1 Introduction

Over the past couple of decades, the role of the engineer in the food industry has gained considerable prominence. The food processing industry is extremely complex, diverse and evolved. With a consumer market becoming evermore sophisticated and demanding, there is a continual need for process innovation. Even allowing for the demands of the consumer for product consistency and quality, the consumer expects excitement, novelty, value for money and a product that is safe in tamper-proof packaging. For the food process engineer, the challenge is to use process plant and associated equipment which is sufficiently flexible to respond to any changes in demand.

The complexity and challenges of food processing engineering is best illustrated by considering the mixing criteria used in the food industry. Process engineers will be more familiar with the handling and mixing of robust components with the aim of achieving homogeneity in which liquids have low viscosity or exhibit straightforward Newtonian behaviour and where scale-up is based on simple power-to-volume ratios.

In contrast, the criteria for food mixing involve ingredients which have complex components with each exhibiting very different chemical and physical properties. They often have high viscosities and exhibit non-Newtonian behaviour. They may also be fragile in nature and easily damaged during high shear mixing in which there is a complex and intimate relationship between the mixing patterns and product characteristics. The scale-up of equipment is governed by the need to maintain textural properties of food.

All of this is further complicated by the need to maintain product quality in terms of texture, colour, appearance, rheology, functionality, aeration, droplet size and particulate integrity particularly when the raw materials used are subject to possible day-to-day and seasonal variations. It is essential that the food products are safe to eat, free from contamination, produced in a safe environment that conforms to food safety standards and other legal requirements. Finally, the process engineer must ensure that the process operation is energy efficient and has minimal environmental impact.

Further, the food process engineer is not only required to have a high regard for all the technical aspects associated with the processing of foods but that the needs and requirements of the consumer are fully appreciated. Consumers are increasingly demanding foods which are nutritious and healthy such as fortified organic and minimally processed foods. There is also a considerable demand for foods which are highly processed such as sausages, burgers, baked beans and dehydrated foods, and foods which have long shelf-life and total sterility such as canned and bottled foods with packaging that is tamper-proof yet can be easily opened.

Yet if that isn't sufficient, the food process engineer must also have a high regard for the food and drink marketplace which is characterised by short time-to-market and competitiveness, production innovation and product complexity. Production runs are becoming ever shorter as tastes and fads change.

While food processing may be classified into either chemical, physical or biological operations, there are many major issues affecting food process engineering including molecular genetics with the use of GMOs, the use of animal cloning, new regulatory procedures, ethical issues, public concerns, planetary considerations and a number of major socio-economic considerations. The underlying requirements for technological progress in food processing are a minimum of risks acceptable for the benefits gains, as well as a full public understanding. The role of the food process engineer is critical in all of this.

1.1 Food Processing

The fundamental necessity for food is to sustain life. The principal reason for the processing food is to make it microbiologically safe to eat. Processing foods can transform unpalatable or unacceptable raw materials into attractive and desirable products.

Nutritional requirements are required to be met throughout the year. Before the development of preservation techniques, winter diets were based mainly on cereals, grains and fruit that were dried on the plant before harvesting. In Northern Europe livestock such as pigs and cows were once slaughtered in the autumn, as there were insufficient foods available to sustain them during the winter months. The meat was then preserved by salting and curing allowing it to be available for out-of-season consumption.

In the processing of foods, it might be assumed that a food product ought to resemble the appearance and taste of the raw food material. While this is the case for tinned or frozen garden peas, foods such as smoked sausages and canned baked beans are quite different from their fresh precursors and are, in some cases, even more popular.

Over the centuries, producers and consumers have become geographically separated through increased urbanisation; supermarkets have flourished which can now handle foods with a minimum of specialised equipment. Tinned and bottled products have a long storage life and require little specialist storage. Diary products with a short shelf-life such as pasteurised milk require little more than refrigeration.

1.2 Food Safety and Control

The highest priority of the food industry is to ensure that the foods which are processed are safe to consume. In recent times, there has been much publicity concerning major issues such as BSE in beef, genetically modified crops, nitrates in water, dioxins in livestock, listeria in blue cheese, E. coli 0157 in cooked meats and melamine in infants' milk to name but a few. A major cause of illness in humans is due to foods contaminated due to poor processing conditions, sanitation, working practices and packaging.

Storing food to prevent spoilage often involves destroying or inactivating contaminating pests such as insects, rodents and microorganisms. When these are capable of producing disease in humans (that is, they are pathogenic) this becomes even more important. The cooking of meat, for example, destroys both spoilage and pathogenic organisms. If care is taken by the provision of a suitable barrier, as in canning, to ensure that they are not reintroduced, the storage life of the product may be extended from a few to hundreds of days.

Once a contaminated food is ingested, the organism continues to multiply inside the body, reaching a population size sufficient to cause noticeable symptoms. Depending on the organism and food, control is either by ensuring that the contaminating organism is unable to infect the food in the first place or by destroying it during a cooking process.

As examples, the harmful bacterium *Staphylococcus aureus*, is readily destroyed by the normal cooking process. Its toxin, however, is very resistant to boiling. Botulism is a very serious type of poisoning caused by eating food containing the toxin produced by the bacterium *Clostridium botulinum* for which the spores are very resistant to many cooking processes.

It is not always necessary to eliminate all contaminating organisms. It may often be necessary to ensure a satisfactory level of safety under given storage conditions. Commercial sterilisation is designed to destroy all micro-organisms and spores, which if present, could multiply in the food while pasteurisation is designed to destroy only those microorganisms which are pathogenic. It makes no attempt at destroying all the microorganisms that may be present.

The growth and viability of micro-organisms in foods is influenced by the availability of water. The presence of high concentrations of osmotically active substances such as salt or sugar also influences growth and viability as well as the presence of acids. Preserved foods vary from neutral pH to acidic. Only fungi are likely to grow below pH 3.7 although a mild heat treatment is often desirable for foods in this category to stop fungal spoilage and inactivate enzymes. Acidic foods, such as fruit, require pasteurisation to destroy vegetative organisms. It is not always necessary for spores to be destroyed in this pH range, as any spores present are unable to germinate below pH 4.5. Low acidic foods such meat, fish and milk require sterilisation to ensure that resistant spores are destroyed.

Since heat treatment often affects the quality, appearance, texture and taste of food as well as micro-organism content, the choice of heat treatment conditions is important. Heat is an effective way of eliminating microbial hazards when combined with adequate hygienic practices, such as the hygiene of personnel and sterilisation of equipment. This also helps to minimise the chance of infection with the larger human parasites such as tapeworms and roundworms.

Heat treatment is a requirement by law for many products. UK and European regulations require that food consisting of meat, fish, milk and egg must be stored below 10°C or above 62°C unless displayed for sale or intended for immediate consumption. This is because the pathogenic bacteria, *Salmonellae, Staphylococci, Streptococci* and *Clostridia* are unable to reproduce outside this temperature range.

1.3 Food Quality

The properties and qualities of foods, which affect acceptability to the consumer, are referred to as organoleptic properties. It is impossible to quantify the definition of food quality because it varies between each person's expectations. Food may be liked or indeed disliked as a consequence of many factors which may be religious, cultural, social, psychological or on health grounds, as well as certain expectations of appearance, texture, flavour and aroma.

Consumers are generally concerned that the quality of a food product has a consistent standard, which may be defined in terms of its organoleptic properties. Food producers, farmers, caterers and food manufacturers must therefore be capable of maintaining certain objective quality standards. The quality of certain products can be tested by a trained panel of experts who can detect whether a product has attained a necessary standard. However, it is rather expensive to use expert panels. Mechanical or electronic techniques and instruments are therefore frequently used which are capable of providing an objective measurement of a particular attribute.

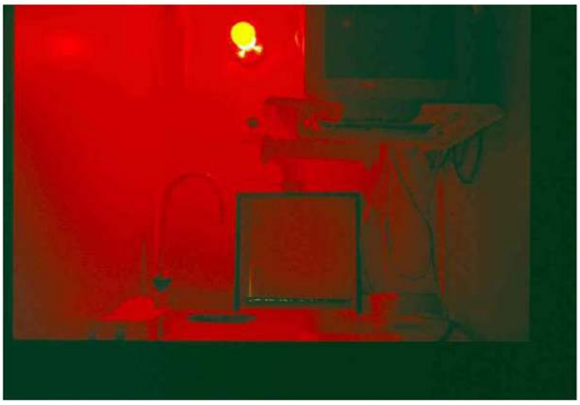
1.3.1 Temperature

The temperature of a food is the easiest attribute to measure and involves a thermocouple linked to a data logger. This can provide important information on the physical, chemical and microbiological changes taking place before, during and after processing.

1.3.2 Colour

The perception of colour depends on both physical and psychological factors. Spectral colour is defined by the predominant wavelength of light while saturation is defined as the degree of mixture of that dominant colour with white. Brightness, on the other hand, is associated with the total amount of light energy reflected or transmitted by the food. The colour of food is most easily measured by matching with standard colours under standard lighting conditions.

Standard lighting colour, along with humidity and temperature control is used during sensory analysis with trained assessors as shown in the photograph below.



1.3.3 Texture

Texture is a complex property relating to the physical and chemical structure of the food. Foods range from hard to soft, brittle to chewy. Hardness is a measure of the force required to cause a given deformation. Softness means that food can be squashed easily between the teeth although disintegration may occur. Cohesiveness and gumminess is the strength which holds the food together and the resistance to the withdrawal of teeth, respectively. In contrast, chewiness is the energy needed to disintegrate the food. The elasticity of foods is the rate at which a deformed material returns to its original shape and adhesiveness is the work necessary to overcome the attractive forces between the surface of the material and the other surfaces in contact with it. Brittleness is the force necessary to cause fracture. Applied to liquids, viscosity is a measure of its thickness or thinness.

To measure the texture of foods, various instruments such as penetrometers are used. These are probes which travel a certain distance into a sample of food when subjected to an applied force. Viscometers are used to measure the consistency of sauces, dressings, purées and batters.

1.3.4 Flavour and Taste

Foods may be liked or disliked based on flavour and taste alone. Flavour components may be present in food in minute quantities. Flavour can be distinguished into the four elements of sweetness, acidity, bitterness and salt. All are sensed by specific cells on the tongue. Taste is these basic flavours combined with odours, sensed in the nose, which arise from the volatile components of the food. Sweetness, for example, is associated with sugars while acidity is associated with organic acids such as vinegar, or mineral acids such as phosphoric acid in cola. A number of compounds in addition to common salt give rise to saltiness, including sulphates, bicarbonates, nitrates and phosphates of calcium, potassium, magnesium and ammonium. Bitterness arises from tannins in tea.