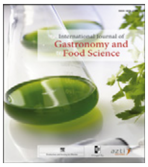

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# The engineering inside our dishes

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## Abstract

For an engineer the real value of a product is not in its molecular composition but in the intrinsic properties derived from the structure that is formed. Nobody cares about the molecules in a cellular phone except that they have to be arranged to receive and emit calls in reliable form. In the case of foods this brings the focus to the "engineering inside the product" rather than on the process engineering of mixing, drying, heating, freezing and so on, which has been the traditional realm of food engineering.

The objective of this article is to introduce food scientists, chefs and amateur cooks to basic concepts and terminology used in food materials science, and to give examples of the engineering inside what we eat.

*Keywords:* Cooking; Engineering; Taste; Microstructure

## Introduction

The structures we eat as foods are derived directly from nature, transformed by processing or developed in the kitchen as recognizable meals and dishes. In fact, our senses are adapted to perceive and identify the unique properties of such structures in the form of appearance, texture, juiciness, sound, etc. Although the scientific study of cooking has traditionally concentrated on chemical and physico-chemical aspects, in the last decades much interest has arisen in understanding the formation and stability of food structures from the materials science viewpoint (Donald, 2004). Advances in this direction have been favored by the availability of powerful microscopes and analytical techniques that probe into the molecular mobility and localized mechanical and rheological properties.

By food microstructure we understand the spatial arrangement and interactions of identifiable elements in a food, whose sizes are $< 100\ \mu m$ (Aguilera and Stanley, 1999). Fig. 1 shows several important structural elements related to foods, their approximate sizes as well as the sciences behind the phenomena at each length scale. The dimensions from molecules to products span almost eight decades. It is unfortunate that most of the structural engineering inside our foods occurs at sizes below 100 μm, being invisible to the naked eye.

For a physicist the range between the molecular size and the macroscopic scale is typical of soft condensed matter, or matter in a state between a liquid and a crystalline solid. At these dimensions molecules may participate in the formation of emulsions, viscous polymer solutions, gels and glasses. Thus, foods can be classed as soft matter but their multi-component nature and complexity set them apart from other forms of soft matter present in our daily life (Mezzenga et al., 2005). One important characteristic of soft matter is that some molecules tend to self-assemble, a first step in the formation of food structures. Thus, some ingredients such as surfactants and globular proteins may spontaneously associate into micelles or gels, respectively, given the right conditions.

For an engineer the real value of a product is not in its molecular composition but in the intrinsic properties

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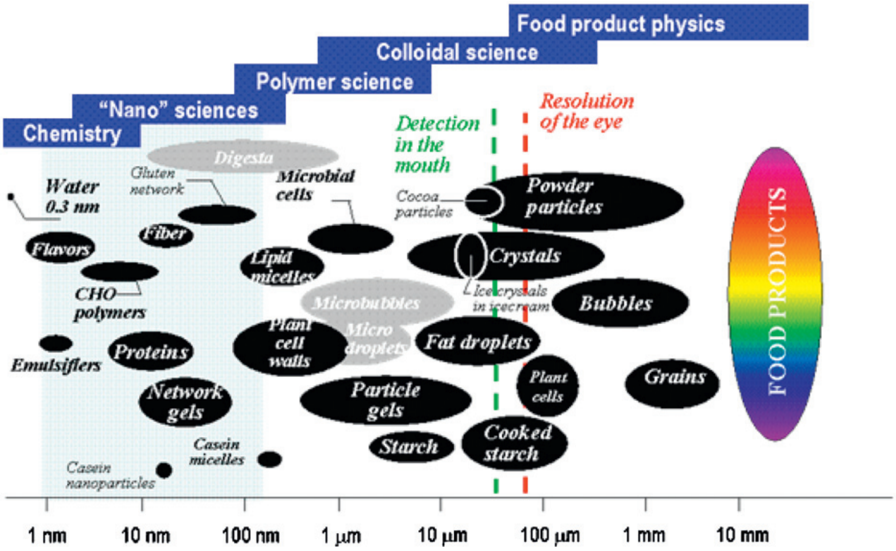

Fig. 1. Important structural elements related to foods and their approximate sizes. Dotted lines show the upper limit for particles to go undetected in the mouth and the minimum size that can be resolved by the naked eye. Gray area is the size range of nanosciences.

derived from the structure that is formed. Nobody cares about the molecules in a cellular phone except that they have to be arranged to receive and emit calls in reliable form. In the case of foods this brings the focus to the "engineering inside the product" rather than on the process engineering of mixing, drying, heating, freezing and so on, which has been the traditional realm of food engineering. One example illustrating this point are liquid dairy cream and whipped cream. Although the initial composition is the same, whipped cream being a foam and having air (which is not considered as an ingredient) dispersed as bubbles is a product with a higher value when it comes to decorating cakes and desserts. There are many other examples where the composition of foods is not a good predictor of their properties, but only a source of molecules to be exploited in making delicious structures.

The objective of this article is to introduce food scientists, chefs and amateur cooks to basic concepts and terminology used in food materials science, and to give examples of the engineering inside what we eat [a glossary of gastronomy and engineering terms may be found in Alicia and elBullitaller (2006)]. The reader who wants to get serious on the subject of food materials science, its principles and applications, is referred to the book edited by Aguilera and Lillford (2008).

## The engineering that cannot be seen but can be tasted

Interestingly, in reviewing the classic text on food and cooking by McGee (2004), the term structure is profusely used to describe the anatomical parts of organisms (that later will become foods) as well as the internal portions of processed foods as seen with an electron microscope. Engineering concepts such as stability of the structure of whipped cream (reinforced at the bubble interface by fat globules), the plasticity and elasticity of wheat dough, etc, are also referred to. This is a tacit recognition that a food "structure" is apparent to food scientists and cooks alike. People in referring to foods during mastication also use a terminology that is related to their structure: tough meat, grainy sauce, soft beans, etc.

In a first approach a food may be regarded as a building, a structure possessing many architectural elements made of different materials (e.g., glass windows, wooden doors, ceramic tiles, etc.) inserted within a continuous frame. Fresh plant foods derive most of their desirable properties from a structure formed by cells (around 100 µm in size) glued together by a complex pectin gel to make a tissue or organ. A thick wall, which is basically a polymer composite reinforced by cellulose fibers, surrounds each cell and provides resistance. Turgor, important in texture, is derived from the osmotic pressure exerted by the solutes in a solution that fills a vacuole inside the cell. Animal cells (e.g., muscle fibers), on the contrary, do not have walls and rely on an internal support system formed by proteins and encasing membranes to keep the cell's (in this case, fiber's) contents.

This construction analogy may be used to explain softening of tissues during cooking. Heating of grains and legumes swell the hydrated starch granules inside cells making them tender, but most of all, it solubilizes the cement binding cells together. Upon biting on a soft cooked bean individual cells slide one past the other, much in the same way as bricks stacked one on top of the other would fall in absence of mortar after being pushed. In a tough bean on the contrary, cells remain bound and mastication has to fracture the cell's content, which is equivalent to tearing down a wall made by bricks held by mortar. Meats also become tender by cooking when the collagen surrounding the fibers is solubilized.

Many processed foods may contain pores or air cells, crystalline and glassy phases, particles, oil droplets, etc, dispersed in a basic matrix (Fig. 2). The "architecture" in