concentration is done by dilution and ensure that it would not cause ground water pollution.	8	8
4.b	**Propagation of yeast:**	1	8

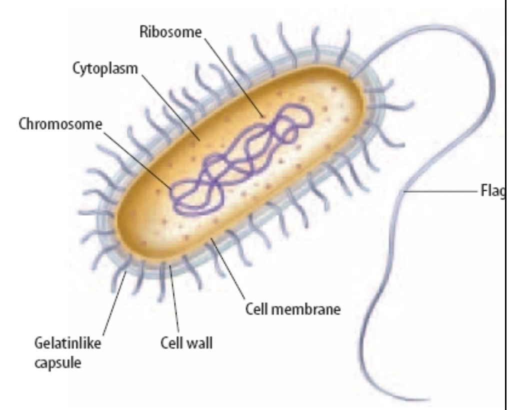
	It is the process where a pure culture of brewer's yeast is propagated in sterile wort usually continuously under aseptic condition. **Process**: 1. Yeast culture is usually stored in a test tube or flask on a culture medium in a fridge .It is sometimes kept in a freezer or under liquid nitrogen. 2. The yeast cells are grown up inj a series of laboratory steps ensuring purity at each step by aseptic transfer and selecting single colonies. They are aerated and shaken at around 20^oC to maximise yeast cell growth upto 5- 6 times. 3. Sterile wort is collected in a small yeast propagation vessel. The cool wort is pitched with the laboratory cultured yeast. Again the culture is maintained at around 20oC with oxygenation at high level to encourage cell mass growth. 4. The content of the smaller yeast propagation vessel is used to inoculate sterile wort in the next vessel. This is repeated until sufficient yeast has been produced to pitch a standard brew or fermentation vessel. **Reasons for propagating yeast:** 1.Yeast picks up and spreads infections to the wort. 2.Yeast character changes due to the genetic mutation. 3.Reduction in viability and vitality of the yeast over time and repitchings. 4.Dead cells contribute unwanted flavor to the beer. 5. Ageing of yeast causes slowing down in the rate of reproduction, changes to cell surface and flocculation behavior, changes to metabolic behavior and general increase in cell size.	4 3	
4.c	**Fermentation**: It is a metabolic process in which an organism converts a carbohydrate such as starch or sugar, into an alcohol or an acid. Eg Yeast performs fermentation to obtain energy by converting sugar into	2	8

	alcohol. $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ **Types of fermentation:** **1.Batch fermentation:** The reactor is filled with sterile nutrient substrate and inoculated with the microorganism. In the course of the entire fermentation, nothing is added except oxygen, an antifoam agent, and acid or base to control the pH. The fermentation process begins and continue until the number of cells in the fermenter is such that some of the contents of the fermenter can be removed with out altering the number of cells in the fermenter. The culture is removed to grow until no more of the product is being made at which point the reactor is harvested and cleaned out for another run. **2. Continuous fermentation:** In continuous fermentation, an open system is set up. Sterile nutrient solution is added to the bioreactor continuously and an equivalent amount of converted nutrient solution with microorganism is simultaneously removed from the system. Two basic types of continuous fermentors are distinguished- Homogeneously mixed bioreactor and plug flow reactor. Homogeneously mixed bioreactor is run either as a chemostat or as a turbidostat. In chemostat, the cell growth is controlled by adjusting the concentration of one substrate. In turbidostat, cell growth is kept constant by using turbidity to monitor the biomass concentration. In plug flow reactor, the culture solution flows through a tubular reactor without back mixing. **3. Aerobic Fermentation:** Using oxygen, the yeast or bacteria convert glucose in to carbondioxide ,water and energy, where most of the energy is devoted to generation of new cells.	6	

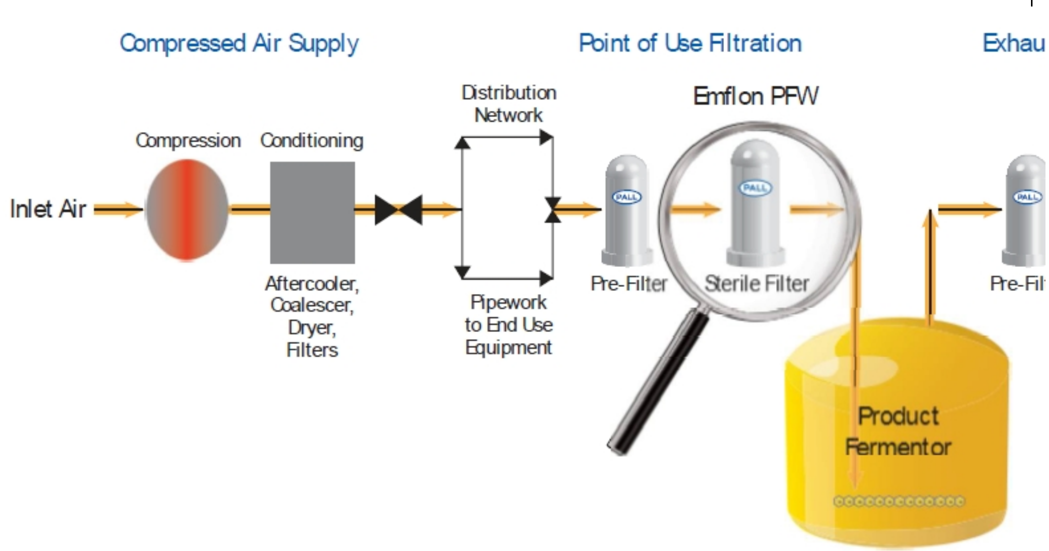
	During this period of time, the yeast can multiply 100-200 folds. Control of dissolved oxygen is crucial at this stage as it determines the successful growth of the culture. Although adequate oxygen must be injected to ensure sufficient bacteria growth, when in excess, it can lead to a reduction in alcohol producing activities and over production of vicinl diketone compounds that produces undesirable tastes. **4.Anaerobic fermentation:** Here fermentation takes place in the absence of oxygen and occurs over a period of 2-3 weeks. Without oxygen, bacteria cannot respire aerobically to produce energy. Growth ceases and the rate of activity slows down. The bacteria switch to anaerobic respiration, when glucose is broken down chemically with enzymes to produce energy. Alcohol and carbondioxide are produced as a side product in the process of anaerobic respiration.		
5.a	**Comparison of yeast and bacteria:**	8	8

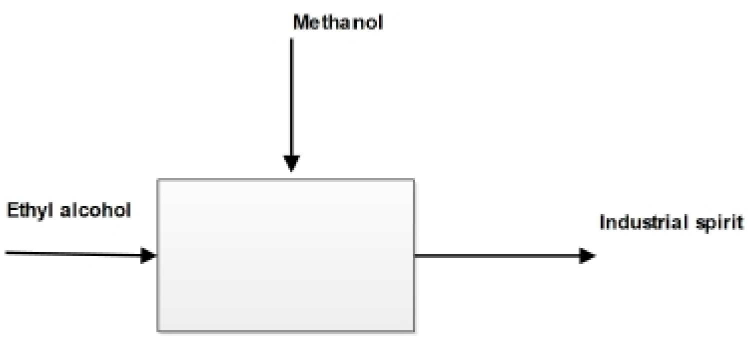
Yeast	**Bacteria**
It is included in kingdom fungi	They are included in kingdom of monera
Yeast is heterotopic and mostly shows saprotrophic mode of nutrition.	Bacteria are heterotrophic and show saprotrophic as well as parasitic mode of nutrition.
Chlorophyll is absent.	In some bacteria chlorophyll is present.
Fungi are eukaryotic organisms (Organized nuclei)	Bacteria are prokaryotic organisms.
Yeast reproduces usually by process of budding.	Bacteria are generally produced by binary fission.





5.b	**Sterilize air:** Food and feed ingredient producers using fermentation as the basis of their process face pressures from food manufacturers for lower pricing and increased output without compromising quality. These fermentations are among the most challenging in the industry with 35 to 350 m3 fermentor batches followed by complex purification steps. Reaching yield targets is a key factor for competitive advantage. One microbial contamination can lead to yield decrease or even complete fermentation batch loss. Contamination may also result in capacity loss and increased cleaning costs that may jeopardize overall profitability of the plant. Contamination control of all process fluids makes the difference. The purity of compressed air, used at up to hundreds of standard cubic meters per minute, is critical during seed, propagation and production fermentation. Bacteria selected for the production of amino acids can be highly sensitive not only to microbial, but also to bacteriophage (bacterial virus) contamination. The treatment of fermentor inlet air is a critical control point (CCP), where microbial sterility of air and freedom from phages is a determinant parameter to protect the yield. To	8	8

	protect the fermentor contents, sterilizing grade membrane air filters additionally validated for high levels of phage removal were required. A significant consideration was filtration operating costs, especially as they related to cost per sterilization cycle. This results in low initial pressure drop, which leads directly to compressor energy savings as well as longer filter life. 		
5.c	**Industrial spirit** is distilled ethyl alcohol (C_2H_5OH), normally of high proof, produced and sold for other than beverage purposes. It is usually distributed in the form of pure ethyl alcohol, completely denatured alcohol, specially denatured alcohol and solvent blends. Pure ethyl alcohol is used in laboratories and in industry for its sanitizing, cleaning and solvent properties. Many medicines, food products, flavorings and cosmetics are made with ethyl alcohol. It is also used to process vaccines, syrups, tinctures, liniments and antiseptics and in the manufacture of pharmaceuticals such as chloroform and barbiturates. It may be used in the production of adhesives, cosmetics, detergents, explosives, inks, hand cream, plastics and textiles.	6	8

	Industrial spirits often have similar properties to alcohol and are chemically similar to drinking alcohol. However, these other types of alcohol may cause a person to become violently ill, damage vital organs or become unconsci ous when consumed. Industrial spirits should never be ingested under any circumstance. Many industrial spirits have colors or bitter tasting additives that are designed to make them unpalatable or unappealing. **Manufacturing of Industrial spirit**  	2	
6.a	**i) Enzyme dosing:** Ethanol production in the dry grind ethanol industry is done by converting the starch in corn to ethanol using enzymes and yeast. Enzyme dosing is required to convert starch to glucose and glucose to ethanol. Optimization the enzyme dose for the production of ethanol and sugar during the simultaneous saccharification and fermentation (SSF) process is required. Experimentation is required to decide the quantity of enzymes required. Samples can be taken at 2, 4, 6, 8, 10, 12, 24, 48, and 72 h from the start of SSF. Samples were analyzed using high-pressure liquid chromatography (HPLC) and near-infrared spectroscopy for the ethanol and sugar contents. Each treatment was replicated three times. Response surface methodology (RSM) was used for studying effects of treatment on the response and	4	8

	optimization of the SSF process. **ii) Nutritional requirement of yeast:** Yeast require carbon source as it can not do photosynthesis. They also required vitamins, minerals and organic nitrogen source. The micronutrient are the source of carbon, nitrogen, phosphate and sulphate. **Sugars** Of the nutrients needed by yeast, sugars are by far the most abundant in raw material typically being in the range 180 – 250 g/L. The sugars present are glucose and fructose. In this range the sugars are well in excess of the yeast's needs. It is unlikely that sugars are ever a limiting factor in yeast fermentations in grape juice. **Vitamins** Yeasts do need a number of vitamins to be able to produce a healthy fermentation. These include biotin, folic acid, inositol, niacin, pantothenate, pyridoxine, riboflavin and thiamin. Raw material is not usually deficient in vitamins unless the vitamin content is depleted by winemaking practices such as cold settling, filtration, fining, pasteurisation, ion exchange, sulfiting and uncontrolled growth of other organisms such as non-Saccharomyces yeasts and lactic acid bacteria during fermentation. **Nitrogen compounds** Nitrogen compounds are the second most important macronutrients for yeast, after sugars. Nitrogen is a limiting factor in most juice fermentations and normally needs to be supplemented if a clean and uninterrupted fermentation is desired. A deficiency of nitrogen can lead to slow or stuck fermentations. Fermentation rate and total fermentation time are related to initial must nitrogen	4	

	content. The strain of yeast used and the fermentation conditions determine the nitrogen content needed. **Nitrogen Supplements** As previously mentioned, DAP is a commonly used nitrogen supplement as it is a cheap nitrogen source. It does, however, only provide a source of ammonium ions and not any amino acids or other nutrients apart from the phosphate ion. The supplements used for amino acids are products derived from yeast. These yeast products are known by several names such as hydrolysed yeast, autolysed yeast or yeast extract. The products can be composed of the entire yeast at the time of drying the yeast cells, or sometimes only the soluble part. They can contain proteins, amino acids, carbohydrates lipids, vitamins and minerals. It is hard to be specific on composition because the production methods vary and so the product compositions can be quite different.		
6.b	**Manufacturing of brandy:** The name brandy comes from the Dutch word *brandewijn*, meaning "burnt wine." The name is apt as most brandies are made by applying heat, originally from open flames, to wine. The heat drives out and concentrates the alcohol naturally present in the wine. Because alcohol has a lower boiling point (172°F, 78°C) than water (212'F, 100°C), it can be boiled off while the water portion of the wine remains in the still. Heating a liquid to separate components with different boiling points is called heat distillation. While brandies are usually made from wine or other fermented fruit juices, it can be distilled from any liquid that contains sugar. All that is required is that the liquid be allowed to ferment and that the resulting mildly-alcoholic product not be heated past the boiling point of water. The low-boiling point liquids distilled from wine include almost all of the alcohol, a small amount of water, and many of the wine's	5	8

organic chemicals. It is these chemicals that give brandy its taste and aroma.

Brandies are easy to manufacture. A fermented liquid is boiled at a temperature between the boiling point of ethyl alcohol and the boiling point of water. The resulting vapors are collected and cooled. The cooled vapors contain most of the alcohol from the original liquid along with some of its water. To drive out more of the water, always saving the alcohol, the distillation process can be repeated several times depending on the alcohol content desired. This process is used to produce both fine and mass-produced brandy, though the final products are dramatically different.

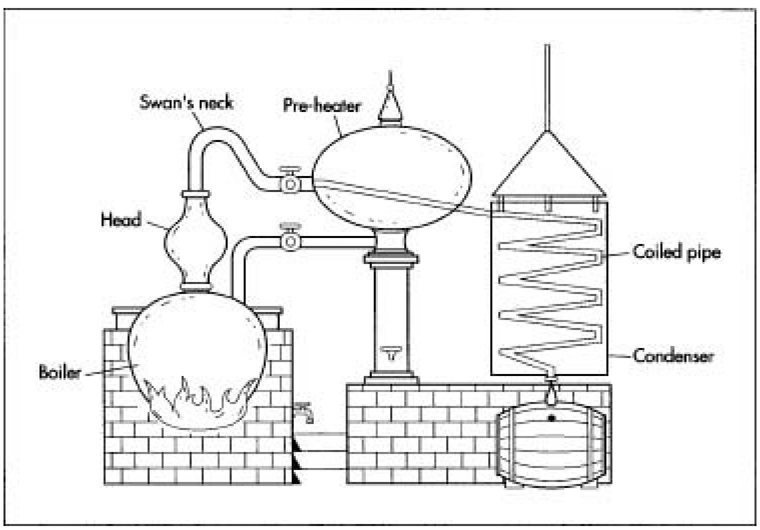
Raw Materials

The raw materials used in brandy production are liquids that contain any form of sugar. French brandies are made from the wine of the St. Émillion, Colombard (or Folle Blanche) grapes. However, anything that will ferment can be distilled and turned into a brandy. Grapes, apples, blackberries, sugar cane, honey, milk, rice, wheat, corn, potatoes, and rye are all commonly fermented and distilled. In a time of shortage, desperate people will substitute anything to have access to alcohol. During World War II, people in London made wine out of cabbage leaves and carrot peels, which they subsequently distilled to produce what must have been a truly vile form of brandy.

1. Mass-produced brandy, other than having the same alcohol content, has very little in common with fine brandy. Both start with wine, though the mass-produced brandies are likely to be made from table grape varieties like the Thompson Seedless rather than from fine wine grapes. Instead of the painstaking double distillation in small batches, mass-produced brandies are made via fractional distillation in column stills. Column stills are sometimes called continuous stills as raw material is

continuously poured into the top while the final product and wastes continuously come out of the side and bottom.

2. A column still is about 30-ft (9-m) high and contains a series of horizontal, hollow baffles that are interconnected. Hot wine is poured into the top of the column while steam is run through the hollow baffles; the steam and wine do not mix directly. The alcohol and other low boiling point liquids in the wine evaporate. The vapors rise while the non-alcoholic liquids fall. As the still is cooler at the top, the rising vapors eventually get to a part of the still where they will condense, each type of vapor at a temperature just above its own boiling point.



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3. Once they have recondensed, the liquids begin to move downward in the still. As they fall, they boil again. This process of boiling and condensing, rising and falling, happens over and over again in the column. The various components of the wine fraction and collect in the column where the temperature is just below the boiling point of that component. This allows the ethyl alcohol condensate to be bled out of

	the column at the height where it collects. The resulting product is a pure spirit, colorless, odorless, and tasteless, with an alcohol content of about 96.5%. At 96.5% alcohol, it can be used to fuel automobiles. It can be diluted and called vodka or diluted and flavored with juniper berries and called gin. 4. Mass-produced brandies are also aged in oak casks and pick up some flavors from them. Like its fine counterpart, the brandies are blended, diluted to around 40% alcohol, and bottled.		
6.c	**i) *Primary treatment*** involves separating a portion of the suspended solids from the wastewater. Screening and sedimentation usually accomplish this separation process. The effluent from primary treatment will ordinarily contain considerable organic material and will have a relatively high BOD. Primary treatment is required to recover chemicals from spent wash. It consists of neutralization, filtration, evaporation and incineration. Aim of primary treatment is to remove compounds present in the waste water by physical means. Chemical or biological methods are not used for this purpose. The objective of primary treatment is the removal of settleable organic and inorganic solids by sedimentation, and the removal of materials that will float (scum) by skimming. Approximately 25 to 50% of the incoming biochemical oxygen demand (BOD_5), 50 to 70% of the total suspended solids (SS), and 65% of the oil and grease are removed during primary treatment. Some organic nitrogen, organic phosphorus, and heavy metals associated with solids are also removed during primary sedimentation but colloidal and dissolved constituents are not affected. The effluent from primary sedimentation units is referred to as primary effluent. However, to prevent potential nuisance conditions in storage or flow-equalizing reservoirs, some form of secondary treatment is normally required in	6	8

	these countries, even in the case of non-food crop irrigation. It may be possible to use at least a portion of primary effluent for irrigation if off-line storage is provided. Primary sedimentation tanks or clarifiers may be round or rectangular basins, typically 3 to 5 m deep, with hydraulic retention time between 2 and 3 hours. Settled solids (primary sludge) are normally removed from the bottom of tanks by sludge rakes that scrape the sludge to a central well from which it is pumped to sludge processing units. Scum is swept across the tank surface by water jets or mechanical means from which it is also pumped to sludge processing units. Primary sludge is most commonly processed biologically by anaerobic digestion. In the digestion process, anaerobic and facultative bacteria metabolize the organic material in sludge (see Example 3), thereby reducing the volume requiring ultimate disposal, making the sludge stable (nonputrescible) and improving its dewatering characteristics. Digestion is carried out in covered tanks (anaerobic digesters), typically 7 to 14 m deep. The residence time in a digester may vary from a minimum of about 10 days for high-rate digesters (well-mixed and heated) to 60 days or more in standard-rate digesters. Gas containing about 60 to 65% methane is produced during digestion and can be recovered as an energy source. In small sewage treatment plants, sludge is processed in a variety of ways including: aerobic digestion, storage in sludge lagoons, direct application to sludge drying beds, in-process storage (as in stabilization ponds), and land application. **ii) List of secondary treatment methods** 1. Anaerobic digestion using anaerobic reactor 2. Activated sludge method 3. Biological evaporation by composting 4. Generation of methane using digestion 5. Incineration for recovery of potash from spent wash	2	
