LARGE-SCALE PRODUCTION OF YEAST IN WHEY

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Cheese whey can cause a water pollution problem if disposed of as a dairy waste. The whey may be utilized, however, as a base for a medium on which yeast will grow. The yeast, containing about 50 per cent protein, vitamins, and other nutritional factors, may be used in the manufacture of animal feeds. The market for a yeast product can be expanded through increased uses of dried yeast in human diets. Previous methods for growing yeast on whey have proved economically unfeasible. A more efficient process for the production of maximum yields of yeast has been described (1). A four-hour yeast growth cycle was developed for batch operations by providing optimum conditions of available oxygen, pH, temperature, inoculum, and medium supplements. Unpasteurized whey can also be used in the medium, which effects a reduction in the cost of producing the yeast.

Preliminary studies were successfully carried out in 500 ml and 15 l propagators in the laboratory. The economic practicality of the yeast production process can be evaluated only by growing the yeast on a large-scale operation. This paper presents the results of propagating yeast in 750-gal volumes and gives an estimate of the cost of operating a yeast plant producing 2.5 tons dried yeast per day.

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Materials and Methods

Propagation Conditions

The conditions for the growth of the yeast, *Saccharomyces fragilis,* are based on those previously described for the laboratory propagators (1) (2). Six hundred gallons of Italian cheese whey, supplemented with 28 lb each of commercial grade ammonium sulfate, monobasic potassium phosphate, and dried brewers yeast, were placed in the propagation tank. The pH of this mixture ranges from 5.5 to 5.7 without further adjustment which is the optimum range for yeast growth. The whey medium was inoculated with 150 gal of yeast cream containing 110 lb yeast on a dry weight basis. The yeast in the inoculum was approximately 20 hr old, having been collected from a propagation on the previous day. It is also possible to build up the required inoculum from a smaller quantity of yeast using less medium and increasing the volume as yeast growth occurs. This method requires more time and it is more convenient when batches of yeast are in continuous operation.

The propagation was carried out at 94°F plus or minus 1° which was maintained by circulating cold water through cooling coils in the tank. Good growth of the yeast can be obtained at temperatures as high as 105°F but this procedure is not recommended because a growth of a rod-shaped bacterium contaminated the yeast.

Oxygen Requirements

The oxygen requirements for the growth of *Saccharomyces fragilis* have been described in previous studies (2)

(3). The oxygen is used to oxidize approximately 35 per cent of the carbon in lactose to CO_2 and water, and provide the energy for the assimilation of the remaining 65 per cent of the sugar. Additional oxygen is needed for the oxidation of the other organic components in the whey and for the endogenous metabolism of the yeast. Thus, the yeast growing in the 750 gal of suspension requires 90 lb of oxygen to oxidize the 240 lb of lactose and approximately 30 lb of oxygen for yeast metabolism and other oxidative purposes. The total oxygen, 0.5 lb of oxygen per lb of sugar, must be furnished during the four-hour propagation period. The addition of equal increments of 30 lb O_2 per hour will not necessarily supply the proper quantities of oxygen to the growing yeast. It has been shown (2) (3) that *S. fragilis* growing in whey medium under the described conditions requires increasing quantities of O_2 during the first 90 to 120 min of growth, reaches a peak rate of oxygen consumption and in the final stages of growth, requires O_2 at a decreasing rate. At the peak of the oxygen demand, the yeast uses the gas at the rate of approximately 5 millimoles/l/min (19 millimoles/gpm), and to supply this demand, oxygen must be dissolved at the rate of 1 lb/min. The equal oxygen increments of 30 lb/hr, or 0.5 lb/min will supply an excess of oxygen during portions of the yeast growth curve, but there will be a condition of limited anaerobiosis during the period of peak oxygen demand. Lowered yeast yields may result because of this period of insufficient available oxygen.

Apparatus

A steel storage tank 5 ft in diameter and 12 ft 8 in. in height was converted into a yeast propagator. The agitation unit, suspended from the top of the tank, extended to within 3 ft of the bottom. The agitator was a 6-vaned turbine, 23 in. in diam, powered by a 7½ hp motor. The turbine rotated at 300 rpm. In operation, the power supplied by the motor was inadequate, but a more powerful motor could not be used because of the difficulties that developed in confining the medium to the tank. Although the tank would contain 1,600 gal, only about 800 gal of medium could be used for the propagation of the yeast; the remaining 50 per cent of the tank capacity was required as head space for the increased volume of the medium emulsion created by the aeration and agitation.

Air was supplied to the medium by a turbo-compressor rated at 360 cfm at 5 psi. A sparger ring with jet orifices was positioned under the agitator turbine so the fine air streams would be dispersed still further by the shearing action of the agitator.

The temperature of the propagation mixture was controlled by passing cold water at 40°F through 118 ft of 1½ in. OD copper tubing arranged in a coil within the tank.

At the end of the four-hour propagation period, the yeast was concentrated to a slurry containing 15 to 18 per cent solids in a centrifuge-type separator. To remove extraneous soluble solids, the yeast cream may be washed by resuspension in an equal volume of water and centrifuged again in the separator. The yeast cream was fed to a double drum drier operated at 85 psi steam pressure, and rotating at 12 rpm; the dried yeast flakes were carried by worm conveyor to a hammer mill, then to a bagging apparatus.

Analytical Determinations

Yeast yields were determined as the weight of the yeast centrifuged from 5-ml samples of the propagation mixture and dried overnight at 220°F. The method of Stiles *et al.* (4) was used for the analysis of the lactose in the medium.

The oxygen absorption rate (OAR)

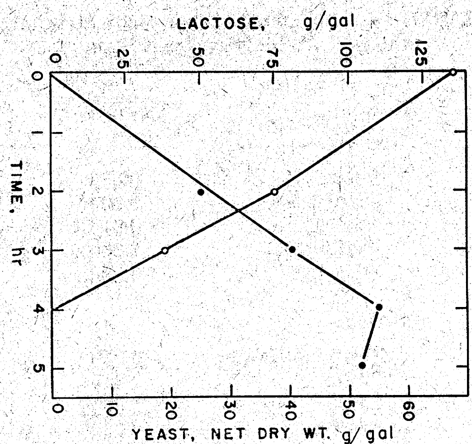

FIGURE 1.—Yeast propagation.

of the propagation apparatus was determined by a modification of the sulfite method of Cooper *et al.* (5).

Results

OAR of the Apparatus

Inasmuch as oxygen was shown to be the limiting factor in obtaining maximum yields of yeast in the laboratory, using the procedure described above, the agitation and aeration systems for the pilot plant tank were designed to dissolve the required amount of the gas. To test the operating efficiency of the equipment, 800 gal of 1N sodium sulfite solution were agitated in the propagator with the blades of the turbine set at 25 in. diam. Aeration was carried out at 360 cfm. The OAR under these conditions was 13 millimoles/gpm. Since the yeast requires 19 millimoles O_2/gpm at the peak demand, the apparatus was capable of dissolving only 68 per cent of the requisite amount of gas. To increase the quantity of dissolved gas, the tank was altered by the installation of four steel baffles, 90 in. long and 8 in. wide attached to the walls of the tank. In addition, the diam of the turbine blades was reduced to 23 in., increasing the peripheral speed of the blades and obtaining a greater shearing effect on the air bubbles. As a result of these changes, the OAR rose to 15 millimoles O_2/gpm, or 80 per cent of the O_2 requirements of the yeast. Although the rate of O_2 solution was still apparently low, further modification of the propagator was not possible and growth of the yeast was carried out with the knowledge that decreased yields might occur.

TABLE I.—Representative Growth of *Saccharomyces Fragilis* in Whey Medium

Item	Amount
Volume whey (gal)	600
Lactose (4.86% of whey) (lb)	242
Lactose used (lb)	242
Volume seed yeast (gal)	150
Wt. seed yeast (lb)	110
Total volume in tank (gal)	750
Gross dry yeast yield (lb)	215
Net dry yeast yield (lb)	105
Theoretical yeast yield (lb)	133
Theoretical yield (%)	79

TABLE II.—Estimated Capital Costs for 2.5-ton/day Yeast Plant

Equipment	Cost
Storage tanks	$ 6,000
Fermenters	15,000
Blower-compressor	3,500
Holding tanks	5,000
Yeast separators	10,000
Drum drier	25,000
Refrigerating plant	20,000
Grinder, bagger, etc.	6,500
Building	23,000
Laboratory	9,000
Piping and auxiliary features	36,000
Total plant cost	$159,000

Yeast Propagation

The results of a representative yeast propagation are shown in Figure 1 and Table I. The 242 lb of sugar present in the 600 gal of whey disappeared in 4 hr and the initial 110 lb of seed yeast increased to 215 lb. Incubation of the yeast beyond four hours did not result in any increase in the yeast weight. In fact, since the sugar had been utilized, further growth may occur at the expense of the yeast already formed and some decrease in weight could be anticipated. Approximately 55 per cent of the weight of the lactose is converted to new yeast material; therefore, the 242 lb of lactose should result in the formation of 133 lb of yeast matter. The 105 lb of yeast formed represents 80 per cent of the theoretical yield.

Economic Analysis

From the experiences of the pilot plant studies an estimate has been made of the cost of constructing and operating a plant growing yeast on whey. The calculations are based on a plant operating 200 days per year and producing 5,000 lb dried yeast/day. Estimated approximate equipment and installation costs are shown in Table II. These values may change with such factors as price variations, locality, and the availability of existing equipment. An estimate of $159,000 has been made for the purpose of further calculations. The estimated fixed capital costs are listed in Table III. These costs amount to 3.657 cents per pound of dried yeast produced.

TABLE III.—Annual Fixed Costs

Item	Cost
Depreciation (10%)	$15,900
Operational expense (5%)	7,950
Insurance, taxes, maintenance (8%)	12,720
Total	$36,570

Estimates of the operating costs in producing yeast from whey are shown in Table IV. The propagation medium components, acid, alkali, and defoamer that are used during yeast growth account for 1.755 cents of the cost of producing a pound of dried yeast. Steam and water, power, and labor (including the salary of a technically trained supervisor) cost 3.15 cents per pound of yeast. The drying operation, at 2.73 cents, increases the total cost of producing a pound of product to 7.715 cents. Total production costs, shown in Table V, are 11.292 cents per pound of yeast.

TABLE IV.—Estimated Labor and Material Costs of 2.5 ton/day Yeast Plant

Item	Cost (cents/lb dried yeast)
Material	
Aqua NH_3	0.038
Dried yeast	0.105
Na_3PO_4	0.012
$(NH_4)_2SO_4$	1.000
Defoamer	0.600
Services	
Steam and water	0.250
Power	1.340
Labor	1.560
Drying	2.730
Total	7.635

At the current market price of animal feed yeast, this process may provide a break-even method for disposing of whey without creating a pollution problem. This estimated cost of production can be reduced, in some cases, by crediting the cost of existing methods of whey disposal.

These figures were prepared for a yeast propagation plant operating in conjunction with a cheese manufacturing plant. No charge was made for the whey itself nor for its transportation. It may become necessary to obtain additional whey from other cheese producers and the purchase and transportation costs will increase the unit cost of the dried yeast. Under these conditions, a product suitable for human consumption can be obtained with only a little more expense in equipment and with a little more care in producing the yeast. The present market price for an edible yeast product makes the use of whey as a growth medium for yeast a profitable venture.

TABLE V.—Unit Costs of Producing a Pound of Yeast

Item	Cost (cents/lb dried yeast)
Operating cost	7.635
Fixed cost	3.657
Total	11.292

Summary

Saccharomyces fragilis, growing in a 750-gal volume of medium composed of Italian cheese whey plus growth supplements, can remove all available lactose from the medium and convert it into new yeast matter. The efficiency of the conversion of sugar to yeast is related to the supply of the proper amount of dissolved oxygen. An estimated economic analysis of the process of propagating yeast for food and feed purposes on cheese whey is presented.

References

1. Wasserman, A. E., Hopkins, W. J., and Porges, N., "Whey Utilization—Growth Conditions for *Saccharomyces fragilis*." *Sewage and Industrial Wastes*, **30**, 7, 913 (July 1958).
2. Wasserman, A. E., Hopkins, W. J., and Porges, N., "Rapid Conversion of Whey to Yeast." *Proc. 15th Intl. Dairy Congress*, **2**, 1241 (1959).
3. Wasserman, A. E., "Whey Utilization. II. Oxygen Requirements of *Saccharomyces fragilis* Growing in Whey Medium." *Applied Microbiol.*, **8**, 291 (1960).
4. Stiles, H. R., Peterson, W. H., and Fred, E. B., "A Rapid Method for the Determination of Sugar in Bacterial Cultures." *Jour. Bacteriol.*, **12**, 427 (1926).
5. Cooper, C. M., Fernstrom, G. A., and Miller, S. A., "Performance of Agitated Gas-Liquid Contactors." *Ind. Engr. Chem.*, **36**, 504 (1944).