0273-2289/94/4546—0181$03.00

Effect of Pretreatment of Molasses and Posttreatment of Fermented Broth in Industrial Production of Ethanol

Scientific Note

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Index Entries: Molasses; preclarification; postclarification; fermentation; yeast separation.

INTRODUCTION

Sugarcane molasses is widely used to produce ethanol in India. The method of fermentation used is either conventional batch type or continuous type. Sugarcane molasses has suspended, inorganic solid matter like calcium and magnesium salts. This suspended matter can interfere with the process of separation of yeast by centrifugal separators. It also causes severe fouling in distillation columns. Average composition of sugarcane molasses used is presented in Table 1.

Preclarification of molasses is being practiced in a few plants to remove part of the suspended solids prior to fermentation. This has been practiced more frequently in plants that employ separation of yeast after fermentation, to prevent the sludge from getting into the yeast cream and to prevent blocking of nozzles of the separator.

Postclarification of fermented broth has been recently introduced in India and is being practiced in plants over last 5 years. This is being done mainly to minimize the suspended solids going to the distillation columns.

The present article discusses methods of preclarification and postclarification. Data from operating plants is presented. Results are discussed based on requirements envisaged.

Table 1
Average Composition of Sugarcane Molasses
(on Wet Basis)

Fermentable sugars, % w/w	35–50
Unfermentable sugars, % w/w	3–7
Inorganic matter, % w/w	12–18
Other organic matter, % w/w	12–25
Water, % w/w	18–30

DESCRIPTION OF CLARIFICATION TECHNIQUES

Preclarification of Molasses

This is carried out on plant-scale with the following steps (*see* Fig. 1):

1. Dilution of molasses: Sugarcane molasses is diluted in a static mixer using recycled, hot, acidic wash-water from the last stage. Usually, molasses is diluted to about 400 Brix (Sp Gr 1.17). pH is about 4.2.
2. Heating of molasses: Diluted molasses is at around 60°C. This is heated further to about 85–90°C by injecting steam into it in a tank.
3. Settling: This hot, diluted molasses is continuously fed to gravity settling tank with conical bottom. This tank has volume with residence time of 6 h. The sludge, which has precipitated out, settles to the bottom of the tank and is drawn continuously. Flow-rate of sludge is controlled manually based on its solids concentration. This content is usually analyzed on plant-scale by determining centrifuge value (which is fraction of the total volume which settles down in the test tube as clearly demarcated sludge layer) of the stream by spinning at 3000 rpm for 5 min in a laboratory centrifuge. The flow-rate of sludge stream is so controlled as to get a centrifuge volume of 0.3 for this stream. Overflow of clarified, diluted molasses is taken to an intermediate tank.
4. Cooling diluted molasses: The clarified, diluted molasses from the intermediate tank is pumped through plate heat exchanger to cool it to the fermentation temperature. It is then fed to fermentation through flowmeter. A standby plate heat exchanger is usually installed to facilitate cleaning of the other unit without interrupting the operation.

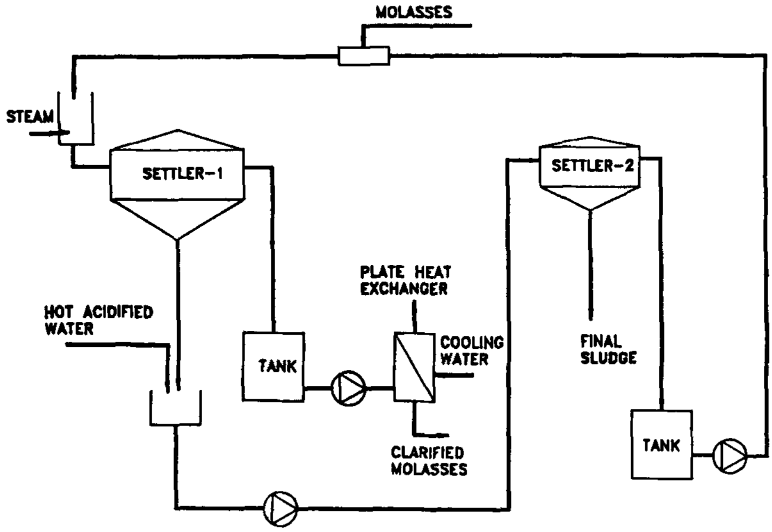

Fig. 1. Preclarification of molasses.

5. Washing of sludge: The sludge stream drawn from the broth settling tank (I settler) is diluted with hot water (85 to 90°C), which is acidified using sulfuric acid. The pH of the resultant diluted sludge solution is between 2.0 and 2.5. All the water required for dilution of molasses is added here in the sludge—trough where mixing takes place. Usually, quantity of water used here is 115% of molasses used (on weight basis).

   The sludge solution is sent continuously to a gravity settling tank (II settler) with conical bottom. It has a residence time of 1.5 h. Final sludge is continuously drawn from the bottom of the tank. Flow rate of final sludge is controlled manually based on analysis of solids concentration. This is done on plant-scale by finding out centrifuge value (as described earlier) of the sludge stream. The flow-rate is so controlled as to get centrifuge value of 0.3.

   Overflow of clarified wash-water from the II settler is continuously taken into an intermediate tank, from where it is pumped to the static mixer for dilution of molasses.

Postclarification of Fermented Broth

This is carried out on plant-scale with following steps (*see* Fig. 2):

1. Settling of fermented broth: Molasses broth is fermented using yeast in usual manner. The broth is ready when fermentation is over with achievement of desired ethanol concentration.

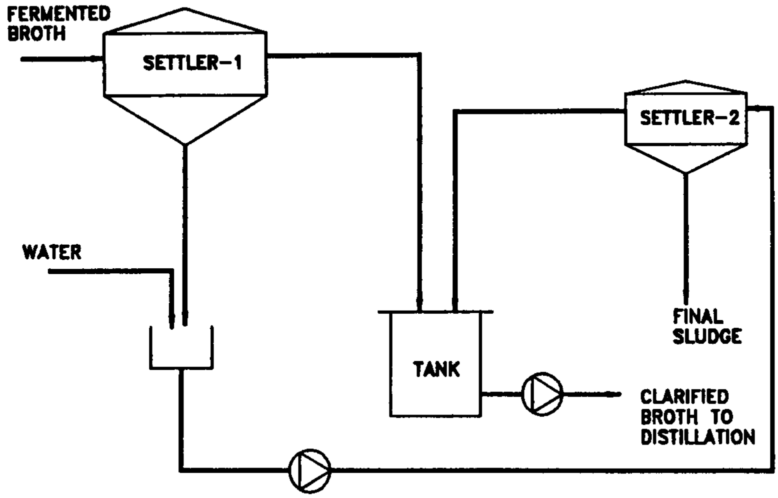

Fig. 2. Postclarification of fermented broth.

The broth is then sent to a gravity settling tank with conical bottom (I Settler). This has tank volume suitable for 5 h of residence time. Part of the suspended solids in the broth settle down and sludge stream is drawn continuously from the bottom of the tank. Flow-rate of sludge stream is decided based on solids concentration. This is determined by its centrifuge value (as defined earlier). The flow-rate is so controlled as to get centrifuge value of 0.3.

Clarified broth overflows to an intermediate tank, from where it is pumped to the distillation plant.

2. Washing of sludge: The sludge stream drawn from the I settler is mixed with water in the sludge-trough. The flow-rate of sludge-stream is usually 2.5–3.0% that of broth flow-rate. The sludge solution is continuously fed into the next gravity settling tank (II settler) with conical bottom. This tank has a residence time of 15 h. Final sludge is drawn continuously from the bottom of the tank with manual control. Overflow of wash-water is sent to the intermediate tank of clarified broth.

RESULTS

Both preclarification of molasses and postclarification of broth are being practiced on plant-scale. Table 2 shows data from a preclarification plant. Settleable sludge in molasses is determined by making an acidified, diluted, hot solution of molasses similar to the one in plant and settling it in a cylinder over a period of 6 h while it is maintained hot at 80°C in a

Table 2
Plant Data for Preclarification of Molasses

Settleable sludge in molasses, % w/w dry matter solids	1.27
Final sludge discharge, % w/w (on the basis of molasses), dry matter solids	0.90
Settling efficiency, %	71
Loss of sugars, % (on the basis of original content)	0.4

Table 3
Plant Data for Postclarification of Broth

Settleable sludge in broth, % w/w dry matter solids	2.3
Final sludge discharge, % w/w (on the basis of broth), dry matter solids	2.1
Settling efficiency, %	91
Loss of ethanol, % (on the basis of original content)	0.4

water bath. The sludge is then collected by decanting the supernatant. The sludge is washed, dried, and weighed. Sludge content of sludge-stream and clarified molasses is determined in the same manner in the laboratory. Loss of sugars is determined by measuring the outflow of sludge stream and the concentration of sugars therein. This is viewed as proportion of sugars coming in with the feed-molasses.

Settling efficiency is defined as amount of setteable solids removed during the treatment as percentage of amount of settleable solids in the feed.

Table 3 shows data from a postclarification plant. Settleable sludge in broth is determined by settling the broth in a cylinder over a period of 5 h. The sludge is then separated by decanting the supernatant. The sludge is washed, dried, and weighed. In the plant, sludge overflow is measured using a metal-tube rotameter and ethanol concentration is measured by drawing a sample and analyzing in an ebulliometer. Loss of ethanol is measured by measuring the sludge outflow and ethanol concentration therein. This is viewed as proportion of ethanol in the feed broth.

Table 4
Comparison of Preclarification and Postclarification

Settling efficiency for suspended, settleable solids, %	71	91
Sludge discharge/1000 kg of molasses used, kg	09	60
Losses, %	0.4	0.4
Requirement of steam on the basis of molasses used, kg/1000 kg	200	0
Equipment	SS 304 Insulated	CS/Epoxy Coated

DESCRIPTION

Table 4 compares results of preclarification plant and postclarification plant. The preclarification process comprises more number of steps as compared to postclarification. Equipment required for preclarification is more elaborate. This has to be in stainless steel and with insulation. On the other hand, equipment for postclarification is in carbon steel with epoxy coating inside.

The settling efficiency of postclarification is higher at 91% than preclarification at 71%. This is mainly owing to lower viscosity of broth as compared to diluted molasses. Moreover, amount of sludge discharged (per unit of molasses used) is much higher at six to seven times in postclarification than in preclarification. This is attributed to precipitation of calcium and magnesium salts with presence of ethanol (after its formation during fermentation). Only inorganic, suspended, settleable solids are separated in such a clarification process. Yeast remains in suspension and does not settle owing to its low specific gravity and small particle size. Yeast gets carried over to distillation. However, yeast does not pose threat of scaling/fouling the distillation column. Thus, amount of sludge going to distillation will be much lower in case of postclarification.

Postclarification requires no steam for operation as against preclarification. Postclarification does not have the step of cooling. On the other hand, preclarification requires frequent cleaning of heat-exchangers.

CONCLUSION

The aim of preclarification is to minimize sludge going to yeast separators. This purpose is partially fulfilled. However, it has been measured during the plant trial runs that preclarification does not noticeably improve fermentation.

The aim of postclarification is to minimize sludge going to distillation. This purpose is well served as noted from the fact that cycle run of distillation columns using postclarification is three times longer (9–12 mo) as compared to the normal one (3–4 mo).

REFERENCES

All the data is collected from production runs of operating plant of MSSK, Pune, India in 1992.