

Experimentation and Modeling

Sir: The article on kinetics of yeast growth (*Chem. Eng. Education*, 6, 134-7 (1972)) should not go unchallenged, for the lesson it teaches is not what designers of the experiments have intended. Oxygen or some constituent other than sugar must have limited growth of the yeast, despite apparent agreement of the data with a simple model.

One can overlook the unexplained failure of Beer's Law to describe turbidity of a yeast suspension or what one hopes is a typographical confusion between corn sugar and cane sugar. (If the latter were indeed used, consistent results for sugar analysis would have been difficult even with a detailed recipe!) Of more consequence is a failure to recognize that the experiment is not at all "patterned after the commercial process for growing yeast," (which employs a low concentration of sugar so as to avoid catabolite repression of respiratory enzymes—the kinetic behavior can be complex).

Results of the published experiment showing departure from exponential growth after only five hours, when the sugar content was still 15 gm/liter, should have alerted the designers to some other rate-limiting constituent like oxygen. Having called attention to such possibilities in presenting theoretical background, the author neglected to perform even the simple test of trying oxygen-enriched air once the rate of growth declined. More elegant of course would have been to use a dissolved oxygen probe. The data suggest that after about five hours growth became linear, a very nice example of mass transfer limitation of a kinetic process.

The sought-for relationship between growth rate and sugar concentration cannot be found with any accuracy by taking slopes off an integral curve as proposed. The correct concentration for half-maximal rate ($1/b_s$) is so small that in any properly conducted experiment the rate curve remains exponential until just before complete exhaustion of sugar when it bends over sharply to zero. Initial rate data were used by Monod; others have used continuous backmix reactors to obtain the desired relationships.

Except for the nagging question of how fractions of a volume per cent of yeast can be measured in 12-ml centrifuge tubes, the experiment itself is a good one. It provides a first-class example of the hazard of overzealous fitting of kinetic data to an *a priori* mathematical model—a hazard fully emphasized in Levenspiel's text.

R. K. Finn
Cornell University

Anderson Replies

Sir: Professor Finn has restated one of the conclusions reached by several of the students who have run the experiment: Another factor may partially limit the growth of the yeast. Those students received top marks, and with a lab report written without jumping to conclusions Professor Finn might also receive top marks. In fact, data of other groups have yielded lower values for ($1/b_s$), but

in all cases the yeast stop growing when the sugar runs out. A simple check on the effect of the oxygen supply can be obtained by varying the air feed rate. Regarding corn vs. cane read corn but buy dextrose from a laboratory supply house. Of course, "patterned after" does not imply exact duplication of a commercial process but merely similarity. The use of 12-ml centrifuge tubes for measuring yeast cell volume is quite simple and gives surprisingly reproducible results as shown by sample replication.

The objectives and requirements of research investigations and undergraduate experiments differ in several important respects. In the former the limitations of time and complexity are not near as severe as in the latter. The time available in an undergraduate course laboratory precludes the use of both initial rate measurements and continuous backmix reactors as suggested by Finn. The data obtained in most batch experiments are adequately represented by the accepted model, which includes the effects of many constituents other than sugar. The model is certainly not an *a priori* model since it results from the "shrewd scientific detective work" (1) of a number of workers over a period of years.

J. B. Anderson
Yale University

(1) O. Levenspiel, "Chemical Reaction Engineering," Wiley & Sons, Inc., New York, 1962, p. 31.

Tenn Tech Is Accredited

Sir: The chemistry survey reported by Dr. James Cobb in the summer 1972 issue of *Chemical Engineering Education* may leave the impression that the Department of Chemical Engineering at Tennessee Technological University is not presently accredited. Without worrying about the merits of achieving accredited status I would like to point out that this department, formed as a department in the fall of 1966, was inspected in the spring of 1970 and accredited by action of the AIChE and ECPD in the summer of 1970. I see other universities in the list that may have similar comments.

While I have this opportunity let me express my appreciation for the efforts you and your associates put into *Chemical Engineering Education*. I find it both interesting and useful.

John C. McGee, Chairman
Tennessee Technological University

Steam Table Correction

Sir: For those chemical engineering teachers of thermodynamics who are accustomed to using the little steam table booklets prepared by Combustion Engineering, Inc., the most recent edition contains an erroneous enthalpy value that might cause a few anxious moments in class for the unwarned. Whereas most of us are familiar with the convention of assigning the value zero to the enthalpy and entropy of "saturated" liquid water at 32°F, the latest edition of "Steam Tables" shows the disquieting value of 0.0179 Btu/lb_m for the enthalpy h_f at this point.

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ticularly HCl, causes very high equipment and utility costs. The loss of chlorine, as in Flowsheets 1 and 2 makes the profit for this process dependent on reactor conversion and chlorine cost.

Flowsheet 5 shows the same independence of conversion as Flowsheet 3. The profit is less due to solvent costs and the additional separator.

A profit nearly as high as that for Flowsheet 3 is obtained for Flowsheet 6. Flowsheet 6 utilizes water to remove hydrogen chloride from the vapors leaving the phase separator. Wet chlorine returning to the reactor inlet is dried by contacting concentrated sulfuric acid. The low cost of the solvent, water, and the fact that the water need not be regenerated make this alternative very attractive. However, the corrosive nature of the hydrogen chloride-water mixture and the sulfuric acid-water mixture require more expensive materials of construction. The danger of water entering the reactor must also be considered. If the reactor and separators are constructed of carbon steel, any traces of water in the presence of the hydrogen chloride reaction product would lead to rapid failure of these units due to corrosion.

Flowsheet 6 has a higher profit than Flowsheet 3 at low conversion. This because of the large amounts of decane solvent required in Flowsheet 3 for low chlorine conversions.

Flowsheets 7 and 8 are the special cases when conversion is complete. Flowsheet 7 has the advantage of only requiring two separators and no recycle. The high conversions using stoichiometric feed ratios lead however, to the production of large amounts of DCD. Hence, the profit for this alternative is low.

Flowsheet 8 represents the situation when large excesses of decane are utilized. Complete conversion of chlorine is achieved, hence no separation is required for its recycle. A small amount of DCD appears in the product. These advantages are offset by the costs associated with the separation and recycling of large amounts of decane.

In summary, three regions exist when comparing the eight flowsheets over wide ranges of conversion. At low conversions process Flowsheet 6, which utilizes water as a means to separate HCl and chlorine, is best. At intermediate conversion levels, process Flowsheet 3 is best. Process 3 utilizes the feed and recycle decane as a solvent for absorbing chlorine from the waste hydrogen chloride stream. For high levels of conversion, process Flowsheet 1, which discards unconverted chlorine, is optimal.

CONCLUSION

An essential difference between the aims of education in science and in engineering ought not be lost. Herbert A. Simon states in the *Sciences of the Artificial*

Historically and traditionally, it has been the task of the science disciplines to teach about natural things: how they are and how they work. It has been the task of the engineering schools to teach about artificial things: how to make artifacts that have the desired properties and how to design. . . . Everyone designs who devises courses of action aimed at changing situations into preferred ones.

Science aims to *analyse* natural phenomena, and engineering aims *synthesize* from natural phenomena preferred situations. For example, while it may be sufficient for a scientist to develop an understanding of the phenomena of ice formation, the engineer ought to be concerned with use of his knowledge in the development, say, of an artifact which economically can produce fresh water from the sea by freezing.

The dominance of science oriented courses in undergraduate education is caused by the very important role analysis has in engineering, and is also caused by the availability of well organized and carefully planned text material in these areas. The natural organization of methods of analysis lends itself to course development and text preparation.

The absence of the organizing influence of basic principles of synthesis is possibly the major reason why analysis tended to dominate education. It remains to be seen if the course described will bring the proper balance between analysis and synthesis in engineering education. □

LETTERS: (Continued from page 3)

A little checking has revealed that the non-zero value is the result of a reformulation of steam table data published by the ASME in 1967.¹ Recognizing that a stable liquid-vapor equilibrium can't exist below the triple point temperature of 32.018°F, the reference conditions were changed so as to assign the value zero to the entropy and *internal energy* of the saturated liquid phase at the triple point. This, of course, forces the associated enthalpy to be (Pv) units greater or about 0.0003 Btu/lb_m. One can certainly estimate the conditions for the metastable vapor-liquid equilibrium at precisely 32°F through simple extrapolation and obtain values of about -0.0181 Btu/lb_m and -0.0178 Btu/lb_m, respectively, for the internal energy and enthalpy of the liquid phase. The error in the Combustion Engineering tables, then, is the omission of the minus sign together, perhaps, with out spelling out the convention not stating (as does the reference above) that the first entry in the saturation table corresponds rigorously to a metastable state. At least one recently published text² on chemical engineering thermodynamics has copied this error, but the new edition of "Steam Tables" by Keenan, Keyes, et al,³ does note both the negative values and metastability below the triple point.

Kenneth R. Jolls
Iowa State University

1. "Thermodynamic and Transport Properties of Steam," American Society of Mechanical Engineers (1967).

2. Balzhiser, R. E., M. R. Samuels and J. D. Eliassen, "Chemical Engineering Thermodynamics," Prentice-Hall, Inc (1972).

3. Keenan, J. H., F. G. Keyes, P. G. Hill and J. G. Moore, "Steam Tables," John Wiley & sons, Inc. (1969).