9.13.4 Yeast Production

9.13.4.1 General[1]

Baker's yeast is currently manufactured in the United States at 13 plants owned by 6 major companies. Two main types of baker's yeast are produced, compressed (cream) yeast and dry yeast. The total U. S. production of baker's yeast in 1989 was 223,500 megagrams (Mg) (245,000 tons). Of the total production, approximately 85 percent of the yeast is compressed (cream) yeast, and the remaining 15 percent is dry yeast. Compressed yeast is sold mainly to wholesale bakeries, and dry yeast is sold mainly to consumers for home baking needs. Compressed and dry yeasts are produced in a similar manner, but dry yeasts are developed from a different yeast strain and are dried after processing. Two types of dry yeast are produced, active dry yeast (ADY) and instant dry yeast (IDY). Instant dry yeast is produced from a faster-reacting yeast strain than that used for ADY. The main difference between ADY and IDY is that ADY has to be dissolved in warm water before usage, but IDY does not.

9.13.4.2 Process Description[1]

Figure 9.13.4-1 is a process flow diagram for the production of baker's yeast. The first stage of yeast production consists of growing the yeast from the pure yeast culture in a series of fermentation vessels. The yeast is recovered from the final fermentor by using centrifugal action to concentrate the yeast solids. The yeast solids are subsequently filtered by a filter press or a rotary vacuum filter to concentrate the yeast further. Next, the yeast filter cake is blended in mixers with small amounts of water, emulsifiers, and cutting oils. After this, the mixed press cake is extruded and cut. The yeast cakes are then either wrapped for shipment or dried to form dry yeast.

Raw Materials[1-3] -

The principal raw materials used in producing baker's yeast are the pure yeast culture and molasses. The yeast strain used in producing compressed yeast is *Saccharomyces cerevisiae*. Other yeast strains are required to produce each of the 2 dry yeast products, ADY and IDY. Cane molasses and beet molasses are the principal carbon sources to promote yeast growth. Molasses contains 45 to 55 weight percent fermentable sugars, in the forms of sucrose, glucose, and fructose.

The amount and type of cane and beet molasses used depend on the availability of the molasses types, costs, and the presence of inhibitors and toxins. Usually, a blend consisting of both cane and beet molasses is used in the fermentations. Once the molasses mixture is blended, the pH is adjusted to between 4.5 and 5.0 because an alkaline mixture promotes bacteria growth. Bacteria growth occurs under the same conditions as yeast growth, making pH monitoring very important. The molasses mixture is clarified to remove any sludge and is then sterilized with high-pressure steam. After sterilization, it is diluted with water and held in holding tanks until it is needed for the fermentation process.

A variety of essential nutrients and vitamins is also required in yeast production. The nutrient and mineral requirements include nitrogen, potassium, phosphate, magnesium, and calcium, with traces of iron, zinc, copper, manganese, and molybdenum. Normally, nitrogen is supplied by adding ammonium salts, aqueous ammonia, or anhydrous ammonia to the feedstock. Phosphates and magnesium are added, in the form of phosphoric acid or phosphate salts and magnesium salts. Vitamins are also required for yeast growth (biotin, inositol, pantothenic acid, and thiamine).

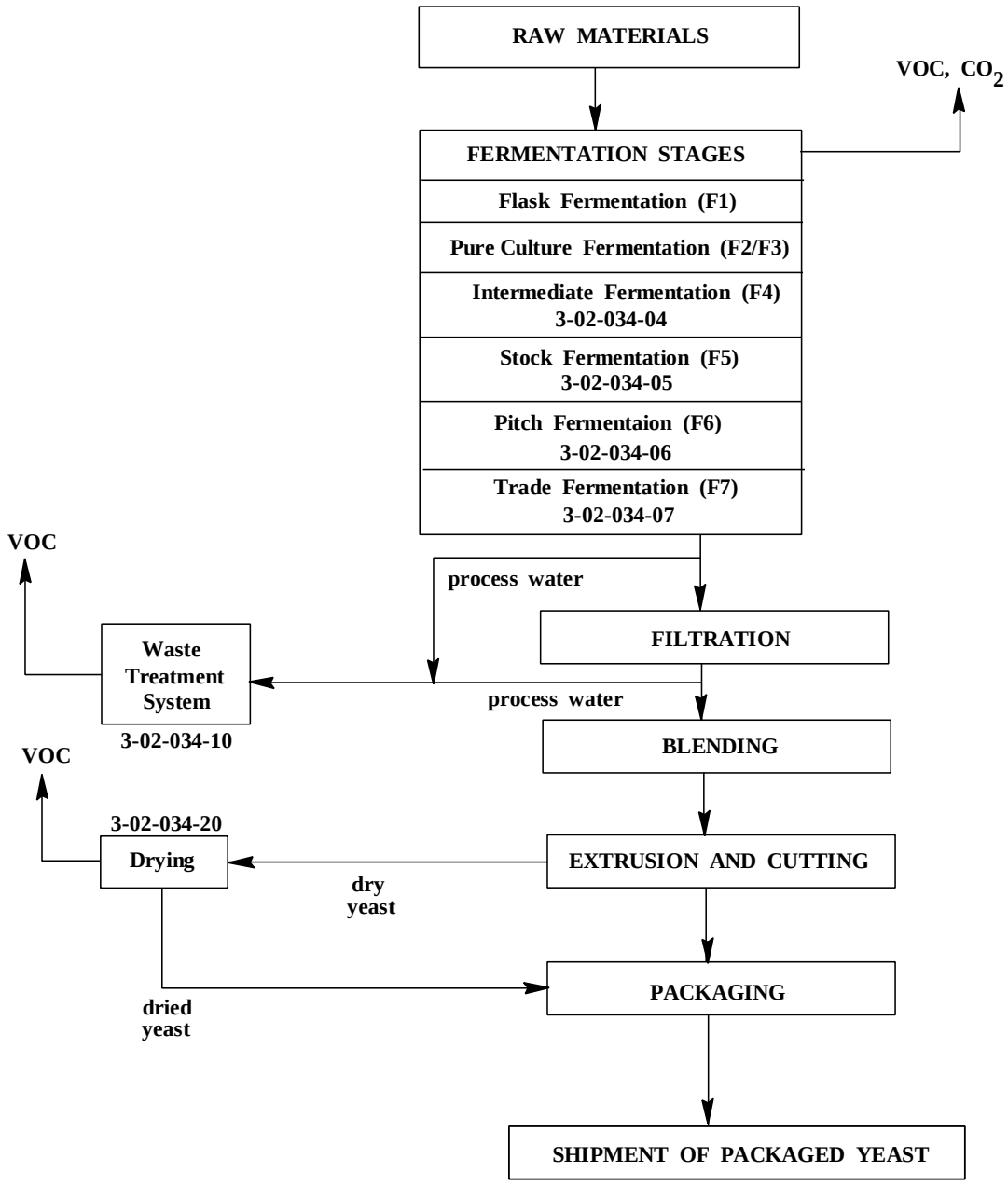

Figure 9.13.4-1. Typical process flow diagram for the seven-stage production of baker's yeast, with Source Classification Codes shown for compressed yeast. Use 3-02-035-XX for compressed yeast.

Thiamine is added to the feedstock. Most other vitamins and nutrients are already present in sufficient amounts in the molasses malt.

Fermentation[1-3] -

Yeast cells are grown in a series of fermentation vessels. Yeast fermentation vessels are operated under aerobic conditions (free oxygen or excess air present) because under anaerobic conditions (limited or no oxygen) the fermentable sugars are consumed in the formation of ethanol and carbon dioxide, which results in low yield.

The initial stage of yeast growth takes place in the laboratory. A portion of the pure yeast culture is mixed with molasses malt in a sterilized flask, and the yeast is allowed to grow for 2 to 4 days. The entire contents of this flask are used to inoculate the first fermentor in the pure culture stage. Pure culture fermentations are batch fermentations, where the yeast is allowed to grow for 13 to 24 hours. Typically, 1 to 2 fermentors are used in this stage of the process. The pure culture fermentations are basically a continuation of the flask fermentation, except that they have provisions for sterile aeration and aseptic transfer to the next stage.

Following the pure culture fermentations, the yeast mixture is transferred to an intermediate fermentor that is either batch or fed-batch. The next fermentation stage is a stock fermentation. The contents from the intermediate fermentor are pumped into the stock fermentor, which is equipped for incremental feeding with good aeration. This stage is called stock fermentation, because after fermentation is complete, the yeast is separated from the bulk of the fermentor liquid by centrifuging, which produces a stock, or pitch, of yeast for the next stage. The next stage, pitch fermentation, also produces a stock, or pitch, of yeast. Aeration is vigorous, and molasses and other nutrients are fed incrementally. The liquor from this fermentor is usually divided into several parts for pitching the final trade fermentations (adding the yeast to start fermentation). Alternately, the yeast may be separated by centrifuging and stored for several days before its use in the final trade fermentations.

The final trade fermentation has the highest degree of aeration, and molasses and other nutrients are fed incrementally. Large air supplies are required during the final trade fermentations, so these vessels are often started in a staggered fashion to reduce the size of the air compressors. The duration of the final fermentation stages ranges from 11 to 15 hours. After all of the required molasses has been fed into the fermentor, the liquid is aerated for an additional 0.5 to 1.5 hours to permit further maturing of the yeast, making it more stable for refrigerated storage.

The amount of yeast growth in the main fermentation stages described above increases with each stage. Yeast growth is typically 120 kilograms (270 pounds) in the intermediate fermentor, 420 kilograms (930 pounds) in the stock fermentor, 2,500 kilograms (5,500 pounds) in the pitch fermentor, and 15,000 to 100,000 kilograms (33,000 to 220,000 pounds) in the trade fermentor.

The sequence of the main fermentation stages varies among manufacturers. About half of existing yeast operations are 2-stage processes, and the remaining are 4-stage processes. When the 2-stage final fermentation series is used, the only fermentations following the pure culture stage are the stock and trade fermentations. When the 4-stage fermentation series is used, the pure culture stage is followed by intermediate, stock, pitch, and trade fermentations.

Harvesting And Packaging[1-2] -

Once an optimum quantity of yeast has been grown, the yeast cells are recovered from the final trade fermentor by centrifugal yeast separators. The centrifuged yeast solids are further concentrated by a filter press or rotary vacuum filter. A filter press forms a filter cake containing 27 to 32 percent solids. A rotary vacuum filter forms cakes containing approximately 33 percent solids. This filter cake is then blended in mixers with small amounts of water, emulsifiers, and cutting oils to form the end product. The final packaging steps, as described below, vary depending on the type of yeast product.

In compressed yeast production (SCC 3-02-035-XX), emulsifiers are added to give the yeast a white, creamy appearance and to inhibit water spotting of the yeast cakes. A small amount of oil, usually soybean or cottonseed oil, is added to help extrude the yeast through nozzles to form continuous ribbons of yeast cake. The ribbons are cut, and the yeast cakes are wrapped and cooled to below 8°C (46°F), at which time they are ready for shipment in refrigerated trucks.

In dry yeast production (SCC 3-02-034-XX), the product is sent to an extruder after filtration, where emulsifiers and oils (different from those used for compressed yeast) are added to texturize the yeast and to aid in extruding it. After the yeast is extruded in thin ribbons, it is cut and dried in either a batch or a continuous drying system. Following drying, the yeast is vacuum packed or packed under nitrogen gas before heat sealing. The shelf life of ADY and IDY at ambient temperature is 1 to 2 years.

9.13.4.3 Emissions[1,4-5]

Volatile organic compound (VOC) emissions are generated as byproducts of the fermentation process. The 2 major VOCs emitted are ethanol and acetaldehyde. Other byproducts consist of other alcohols, such as butanol, isopropyl alcohol, 2,3-butanediol, organic acids, and acetates. Based on emission test data, approximately 80 to 90 percent of total VOC emissions is ethanol, and the remaining 10 to 20 percent consists of other alcohols and acetaldehyde. Acetaldehyde is a hazardous air pollutant as defined under Section 112 of the *Clean Air Act*.

Volatile byproducts form as a result of either excess sugar (molasses) present in the fermentor or an insufficient oxygen supply to it. Under these conditions, anaerobic fermentation occurs, breaking down the excess sugar into alcohols and carbon dioxide. When anaerobic fermentation occurs, 2 moles of ethanol and 2 moles of carbon dioxide are formed from 1 mole of glucose. Under anaerobic conditions, the ethanol yield is increased, and yeast yields are decreased. Therefore, in producing baker's yeast, it is essential to suppress ethanol formation in the final fermentation stages by incremental feeding of the molasses mixture with sufficient oxygen to the fermentor.

The rate of ethanol formation is higher in the earlier stages (pure culture stages) than in the final stages of the fermentation process. The earlier fermentation stages are batch fermentors, where excess sugars are present and less aeration is used during the fermentation process. These fermentations are not controlled to the degree that the final fermentations are controlled because the majority of yeast growth occurs in the final fermentation stages. Therefore, there is no economical reason for manufacturers to equip the earlier fermentation stages with process control equipment.

Another potential emission source at yeast manufacturing facilities is the system used to treat process waste waters. If the facility does not use an anaerobic biological treatment system, significant quantities of VOCs could be emitted from this stage of the process. For more information on waste water treatment systems as an emission source of VOCs, please refer to EPA's Control Technology Center document on industrial waste water treatment systems, *Industrial Wastewater Volatile Organic Compound Emissions - Background Information For BACT/LAER*, or see Section 4.3 of AP-42. At facilities manufacturing dry yeast, VOCs may also be emitted from the yeast dryers, but no information is available on the relative quantity of VOC emissions from this source.

9.13.4.4 Controls[6]

Only 1 yeast manufacturing facility uses an add-on pollution control system to reduce VOC emissions from the fermentation process. However, all yeast manufacturers suppress ethanol formation through varying degrees of process control, such as incrementally feeding the molasses mixture to the fermentors so that excess sugars are not present, or supplying sufficient oxygen to the fermentors to optimize the dissolved oxygen content of the liquid in the fermentor. The adequacy of oxygen distribution depends upon the proper design and operation of the aeration and mechanical agitation systems of the fermentor. The distribution of oxygen by the air sparger system to the malt mixture is critical. If oxygen is not being transferred uniformly throughout the malt, then ethanol will be

produced in the oxygen-deficient areas of the fermentor. The type and position of baffles and/or a highly effective mechanical agitation system can ensure proper distribution of oxygen.

A more sophisticated form of process control involves using a continuous monitoring system and feedback control. In such a system, process parameters are monitored, and the information is sent to a computer. The computer is then used to calculate sugar consumption rates through material balance techniques. Based on the calculated data, the computer continuously controls the addition of molasses. This type of system is feasible, but it is difficult to design and implement. Such enhanced process control measures can suppress ethanol formation from 75 to 95 percent.

The 1 facility with add-on control uses a wet scrubber followed by a biological filter. Performance data from this unit suggest an emission control efficiency of better than 90 percent.

9.13.4.5 Emission Factors[1,6-9]

Table 9.13.4-1 provides emission factors for a typical yeast fermentation process with a moderate degree of process control. The process emission factors in Table 9.13.4-1 were developed from 4 test reports from 3 yeast manufacturing facilities. Separate emission factors are given for intermediate, stock/pitch, and trade fermentations. The emission factors in Table 9.13.4-1 are expressed in units of VOC emitted per fermentor per unit of yeast produced in that fermentor.

In order to use the emission factors for each fermentor, the amount of yeast produced in each fermentor must be known. The following is an example calculation for a typical facility:

Fermentation Stage	Yeast Yield Per Batch, lb (A)	No. Of Batches Processed Per Year, #/yr (B)	Total Yeast Production Per Stage, tons/yr (C = A x B/2,000)	Emission Factor, lb/ton (D)	Emissions, lb (E = C x D)	Percent of Total Emissions
Intermediate	265	156	21	36	756	0.84
Stock	930	208	97	5	485	0.54
Pitch	5,510	208	573	5	2,865	3.18
Trade	33,070	1,040	17,196	5	85,980	95.44
TOTAL	—	—	—	—	90,086	100

In most cases, the annual yeast production per stage will not be available. However, a reasonable estimate can be determined based on the emission factor for the trade fermentor and the total yeast production for the facility. Trade fermentors produce the majority of all VOCs emitted from the facility because of the number of batches processed per year and of the amount of yeast grown in these fermentors. Based on emission test data and process data regarding the number of batches processed per year, 80 to 90 percent of VOCs emitted from fermentation operations are a result of the trade fermentors.

Using either a 2-stage or 4-stage fermentation process has no significant effect on the overall emissions for the facility. Facilities that use the 2-stage process may have larger fermentors or may produce more batches per year than facilities that use a 4-stage process. The main factors affecting emissions are the total yeast production for a facility and the degree of process control used.

Table 9.13.4-1 (Metric And English Units). VOLATILE ORGANIC COMPOUND (VOC) EMISSION FACTORS FOR YEAST MANUFACTURING[a]

EMISSION FACTOR RATING: E

Emission Point[b]	VOC[c]	
	VOC Emitted Per Stage Per Amount Of Yeast Produced In A Stage, kg VOC/Mg Yeast	VOC Emitted Per Stage Per Amount Of Yeast Produced In A Stage, lb VOC/ton Yeast
Fermentation stages[d]		
Flask (F1)	ND	ND
Pure culture (F2/F3)	ND	ND
Intermediate (F4) (SCC 3-02-034-04)	18	36
Stock (F5) (SCC 3-02-034-05)	2.5	5.0
Pitch (F6) (SCC 3-02-034-06)	2.5	5.0
Trade (F7) (SCC 3-02-034-07)	2.5	5.0
Waste treatment (SCC 3-02-034-10)	See Section 4.3 of AP-42	
Drying (SCC 3-02-034-20)	ND	ND

[a] References 1,6-10. Total VOC as ethanol. SCC = Source Classification Code. ND = no data. F numbers refer to fermentation stages (see Figure 9.13.4-1).

[b] Factors are for both dry yeast (SCC 3-02-034-XX) and compressed yeast (SCC 3-02-035-XX).

[c] Factors should be used only when plant-specific emission data are not available because of the high degree of emissions variability among facilities and among batches within a facility.

[d] Some yeast manufacturing facilities use a 2-stage final fermentation process, and others use a 4-stage final fermentation process. Factors for each stage cannot be summed to determine an overall emission factor for a facility, since they are based on yeast yields in each fermentor rather than total yeast production. Total yeast production for a facility equals only the yeast yield from the trade fermentations. Note that CO_2 is also a byproduct of fermentation, but no data are available on the amount emitted.

References For Section 9.13.4

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