A Course in
Chemical, Pharmaceutical and Food Processing

Claude Cohen, Robert K. Finn, Steven J. Mulvaney
Cornell University

INTRODUCTION

We have developed a course which covers the process fundamentals, design, and strategy of chemical, pharmaceutical and food processes. The course is targeted to seniors and Professional Masters of Engineering (MEng) students of several engineering fields. Besides students from the chemical discipline, we have attracted students from civil and environmental, electrical, materials, mechanical, operation research and industrial engineering. These fields participate in the MEng Option in Manufacturing coordinated by Cornell's Center for Manufacturing Enterprise. The course is almost equally divided into its three components with each component taught by a different instructor. In the past three years we have co-taught this course, we have found the pharmaceutical and food parts of the course to be popular electives with chemical engineering seniors. These students take only these two parts of the course as the first part covers basic chemical engineering material which they have already assimilated in prior courses. Non-chemical engineering students are required to take the chemical portion of the course as some of the basic principles needed in the other parts of the course are covered in this first part. These students thus take the chemical processes portion as a pre-requisite to the pharmaceutical or/and food processes, whereas chemical engineering students enroll in either or both pharmaceutical and food processes. Each portion of the course is worth 1 credit hour in a variable (up to 3) credit hours course.

COURSE OBJECTIVES

The idea for a course in the area of chemistry-related processes to serve as an elective for MEng students in the Manufacturing Option was developed during discussions with the Director of Cornell's Center for Manufacturing Entreprise, as part of a grant proposal to the Sloan Foundation. As the concept for the new course gained momentum and discussions with potential instructors took place, the idea of using this opportunity to offer chemical engineering senior students an elective in pharmaceutical and food processes became quite appealing. Both pharmaceutical and food industries are offering increased employment opportunities for these students as well as for students of other engineering disciplines. Such a course would clearly fit in our educational mission. The two objectives of the course were then: educate non-chemical engineers in the area of continuous chemistry-related processes and provide challenging and interesting aspects of pharmaceutical and food processes to all the students. To combine both objectives, chemistry and chemical engineering concepts to be used in the course are presented at the simplest level and covered primarily in the first part of the course. In this part, open for enrollment to non-chemical engineering students only, case studies of chemical processes are also presented. The pharmaceutical processes section of the course which follows the chemical processes has the educational objectives of presenting typical pharmaceutical processes with simple chemistry. The material is presented at a level such that i) engineers with only one or two terms of college chemistry and the principles covered in the first part of the course can appreciate the process design and regulatory restraints in this field, and ii) chemical engineers can gain insight into nuances of fine chemicals production. The objectives of the food processes component of the course are to illustrate how the interplay between engineering science, design principles and the material properties of food biopolymers influences food

manufacturing operations. It is not the intent of the instructors to provide a survey course of the variety of processes encountered in each of the area under consideration, but rather the intent is to stress general principles and concepts behind a few processes. Examples of how these principles are applied highlight some of the unique features pertaining to each area of manufacturing. Homework problems are assigned to help assimilate the concepts and principles learned in class.

COURSE CONTENT

After a general overview of the chemical processing industries, the non-chemical engineering students are first taught the concepts of material and energy balances [1]. A first case study of a chemical process of some general appeal dealing with fly-ash and sulfur dioxide removal from the stack gases of a coal-burning electricity-generating plant is considered. Design and strategy for the removal of SO_2 to meet EPA regulations are considered. The advantages of the limestone scrubbing operation are discussed [2]. After this case study, the students are introduced to idealized chemical reactors at the level of the first few chapters of Levenspiel's *The Chemical Reactor Omnibook* [3]. Simple separation operations covering distillation, absorption and extraction follow [4]. The students are then ready to digest a second more complex case study involving the design and flowsheet of a styrene plant [5]. The choice of styrene leads naturally to polystyrene production and to plastics manufacturing processes such as molding and extrusion [6].

The pharmaceutical section starts with an introduction and history of antibiotics and pharmaceuticals manufacturing illustrating the special challenges encountered in this field [7]. The process design of antibiotic manufacturing is then taken up with details covering problems in bio-reactor operations including sterilization, aeration-agitation, and downstream processing, e.g. extraction. Recombinant protein production and associated methods of protein purification such as ultrafiltration and chromatography are presented [8]. Crystallization as a means of bioseparation is discussed in one lecture. A case study of the manufacture of vitamin C (ascorbic acid) is analysed in some details. Both batch and continuous processing are used to convert D-glucose (corn sugar) which markets for about 25 cents/kg into ascorbic acid worth $17/kg. The reasons for each step and alternate ways of accomplishing the goal are emphasized along the production economics, recycling of waste streams, and product quality [9]. The final lectures in this part of the course cover validation, economics, marketing and business aspects of the industry.

In the Food Processing part, an emphasis is given to food preservation processes. The students are first introduced to the role of water activity in the perishability of food and to freezing [10], evaporation and spray drying processes [11]. Several heat processes (pasteurization, sterilization, microwave processing) and their applications in the food industry are covered. The basic aspects of extrusion processing are presented in some detail as food extrusion represents one of the main research interests of the instructor. Different types of extruders (single vs twin-screw), screw configuration and use of dies for shaping food products are discussed. The concept of system analysis is introduced. The effect of operating variables (screw speed, barrel temperature, moisture content, etc) on state variables such as product temperature, materials properties, pressure and mechanical energy input and their influence on product properties are discussed [12]. Extrusion cooking processes relevant to the manufacture of ready-to-eat breakfast cereals and snack foods are used as case studies.

TEACHING STRATEGY AND COURSE REQUIREMENT

Because of the diversity in student background in the course, attempts are made to present concepts in simple words with familiar examples that a senior in any science or engineering field would comprehend. Many terms that become second nature to chemical engineers or chemists, such as chemical activity, enthalpy, molar concentrations, etc are introduced and defined in the first part of the course. After using the word "fluid" for the first time in class, the instructor realised that the meaning of the word may not be obvious and asked the class of non-chemical engineers for its explanation. As no appropriate answer was forthcoming, the situation provided an opportunity for a short digression on the one-component phase diagram and the region above the critical point where the distinction between liquid and vapor phases vanishes. As can be imagined, similar episodes occur in the pharmaceutical and food sections where new terms are defined and digressions from the prepared lecture notes are necessary and often stimulate both the students and the instructor.

After the first five weeks of the course that cover the Chemical Processes, our class size more than doubles (going from around 15 students to over 30 students) with the influx of chemical engineering students attending the Pharmaceutical and Food parts of the course. Each of these subsequent parts are covered in a four-week period. Three tests make up for the fourteenth week of the course. References, handouts and reading assignments are given regularly to the students. During each part of the course, three homework sets are assigned and the grades are based on the homeworks and one-hour exams at the end of each section of the course. Occasionally, we have had other faculty or industrial visitors as guest lecturers or organised half-days plant trips.

COURSE OUTLINE

Chemical processes:	Material and energy balances
	Case study of fly-ash and SO_2 removal
	Batch and flow reactors
	Separations
	Case study of Styrene plant
	Safety and environmental issues
	Polystyrene and polymer processes
Pharmaceutical processes:	Antibiotic manufacturing
	Process design of antibiotics
	Recombinant protein production
	Bioconversion and enzyme reactions
	Vitamin C manufacturing
	Bioseparations
	Vaccines and other biological drugs
	Finishing steps. Validation
	Economics, marketing, ethical issues.
Food processes:	Introduction, water activity
	Freezing process
	Evaporation processes
	Spray/drum drying
	Membrane separation
	Microwave processes
	Pasteurization and sterilization
	Extrusion cooking
	Ceral processes.

STUDENT PERSPECTIVES

The course has been well received and its popularity has been on the rise since its inception.

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BIOGRAPHICAL INFORMATION

CLAUDE COHEN is professor of chemical engineering. He received his PhD from Princeton and joined Cornell in 1977. He presently also teaches an Introduction to Chemical Engineering for freshmen and a graduate level Physical Polymer Science course. His research field is polymer science and engineering with interests in rheology, light scattering, polymer processes and elastomeric materials.

ROBERT K. FINN is emeritus professor of chemical engineering. He has taught and pursued research at Cornell in biochemical engineering for thirty-four years. His particular interests are in fermentation processes, conversion of renewable resources into more valuable chemicals and the biological treatment of wastewaters. He came out of retirement to co-develop the course described here.

STEVEN J. MULVANEY is associate professor of food science. He received his PhD in food engineering from Cornell and after a short stay at the University of Missouri , he returned to Cornell in 1990. He teaches classes in food processing and engineering. The major goal of his research program is to improve the efficiency and understanding of food processing technologies with particular interest in extrusion processes.