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Physical Properties of Foods

PHYSICAL PROPERTIES OF FOODS

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Preface

In 1980 the IFT Basic Symposium Committee selected the topic "Physical Properties of Foods" as the theme of the 1982 IFT–IUFoST Basic Symposium, to be held immediately preceding the 42nd Annual IFT Meeting in Las Vegas, Nevada. This was a result of the growing importance of this field to the food industry as well as to government and academia. The term "physical properties" itself means many things to many people. It covers a large variety of physical phenomena that are dealt with by a multitude of scientific disciplines. Because of the vastness of the domain, the choice of topics to be discussed in the symposium was extremely difficult because of the inevitable result that, whatever was included for the limited time available, other important and interesting topics would be left out. The selection of topics was also limited by two other considerations. Instrumental aspects will be covered in a separate symposium in 1983. Engineering properties (e.g., thermal, electrical) were discussed at the 41st Annual IFT Meeting in Atlanta, Georgia (1981) during a symposium sponsored by the IFT Food Engineering Division, and the proceedings were published as an OverView in the February, 1982, issue of *Food Technology*. It was not possible to eliminate all reference to either instrumental aspects of engineering properties from discussions of physical properties in general, but the format and topics were chosen to minimize overlap with the 1981 and 1983 symposia. The final 1982 program, covered in four half-day sessions, was devoted to the following subject areas.

Session I: Principles and methods of measuring physical properties including electron microscopy, colorimetry, and differential scanning calorimetry.

Session II: Structure and other characteristics of plant, animal, synthetic, baked, and particulate foods.

Session III: Rheology of foods, doughs, and emulsions.

Session IV: Volatility, expressibility, stickiness, and phase transitions in carbohydrates.

The symposium took place on June 20 and 21, 1982, at Caesars Palace Hotel, in Las Vegas, Nevada. The success of the program is attested to by the excellent response, with 160 participants attending from the United States and abroad. The timeliness of the topic is apparent from this result and thanks are due to the Basic Symposia Committee for their foresight in choosing this topic area. The committee consisted of the following people: Ernest J. Briskey (Chairman), Oregon State University; John R. Whitaker (Past Chairman), University of California-Davis; Wassef Nawar (1982), University of Massachusetts; John D. Sink (1982), West Virginia University; Darrell E. Goll (1983), University of Arizona; Richard V. Lechowich (1983), University of Arizona; Larry R. Beuchat (1984), University of Georgia; and Thomas Richardson (1984), University of Wisconsin-Madison.

There are many details to be arranged in such a meeting, from publicity to meeting room arrangements. Thanks are therefore extended here to the IFT staff, under the direction of Calvert L. Willey, Executive Director of IFT, for the very smooth and trouble-free operation. Special thanks are accorded to John B. Klis, Director of Publications, and Anna May Schenck, JFS Assistant Scientific Editor, for their invaluable help, not only before and during the meeting, but for their patience, persistence, and expertise in bringing this volume to completion.

We also thank the management and secretaries of the USDA Northern Regional Research Center and the Department of Food Engineering at the University of Massachusetts for their assistance. Without their cooperation this symposium and book would not have been possible.

MICHA PELEG
EDWARD B. BAGLEY

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Physical Properties of Foods: What They Are and Their Relation to Other Food Properties[1]

Alina Surmacka Szczesniak[2]

INTRODUCTION

In a broad sense, the physical properties of foods may be defined as those properties that lend themselves to description and quantification by physical rather than chemical means. Their importance stretches from product handling, to processing, to consumer acceptance. Most of the early advances in this area have been made in the context of agricultural products, with much credit due to agricultural engineers, quality control personnel, and agriculture-oriented universities. More recently, food process engineers and food scientists interested in this area have made significant contributions. Although much still needs to be researched and understood, these efforts have resulted in a sizeable body of organized knowledge.

Much of this knowledge has been developed against the objective of determining and quantifying quality factors that govern consumer acceptance, suitability of the product for specific uses and, thus, its economic value. Kramer defined quality of foods "as the composite of those characteristics that differentiate individual units of a product, and have significance in determining the degree of acceptability of that unit by the buyer" (Kramer and Twigg 1970). He classified quality attributes as quantitative (e.g., proportion of ingredients, drained weight); hidden

[1]This chapter is dedicated to Prof. Amihud Kramer whose death on Dec. 8, 1981, prevented him from discussing this subject within this Symposium.

[2]Central Research, General Foods Corp., White Plains, New York 10625.

(e.g., nutritive value, adulterants, toxic substances); and sensory (e.g., appearance, kinesthetics, flavor). Physical properties classified as sensory attributes are of specific interest to this discussion and will be treated in some detail.

Another area of technical needs that gave impetus to research on physical properties of foods were problems in handling and processing of foods. Important in handling are the engineering parameters of shape, size, volume, density, and surface area. Furthermore, storage of grains and seeds in silos, mechanical harvesting, and transport of fruits and vegetables over long distances require that the products withstand static and dynamic loading, the latter often of impact type. Thus, the engineering parameters having a bearing on the behavior of foods on handling must encompass the stress–strain–time relationships. Friction, as in silos, both against the surface of the grain and against the surface of the construction material is another physical force of importance.

Processing may involve thermal, mechanical, rheological, electrical, and other physical properties of foods. Thermal properties, such as specific heat and conductivity, are important in food preservation processing involving adding or removing heat as in canning, pasteurization, and freezing. They are also important in dehydration, although mass transfer and other physical properties of the food, such as its porosity, may be more important.

Within the group of electrical properties are electrical conductivity and capacitance, dielectric properties, and reaction to electromagnetic radiation. The ability of a particle to hold a surface charge, which is determined by its electrical conductivity, has been used to separate similar seed varieties and to make hydrocolloids more dispersible in water. Dielectric properties govern the behavior of the food in dielectric and microwave heating. The most important application of microwave energy is rapid thawing–heating–cooking both in the home and in institutional feeding establishments. Its applications to food processing have been limited by cost comparisons to other heat sources and by cost–quality relationships. Key industrial applications have been in finish drying, e.g., of potato chips.

Mechanical properties and rheological properties govern the behavior of solid materials during size reduction processes such as grinding or pureeing of fluids during flow through pipes and orifices, and very importantly, they affect the consumer acceptance through the sensory property of texture. Included in this concept are also the terms "consistency" and "mouthfeel."

Other physical properties of foods important in handling and processing are aero- and hydrodynamic characteristics affecting transfer through air or water, and surface properties: surface tension, contact angle and surface rheology.

Let us now examine some selected physical properties of foods in detail and address their bearing on food quality.

GEOMETRICAL PROPERTIES

Historically, geometrical properties encompass the parameters of size, shape, volume, density, and surface area as related to homogenous food units. Included in this group of physical properties should also be the geometrical characteristics of texture (Szczesniak 1963A) which, for the most part, refer to structural geometry and structurally heterogenous foodstuffs. The geometrical texture characteristics can be divided into two classes: those referring to particle size and shape (gritty, grainy), and those referring to particle shape and orientation (fibrous, cellular). These are best treated within a discussion of textural parameters and will not be discussed here.

Size and Shape

We can differentiate here two general cases: (1) food products, such as agricultural commodities, in which the shape and size can be differentiated with the naked eye, and (2) food powders, such as ground coffee, salt, and milk powder, in which the differentiation of shape and size can be best done with the aid of magnifying lenses.

The size and shape of an agricultural commodity, or of a processed product, not only have hedonic connotations (i.e., affect the degree of consumer acceptance) but in many cases also influence packaging, distribution of stresses when forces are applied, and processability. Round tomatoes are difficult to harvest mechanically and to pack, and the concentration of stresses in small areas results in easy bruising. Thus, considerable efforts were expanded by plant breeders to produce a "square" tomato (Stevens *et al.* 1976).

In the area of food powders, serious processing problems are encountered in soluble coffee manufacturing owing to the presence of fines in ground coffee. These will clog extraction columns causing machinery downtime. Similarly, fines will clog filters in home brewing equipment. Particle size and, especially, particle size distribution in porous media have been shown to govern permeability to water and, thus, will affect extractability and solubility characteristics.

As pointed out by Medalia (1980), "to define the shape of a body fully, one must specify the location of all points on the external surface." This is a very time-consuming process that also poses mathematical difficulties, especially when applied to powders whose shape tends to be much more irregular than that of agricultural commodities. This is especially true of agglomerated powders.

For these reasons, qualitative shape descriptions are the most popular with food graders. The shapes of fruits and vegetables have been classified into 13 categories such as round, oblate, oblong, conic, elliptical, truncated, ribbed, etc. (Mohsenin 1965). Standard charts have been prepared such as the one shown in Fig. 1.1 for apples. They enable the grader to characterize the shape either by a number on the chart or by word description.

The most prevailing method for quantitative shape description involves calculations of similarity to a sphere:

$$\text{sphericity} = d_e/d_c$$

where d_e is the diameter of a sphere of the same volume as the test object and d_c is the diameter of the smallest circumscribing sphere (usually the longest diameter of the test object). Other equations for calculating sphericity have been given by Mohsenin (1980). Published values for the sphericity of fruits are of the order 89–97. These values are ex-

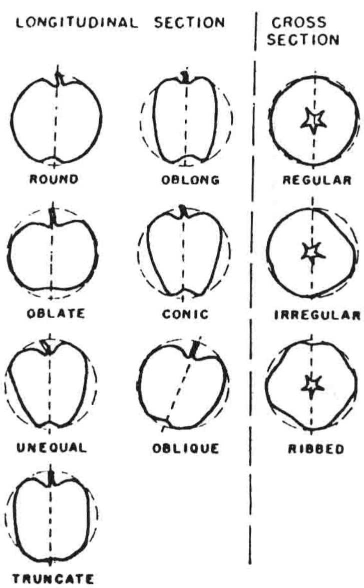

Fig. 1.1. Charted standard for describing the shape of apple fruit.
From Mohsenin (1980).