Journal of Applied Food Technology 8 (2) 39–43

Journal of Applied Food Technology

Home page : https://ejournal2.undip.ac.id/index.php/jaft

Integrating Food Processing Technology in Chemical Engineering Undergraduate Teaching

Ching Lik Hii

Department of Chemical and Environmental Engineering, University of Nottingham Malaysia

Abstract

Chemical engineering and food processing are two individual disciplines that are related to each other in many scientific and engineering principles. However, food processing is not widely taught in a typical chemical engineering curriculum. In this paper, an overview of the Food Processing Technology subject taught in the Department of Chemical and Environmental Engineering, University of Nottingham Malaysia is presented and discussed with lecture application examples and outcome of assessments based on the Engineering Accreditation Council guideline (Malaysia). The outcome of the assessment will be based on the recent academic session for the year 2019-2020. Attainment of students is also evaluated based on learning outcomes (LO) and program outcome (PO) analyses. The purpose of this evaluation is to reflect and improve the curriculum and for continuous quality improvement purposes which is the key process in accreditation and also to enhance student's learning experience.

Article information:
Received: 06 January 2021
Accepted: 11 November 2021
Available online: 23 November 2021

Keywords:
accreditation
chemical engineering
food processing
learning outcome
program outcome

doi: 10.17728/jaft.10002

Introduction

Food processing links the science and engineering of various unit operations that affect the quality of food products when raw materials are processed by changing their properties. Particularly, chemical engineering is a discipline where processes are designed and optimized not only for the chemical but also for the food industries (Hii, 2014). However, food processing related subjects are seldom introduced in conventional chemical engineering curricula and most of the program structures are still putting emphasis on applications in oil and gas, petrochemical, and fine chemical productions. Table 1 shows examples of chemical engineering principles that are applicable in teaching food processing to undergraduate students.

Table 1 Application of chemical engineering principles in food processing

Chemical engineering principles	Application in food processing
Heat transfer	Sterilization, frying, roasting, freezing
Mass transfer	Drying, osmotic dehydration, evaporation
Particle size reduction	Milling, grinding, cutting
Filtration	Oil pressing, belt pressing, vacuum drum filter
Fluid mechanics	Beverage processing, filling and packaging

The subject Food Processing Technology (FPT) is a year 4 optional subject (10 credits) that was introduced in the Department of Chemical and Environmental Engineering, University of Nottingham Malaysia, in 2013 by the author. The subject introduces students to various aspects of food processing technology and its related areas such as the food industry, the food act, properties of food materials, ambient temperature processing, thermal processing, processing using steam or water, processing using hot oils, processing using radiated energy, processing by heat removal, packaging, and labeling, sanitation and cleaning, food safety and food quality management (Hii, 2013).

In this paper, an overview of the FPT subject, lecture application examples, and outcome of assessments will be presented and discussed. The outcome of the assessment will be based on the recent academic session during the autumn semester for the year 2019-2020.

Materials and Methods

Materials

Most of the lecture materials and examples are based on three major reference textbooks namely Food Processing Technology by Fellow (2009), Handbook of Food Processing Practice by Valentas et al. (1997), and Transport Processes and Separation Process Principles by Geankoplis (2003). The academic session presented in this paper is based on the year 2019/20 with a classroom size of 64 students in total. Two postgraduate master's students enrolled in this subject as well.

Methods

The Food Processing Technology subject covers the following topics throughout a 12-week teaching period in the autumn semester (September – December) of the academic session. The topics are as follows:

- Overview of food processing – history, industry, and commercial outlook
- Ambient temperature processing - preparation, size reduction, forming/molding, and separation/concentration
- Hot air processing - drying and baking/roasting
- Processing using steam/water - evaporation, high-pressure processing, and pasteurization/sterilization
- Processing using hot oils - frying
- Processing by heat removal - chilling and freezing
- Packaging and labeling - packaging materials and food labels
- Food handling and hygiene - cleaning and sanitation
- Food safety - GMP and HACCP
- Food quality - physical, chemical, biological, and nutritional attributes

Besides the marks from the general final exam and coursework assessments. The subject is also evaluated based on the following learning outcomes (LO1 - LO5) according to the subject outline namely:

- LO1: Application of chemical engineering principles in food processing unit operations
- LO2: Apply material and energy balances in food processing principles
- LO3: Understanding the concept of safety which includes hygiene, sanitation, and cleaning
- LO4: Describe the typical food processing operations and equipment in the industry
- LO5: Ability to apply food quality management

The above learning outcomes are also linked to the Engineering Accreditation Council, Malaysia (EAC, 2020; Law et al., 2020) program outcomes as follows:

- Problem Analysis (PO2): Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- The Engineer and Society (PO6): Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to professional engineering practice.
- Communication (PO9): Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

At the end of the semester, the results obtained from the general assessments (exam and coursework) will be used for the LO-PO attainment analysis. This is a requirement from the EAC to ensure continuous quality improvement has been carried out for the subject annually. Table 2 shows the mapping of the learning outcomes against the program outcomes for the FPT subject.

Table 2 Mapping of LO against PO for FPT subject

Mapping	LO1	LO2	LO3	LO4	LO5
PO2	X	X		X	
PO6			X		
PO9					X

LO = learning outcome, PO = program outcome

Tables 3 and 4 show a typical breakdown of the assessment with reference to LO and PO mapping. In this subject, the students are assessed based on one coursework and one final exam. The components assessed constitute 20% of coursework and 80% of final exam, respectively.

Table 3 Assessment and its percentage distribution with reference to LO

Type of Assessment	% Distribution

Assessment	Weightage	LO 1	LO 2	LO 3	LO 4	LO 5	Total
Exam	80	25	25	25	25	0	100
Course work	20	0	0	0	0	100	100

Table 4 Assessment and its percentage distribution with reference to PO

Type of Assessment		% Distribution			
Assessment	Weightage	PO 2	PO 6	PO 9	Total
Exam	80	75	25	0	100
Coursework	20	0	0	100	100

Results and Discussion

Lecture application examples

The following are selected examples of some of the applications of chemical engineering principles in food processing applications. Students are taught about these concepts in lectures and examples are presented to them during problem-solving lessons.

Example 1 (Mass transfer in drying process): In a typical drying operation, mass transfer occurs whereby moisture diffusion occurs inside a food product and is removed from the outer surface through evaporation (Asiah et al., 2017). The diffusion process can be described by Fick's second law equation (Crank, 1975) which is also applied in many chemical process operations (Eq. 1).

$$\frac{\partial m}{\partial t} = D_e \frac{\partial^2 m}{\partial X^2} \qquad (1)$$

where m = moisture content (g water/g dry solid), D_e = effective diffusivity (m^2/s), X = distance (m) and t = time (s).

This equation can be solved to obtain the general solutions that can be used in the estimation of effective diffusivity (D_e), an important parameter in drying equipment design (Yap et al., 2020). Students were given the task of determining this parameter from a drying curve (Figure 1).

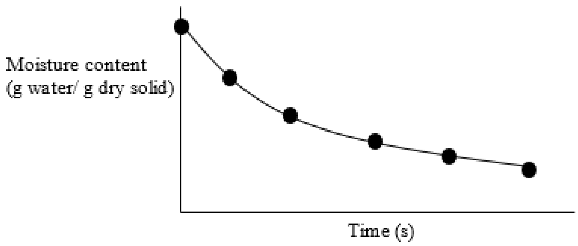

Figure 1 Drying curve (moisture content vs time)

For example, assuming an operation that involves drying fruit slices using a hot air dryer, the general solution for a slab geometry is given by:

$$MR=\frac{8}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{2n-1}\exp^{-(2n-1)^2\frac{\pi^2 D_e t}{4L^2}} \qquad (2)$$

where MR = moisture ratio, L = half thickness (m) and n = 1,2,

Students may make an assumption by taking only the first term of the equation (Rumaisa et al., 2018), by plotting the graph of ln MR vs. time (Eq. 3), the slope of the graph ($\pi^2 D_e/4L^2$) can be used to determine the parameter D_e.

$$\ln MR=\ln\frac{8}{\pi^2}-\frac{\pi^2 D_e}{4L^2}t \qquad (3)$$

Example 2 (Heat transfer in sterilization process): A typical sterilization process would involve taking temperature measurement from the thermal center of a canned food. The temperature (T) development can be described using the heat conduction equation (Hii et al., 2017) as shown in Eq. 4.

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial X^2} \qquad (4)$$

By determining the thermal diffusivity (α) of the food material, the temperature profile (T = f(X, t)) can be determined by using the explicit finite difference method (Ozisik, 1985). In this method, Eq. 4 is discretized to obtain its finite form, in which temperature development at each time interval (Δt) can be determined using Eq. 5.

$$T_n^{i+1} = r\left(T_{n-1}^i + T_{n+1}^i\right) + (1-2r)T_n^i \qquad (5)$$

where $r = \alpha\Delta t/\Delta x^2$, Δx = distance interval (m), Δt = time interval (s), α = thermal diffusivity (m^2/s) and i = 0, 1,… and n = 1,2,….N-1

The above equation can be used by taking the temperature at the boundary condition (surface) same as the steam temperature (e.g., T> 100°C) used for sterilization.

Example 3 (Nutrient degradation kinetics): Some typical nutrient degradation processes (e.g. vitamins and antioxidants) can be modeled using a first-order reaction kinetics (Eq. 6). For example, the polyphenols degradation process can be fitted using this model and the rate constant can be determined through graphical method (Kyi et al., 2005).

$$\frac{dC_{pp}}{dt} = -kt \qquad (6)$$

where C_{pp} = concentration of polyphenols (mol/m^3), k = rate constant (1/s) and t = time (s).

By integrating the above equation, it can be simplified to the following model (Eq. 7).

$C_{pp} = C_0 exp^{-kt}$ (7)

By plotting Ln C_{pp} vs time, the slope of the graph is used to obtain the rate constant (k). The rate constant can be obtained for several temperatures, which can then be used to obtain the Arrhenius relationship. (Eq. 8).

$k = k_0 exp^{-E/RT}$ (8)

where E = activation energy (J/mol), R = universal gas constant (8.314 J/mol.K) and T = temperature (K)

The Arrhenius relationship enables the determination of the rate constant (k) at various operating temperatures of the equipment (Figure 2). For example, the higher k value indicates a faster degradation rate of polyphenols during processing (Teh et al., 2016).

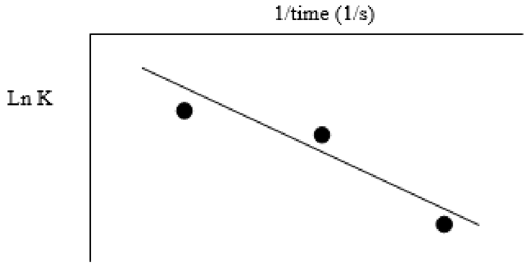

Figure 2 Arrhenius plot (Natural log rate constant vs 1/time)

Outcome of assessments

In the most recent academic session for the year 2019/20 (total = 64 students), the subject was assessed by coursework (20%) and final examination (80%). In the final examination, students were requested to answer all compulsory questions (typically four questions). In coursework, the students were required to carry out a mini-project and sit for an interview. Table 5 shows the outcome of the LO and PO attainment analyses (Hii, 2020).

From the above analyses, it can be seen that 42%, 43.8%, and 31.3% failed LO1, LO2, and LO4, respectively, but none failed LO3 and LO5. In terms of PO attainment, 31.2% failed PO2 but none failed PO6 and PO9. The much higher failure rates in LO1 and LO2 are linked to questions related to the design of unit operations and calculation of mass and energy balances in food processing applications. In this particular session, due to the Covid-19 pandemic outbreak, the exam was conducted online and the questions were made more open-ended. This also resulted in a higher level of difficulty where the students were required to apply complex problem-solving. Hence, this is one of the reasons that possibly explains why the failure rate is particularly higher in some of the LOs. In terms of PO attainment, as PO2 is mapped to multiple LOs (1, 2, and 4), this also explains why the failure rate is higher as failure rates are also higher in these LOs.

Table 5 Performance indicator based on LO and PO attainment

Descriptor	Attainment
LO	27 students (42%) failed LO1
	28 students (43.8%) failed LO2
	0 students (0%) failed LO3
	20 students (31.3%) failed LO4
	0 students (0%) failed LO5
PO	20 students (31.2%) failed PO2
	0 students (0%) failed PO6
	0 students (0%) failed PO9

Although attainment analyses showed failure rates in some of the LO and PO, this does not translate into direct failure of the final marks awarded to the students. This is because LO and PO attainment are mapped explicitly to individual sections in a particular set of exam questions and coursework, but students are still able to obtain marks explicitly (e.g., full or better marks) in various parts of the questions. When final exam marks are added with marks from coursework, the students are still able to pass the subject (e.g., > 40% marks).

Conclusion

Chemical engineering principles are commonly applied in food processing unit operations as these two disciplines are related to each other in many scientific and engineering principles. In this paper, examples have shown that some of the principles can be applied in drying (mass transfer), sterilization (heat transfer), and nutrient degradation (reaction kinetics). Besides analyses based on marks obtained from final exam and coursework, the attainment of students are also evaluated based on learning outcomes (LO) and program outcome (PO). Analyses have shown that some students failed LO1, LO2, LO4, and PO2. Nevertheless, the purpose of doing such analyses is to reflect and improve the curriculum and ultimately for continuous quality improvement.

Acknowledgment

The authors would like to thank the Accreditation and CQI Team as well as the Year Leaders for their support of the department.

References

Asiah, N., Djaeni, M., Hii, C.L. 2017. Moisture transport mechanism and drying kinetic of fresh harvested red onion bulbs under dehumidified air.

International Journal of Food Engineering. 13(9). DOI:10.1515/ijfe-2016-0401

Crank, J. 1975. The Mathematics of Diffusion. UK, Oxford University Press.

EAC. 2020. Engineering Programme Accreditation Standard 2020. https://www.eac.org.my/web/document/EAC%20Standard%202020_approved%20BEM19April2020%20upload%2015June2020.pdf (accessed 29 December 2020)

Fellows, P.J. 2009. Food Processing Technology: Principles and Practice (3rd edition). UK, Woodhead Publishing Ltd.

Geankoplis, C.J. 2003. Transport Processes and Separation Process Principles. USA, Pearson.

Hii, C.L., Menon, A.S., Chiang, C.L., Suzannah, S. 2017. Kinetics of hot air roasting of cocoa nibs and product quality. Journal of Food Process Engineering 40(3):e12467. DOI: 10.1111/jfpe.12467

Hii, C.L. 2013. Food Processing Technology Module Outline. University of Nottingham Malaysia.

Hii, C.L. 2014. Teaching food processing technology in chemical engineering undergraduate program. IEM technical talk. University of Nottingham Malaysia.

Law, C.L., Hii, C.L., Anurita, S., Ianatul, K., Vasanthi, S., Faye, C.S.H., Lim, S.S., Tiong, T.J., Nishanth, C. 2019. In: Proceedings of Continuous Quality Improvement Conference (CQIC 2019), University of Nottingham, Malaysia, 22 - 26 July 2019. eISBN 978-967-11279-7-1

Law, C.L., Hii, C.L., Anurita, S., Ianatul, K., Vasanthi, S., Faye, C.S.H., Lim, S.S., Tiong, T.J., Nishanth, C. 2019. In: Proceedings of Continuous Quality Improvement Conference (CQIC 2019), University of Nottingham, Malaysia, 25-26 August 2020. In press.

Kyi, T.M., Daud, W.R.W., Mohammad, A.B., Wahid Samsudin, M., Kadhum, A.A.H., Talib, M.Z.M. 2005, The kinetics of polyphenol degradation during the drying of Malaysian cocoa beans. International Journal of Food Science & Technology, 40: 323-331. DOI: 10.1111/j.1365-2621.2005.00959.x

Ozisik, M.N. 1985. Heat Transfer: A Basic Approach. USA, McGraw-Hill.

Rumaisa, N, Hanim, M.R.N., Hii, C.L. 2018. Superheated steam drying of black tea and quality improvement. International Journal of Food Engineering. 14(9-10): 20180185. DOI: 10.1515/ijfe-2018-0185

Teh, Q.T.M., Tan, G.L.Y., Loo, S.M., Azhar, F.Z., Menon, A.S., Hii, C.L. 2016. The drying kinetics and polyphenol degradation of cocoa beans. Journal of Food Process Engineering 39(5):484-491. DOI:10.1111/jfpe.12239

Yap, J.Y., Hii, C.L., Ong, S.P., Lim, K.H., Abas, F., Pin, K.Y. 2020. Effects of drying on total polyphenols content and antioxidant properties of Carica papaya leaves. Journal of the Science of Food and Agriculture. 100(7):2932-2937. DOI: 10.1002/jsfa.10320

Valentas, K.J., Rotstein, E., Singh, R.P. 1997. Handbook of Food Engineering Practice. USA, CRC Press.