FOOD MIXING

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Summary

The term “mixing” essentially refers to operations reducing the non-uniformities in the spatial distribution of composition, properties, or temperature within bulk material. In the context of food processing, this is a necessary step. A variety of equipment is commercially available for use in specific mixing operations, such as dispersing flavor into solutions or solids, homogenizing a suspension of particulates, forming pastes, and dissolving gases in aqueous solutions.

These types of equipment are invariably very complex in design and the mechanisms by which homogeneity is brought about are not fully understood. This article highlights the characteristic features of food mixing, and provides an overview of the methods used to assess mixture quality and the types of equipment used for different processing operations. The scale of scrutiny determines whether a mixture can be considered as homogeneous or not. When a product contains several different phases, it is inevitable that it will appear segregated at a sufficiently small scale of scrutiny. The key consideration for any processor is to ensure that the product maintains homogeneity when examined on the consumer’s scale of scrutiny.

1. Introduction

Mixing or dispersing ingredients is an essential step in most food processing operations. Ingredients can be used in any physical state of matter - solid, liquid or even gas. They can be dissolved to form a single uniform phase, or dispersed homogeneously to form multiphase mixtures. Today, a large majority of processed ready-to-eat products are indeed multiphase dispersions: solids dispersed in liquids (e.g., baked beans), emulsions (e.g., soups), or bubbly dispersions (e.g., ice cream, meringue, sponge cakes, etc.). Mixing is therefore recognized as one of the most widely practiced food processing operations. A wide variety of mixing equipment is in use, and novel mixing technologies are constantly emerging on the industrial scene. A glance at some of the recent issues discussed in food abstracts provides ample evidence of innovation occurring in this area, especially in the issues relating to mechanical features. Yet, it would not be inaccurate to describe food mixing as one of the least understood processing operations. Despite the wide existence of a variety of mixers effectively used thus far, the mixing mechanisms operating within these devices are hardly understood. Consequently, it is extremely difficult to relate operating conditions with product quality on a firm scientific basis; and process design and control can only be achieved with the help of expensive practical trials. This article discusses the process engineering issues related to food mixing, and highlights some of the practical challenges.

A series of papers published in the first half of the 1990s reviewed and divided food mixing into five parts. The first segment described the fundamentals of mixing and discussed mechanisms that affect the process. The second part focused on the mixing of highly viscous and cohesive materials, while the third addressed powders and particulate materials. The fourth described methods to assess and monitor mixture quality; and, finally, the fifth discussed the types of mixers used in practice. Although these reviews provided an exhaustive summary of literature relevant to food mixing, the special features of mixing in modern food processing were highlighted in two other articles. It would be worthwhile summarizing these at this stage.

2. Special Features of Food Mixing

- Mixing involves a whole spectrum of materials from dry free-flowing powders to thin, viscous liquids and viscous pastes such as dough.
- More often than not, mixing involves too many components existing in different physical states, which have widely differing and time-dependent properties.
- Energy requirements for dispersing each component can also differ widely. For instance, emulsification requires high energy, whereas dispersion of delicate particulate matter in shear sensitive liquids requires relatively lower energy levels (e.g., dispersion of nuts into chocolate or whole fruits into yogurt).
- Mixing particulates also involves other characteristics: mixing and segregation occur simultaneously, and particulates are often polydisperse. Particle-liquid dispersion either involves particles dispersed into liquid bulk, or relatively low amounts of liquids dispersed with high volumes of particles (e.g., dispersion of flavors). Furthermore, when particles are dispersed into liquids, the rheological and interfacial properties of the continuous phase can change as mixing progresses (see

Food Suspensions). Moreover, segregation of blended components can also occur during discharge from the mixer: design of discharge is therefore critical.

- Food mixing can involve dispersion of air or gas bubbles into liquids and pastes. Bubble incorporation in processes (e.g., the manufacture of ice creams, sponge cakes, meringues, and bubbly chocolate confectionery) is so widely practiced that air and gases are increasingly being recognized as "food ingredients".
- In contrast, bubble incorporation, which inevitably accompanies the mixing of viscous recipes (e.g., sauces and salad cream), is undesirable, since it can result in inconsistent filling of packages and acceleration in spoilage. De-aeration or bubble exclusion can be classified as a food mixing operation since the end product results in a greater level of homogeneity.
- An idiosyncratic feature of food mixing (like many other food processing operations) is that it is rarely a process where mixing is the sole intended effect. A multitude of physico-chemical processes occurs simultaneously in the mixer environment, and the effectiveness of mixing can only be assessed in the context of end product quality.
- Finally, the effect of mixing can continue well after the mixing action has ceased, and it could be quite some time before the end point is reached. In such situations, on-line monitoring and process control can be very challenging.

It is therefore evident that the state of any mixture is the result of several highly complex mixing mechanisms operating in parallel. At this stage, it is desirable to discuss the ways of describing mixtures.

3. Assessment of Mixedness

3.1. Scale of Scrutiny

Although mixing normally aims to achieve an almost uniform distribution of components, the degree of uniformity must be assessable. An obvious method is to measure the concentration of each component and express it in terms of appropriately defined relative concentration. A problem at once arises. Since such assessments depend on sample size, what then should the *scale of scrutiny* be? It is inevitable that, as the scale of scrutiny decreases, a given component will appear more segregated. This is illustrated in Figure 1. It is necessary that any practical process should achieve homogeneity on a pre-determined scale of scrutiny. From a producer's perspective, this scale may correspond to the volume of unit packages.

However, this does not necessarily correspond to the consumer's scale of scrutiny, which could be much smaller. One example used concerns the mixing of nutrients to form a cake for animal feeding. If the primary concern were to ensure that each animal receives the correct amount of nutrients daily, then the appropriate scale of scrutiny would be the volume corresponding to the daily intake of cake. However, if the criterion is to control the nutrient intake on a weekly basis, then the scale of scrutiny should be chosen according to the weekly consumption of cake. In the latter case, significant variations in nutrient concentration between daily feeds might exist, but averaged over the entire week, the nutrient intake would satisfy the overall requirement. It is therefore important to produce a product that is homogeneous based on the *consumer's scale of scrutiny*.

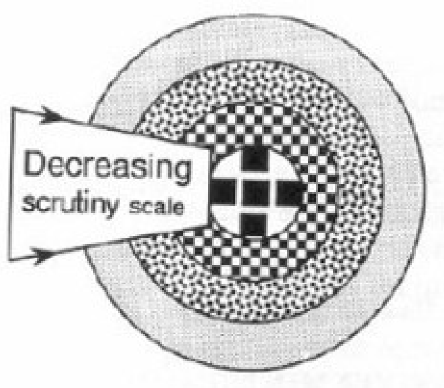

Figure 1. Appearance of mixture as scale of scrutiny decreases progressively. It is evident that the components appear more segregated.
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Biographical Sketch

Keshavan Niranjan is a Senior Lecturer in Food and Bioprocess Engineering at the School of Food Biosciences, The University of Reading (UK), where he has worked since 1989. Before this, Dr. Niranjan worked at the Department of Chemical Engineering in Cambridge, and the Department of Chemical Technology at the University of Bombay where he completed his Ph.D. His key expertise includes modeling of processing operations, which involves mass transfer, heat transfer and mixing in multiphase biological systems, especially those involving sparged bubbles. Dr. Niranjan is currently Chairman of the Food Engineering Group of the Society of Chemical Industry (SCI) in London. He is also a Food Engineering Subject Editor for the *Transactions of the Institution of Chemical Engineers (Part C).*