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Article

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Re-Engineering Food Engineering

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The case for food engineering as a stand-alone discipline:

For years, Food Engineering has struggled to establish a strong identity of its own as an academic discipline, and it has been conducted as a subset of other branches of Engineering - principally, Agricultural or Biosystems Engineering, Chemical Engineering, and Mechanical Engineering - which initially served to incubate the discipline. Even though UK has made a substantial contribution to Food Engineering over the years, especially in terms of process and equipment innovation, and research and training, its profile and standing within the higher education sector has never been commensurate with its achievements and legacy. Today, Food Engineering exists as an optional specialism in a handful of undergraduate chemical engineering programmes, in addition to a few MSc programmes. The tide is however changing in favour of the discipline with universities such as Nottingham and Sheffield Hallam commencing full blown programmes in Food Engineering, to add to the very strong Food Engineering interest in the chemical engineering department at Birmingham. Of course, the academic interest in food engineering also exists in the various food science and technology departments up and down the country. Even with these undoubtedly encouraging recent developments, it would not be unreasonable to conclude that UK offers very limited formal training in the subject. In contrast, there has never been a lack of enthusiasm to promote the subject within industry, especially by the Institution of Chemical Engineers, Institution of Mechanical Engineers, Institute of Food Science and Technology, and the Society of Chemical Industry. All these organisations, together with the Food and Drink Federation, have effectively served a significant body of practising food engineers. Thus, if 1) training, 2) research and 3) enterprise are considered to be the three cornerstones of any discipline, UK food engineering is strong in terms of the latter two, but relatively light on training. The international scenario on the research and enterprise front is similar to UK with these portfolios being considerably buoyant. The training portfolio, on the other hand, depends on the country. For instance, Brazil, Turkey, Mexico, Chile and Thailand have very strong food engineering training programmes, whereas it is taught as a part of food science programmes in some countries (e.g. China) or agricultural engineering programme (e.g. India). But what is striking is that food engineering training has had a relatively low profile in Northern and Western Europe, and in USA and Canada – which have been the traditional torchbearers of training in most disciplines. To an extent, this has resulted in a subject leadership vacuum for driving changes in the way the discipline responds to current and future challenges; and training in the discipline is unfortunately meandering the way it was in the last century.

It is worth noting that the food sector accounts for 19% of total manufacturing turnover and generates a gross value addition of £28 billion to the UK economy – which, according to a recent report published by the Institute of Physics (2016)[1], is bigger than the automotive and aerospace industries put together! One wonders, how can the Food Industry, which is such a key industrial sector within our economy, do without properly trained and qualified Food Engineers? It was believed some time ago that the industry could employ engineers who have qualified in various branches such as chemical, mechanical etc, and train them in the knowledge of foods. But this approach is severely flawed, because it has meant that engineers working in the food industry do not have an in-depth understanding of the very products they are dealing with. As a result, their participation in innovation, especially new product development – which is at the heart of business growth in the food sector – has become peripheral. *Engineering is therefore seen merely as a service; not a strategic business driver*. This side-lining of engineering has disadvantaged both business as well as engineering discipline. The time has come to abandon such practices which can only work as stopgap measures, and instead, plan for the longer term strategic interest of the business by supporting the training of food engineers. At the same time, it is also imperative that Food Engineering asserts its independence as a discipline and develops a strategic role for itself at the very heart of the business. If the discipline fails to assert itself in a meaningful way, a key link in the translation of the rapidly growing laboratory and clinical knowledge into practical products and processes, will be missing, thereby disadvantaging both, the manufacturing sector and the society. One cannot emphasise how important it is to recognise that the time is ripe for the discipline to take a fresh look at its own identity, core competencies, and training programmes. This article addresses how Food Engineering can re-brand itself and claim its rightful place in guiding the strategic growth of food business as well as the health of the nation.

How can Food Engineering discipline be re-shaped?

First and foremost, it is necessary to recognise that the key drivers of the discipline are: *health*, *environment* and *security*. Whilst food is a basic need for our very existence, its health impact shapes the quality of our existence in a significant way. Thus, the relationship between food quality and existential quality has to be explored and learnt. Secondly, food production and consumption has its inevitable environmental impact, which can only be ignored at our own peril. Thus, the link between food and the environment becomes an essential part of learning and exploration. Finally, food production has to be secured to sustain our very existence against all odds, and therefore the study of food security becomes necessary. Thus Food Engineering, as an academic discipline, has to be developed in such a way that it includes the study of all these relationships.

Developing and implementing *design methodologies* are at the heart of all engineering disciplines, and food engineering is no exception. But what is food engineering supposed to design? Is it the food product? Or is it the process for developing the product? Over the years, chemical Engineering has also struggled with these questions, with terms such as *process engineering,* and more recently, *product engineering* being used to describe the designing of processes and products. The analysis within process engineering has been too generic and inadequately sensitive to the nature of products. For instance, the analysis of distillation and other unit operations – as expounded in many text books – remains the same regardless of whether it is to be applied to petroleum based products or to alcoholic beverages meant for human consumption. This legacy of chemical engineering cannot be bequeathed to food engineering, because designs are inherently product sensitive, especially given how profoundly food impacts with the three key drivers mentioned above. Food Engineering needs to combine *process engineering* as well as *product engineering* in a meaningful way, which requires a substantive change in the mind-set. In a recent paper[2] the author of this article proposed that the core engineering competencies needed to formulate and manufacture food products be known as *food product realisation engineering*. The product formulated therefore becomes the goal and the process becomes the means to realise the goal. This approach, especially within the context of an academic discipline, also enables us to address some of the idiosyncratic features of food businesses, such as producing the same end product despite having significant regional and seasonal variability in starting materials, or running the same set of equipment in short campaigns to produce a range of very different products. It is important to note that Product Realisation Engineering is not Food Engineering *per se*, but a core subject knowledge competency of Food Engineering, which must also include other key competencies necessary to address the three discipline drivers mentioned above. The five subject knowledge competencies of Food Engineering are stated in Table1, and the following definition of food engineering is proposed[2]:

"*Food Engineering is the work of designing, formulating and manipulating food products which have desired sensory, satiety, health and well-being responses; and developing - across various operational scales - designs for the lowest environmental impact processing, packaging and storage systems capable of realising the products and attributes*."

It is necessary to note that Table 1, and indeed this article as a whole, only addresses the subject competencies of food engineering; not the core professional competencies of a food engineer which must comply with the requirements of national bodies representing engineering profession in any country, such as the Engineering Council in UK. Thus, the subject competencies have to be combined with other competencies, such as those relating to communication, inter-personal and leadership skills, in order to arrive at an exhaustive set of professional competencies. Regardless, the definition of food engineering stated above and the core subject competencies identified, lend themselves to the development of a core Higher Education degree curriculum which will be explored in the next section. It may be noted that the purpose of this article is not to structure the actual academic programme and pedagogy, which is best left to individual institutions, but to structure the core food engineering content of the programme.

Structure of an undergraduate food engineering programme

If we re-visit the above definition of food engineering, it is clear that the core programme content must not only address product design methodology, but also the product's sensory, satiety, health and well-being attributes. In addition, the core programme must also include design methodologies for environmentally sustainable processing, packaging and storage operations. All these aspects, together, cover a vast area of knowledge because one can only become competent in each area by combining a detailed study of its theoretical principles with the exploration of practical applications. As a result, the number of courses in the programme inevitably becomes very large, and students and stakeholders fail to understand the importance of the linkages within and between courses, and instead, view the program as a collection of discrete and disconnected subjects. One way of mitigating such an effect is to classify the subjects into themes which, in principle, can run through the duration of the programme (Table 2). The paper published by this author[2] recommends the core study of Food Engineering to be classified into five themes, which collectively encapsulate the scope and spirit of the discipline. Moreover, each theme comprises courses designed to highlight the continuous and connected nature of studying, which can potentially bring out the pedagogical features.

It is obvious from Table 2 that the engineering design and analysis addressed by Food Engineering requires the application of several underpinning sciences, ranging from mathematics, physico-chemical sciences, and engineering sciences, to microbial and human life sciences, sensory sciences, psychology and environmental sciences. Thus food engineering will require a much broader science base than other branches of engineering. Hence, considerable thought will have to go into the development of *enabling courses*, which will form the launch pad for learning and exploring the five core themes. Moreover, it is very unlikely that the five core themes will be applied individually. The success of any curriculum will critically depend on how well the students are able to integrate and synthesise the knowledge gained under each theme. Therefore, *integrating or knowledge synthesising courses* will play a key role in determining how well graduating students are trained to face up to the challenges posed by the real world. Thus the *five core themes* have to be structured with *enabling* and *integrating courses*, which together, constitutes the Food Engineering Edifice (Fig. 1) – which one hopes will form the basis for designing higher education curricula.

To conclude, it is evident that Food Engineering has maintained a low profile for far too long in terms of training in the Higher Education sector. The time has come for it to become more visible, and assert itself to take its rightful place, especially now, when major laboratory breakthroughs in curing and preventing diseases with so called "functional foods" (i.e. foods which have health impact beyond basic nutrition) are being reported almost daily. Without food engineering competencies, such breakthroughs will languish in the laboratory, and not be translated into practical products produced on a scale required by the society at large. Hippocrates' age old prophecy "let thy food be thy medicine, and thy medicine be thy food" cannot be realised in a modern world without Food Engineering education and practice!

References:

[1] The Health of Physics in UK Food Manufacturing. http://www.iop.org/publications/iop/2016/file_68330.pdf

[2] K.Niranjan, A possible reconceptualization of Food Engineering Discipline. *Food and Bioproducts Processing* **99** pp. 78-89 (2016)

Table 1: Core Subject Knowledge Competencies of Food Engineering Discipline:

- Product Realisation Engineering
- Microbiological and chemical aspects of food safety
- Food Quality
- Sensory, consumer and psychological aspects of food
- Physico-chemical and metabolic phenomena occurring in the GI tract, and their health and well-being implications
- Assessing the environmental legacy of food

Table 2: The five themes constituting the core study of Food Engineering with typical contents; each theme is expanded in detail in reference 2.

Theme	Title	Typical courses
Theme 1	Food Safety, Quality and Formulation	Chemical and microbial safety; Major and minor chemical/biochemical components; Food ingredients and their role in formulated products
Theme 2	Food structural Engineering and sensory analysis	Study of Food Texture and rheology; Food structure, microstructure and nanostructure; Food emulsions, foams and stabilizing agents; Experimental and statistical methods in sensory analysis and consumer science
Theme 3	Food Product Realisation Engineering	Product manufacturing design; Food packaging; Plant and Equipment Operations Management; Design and Control of safety in food manufacture; Design and control of hygiene in food manufacture; Supply chain and food distribution; Economic Viability Analysis and Project Management
Theme 4	Transport processes in the GI tract, metabolism, satiety, health and well being	Transport processes in GI tract; Nutrition, Bioavailability and Food Metabolism; Design, delivery and action of functional foods; Elements of Food Psychology
Theme 5	Environmental Impact, food sustainability and security	Food production, processing and the environment; Energy and Waste management in the food industry; Sustainable soil, water and intensified agricultural production; Food Security

Fig. 1: The Food Engineering Edifice