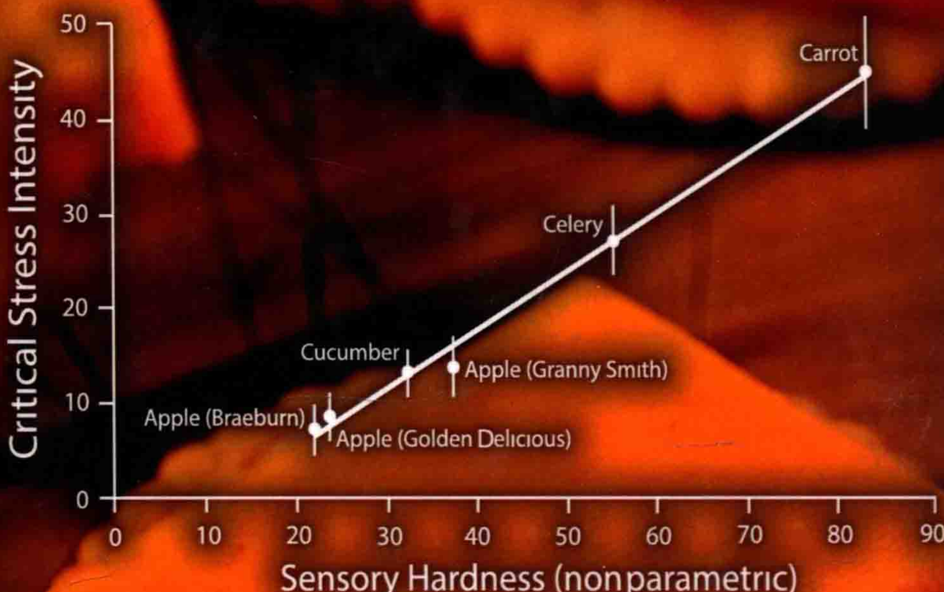
TON VAN VLIET

RHEOLOGY and FRACTURE MECHANICS of FOODS



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Preface

The main theme of this book is the rheological and fracture behavior of foods. The focus is on the basic principles of this behavior, the determination of rheological and fracture properties, and the relation between these properties and the structure of model food products.

People working in the field of food production have realized for quite some time that the mechanical properties of food are essential quality characteristics of these products. These properties play an important role during the manufacture of food and intermediate products, their storage, handling, and last but not least during consumption.

Initially, mainly empirical approaches were used for determining the mechanical properties of food. This was especially the case with respect to getting instrumentally an impression of humans' perception of these properties during consumption and meal preparation. Less than a century ago, scientists generally considered sensory perception of the mechanical properties of food during handling and consumption so subjective and unreliable that it could not be studied seriously in a profound way.

On the other hand, process engineers started to realize quite soon the great value of determining the rheological properties of liquid and liquid-like food products for improving existing processes of food production and developing new ones. For this purpose, they could make use of series of measuring methods and sets of equations describing the flow of liquids under various conditions that were developed outside food science and technology. However, many liquid and liquid-like foods are structurally very complex. The description of the flow behavior of these products turned out to be more complex than, for instance, that of simple polymer solutions. Moreover, the relation between the rheological properties of foods and their sensory properties turned out to be very complicated. Pioneering work on the rheology of food products was carried out by the famous British scientist, Scott Blair, and his coworkers.

It was the valuable contribution of Alina Szczesniak and coworkers and many other scientists that highlighted the essential role that the mechanical (both rheological and fracture) properties of food (food texture) play with respect to the appreciation of solid and solid-like food products. Moreover, after 1960 more and more methods became available for determining these properties in such a way that the results obtained were relevant for estimating the texture perception of food products. In addition, there was a growing awareness of the importance of many more aspects of the fracture behavior of food products for texture perception of solid and solid-like foods than originally thought.

Initially, the fracture behavior of brittle (hard solid) food products was characterized relatively simply by determining the stress at which the product fractured. However, for soft solid products such as margarines, butter, gels, various cheeses, jellies, dough, meat and meat products, fracture behavior was observed to be much more complex than that of materials usually studied in the field of fracture mechanics. Fracture behavior was observed to depend on certain factors such as speed and the way of deformation. It turned out that for a profound characterization of the mechanical properties of soft solid products, concepts developed in the fields of rheology and fracture mechanics are required.

There are several good books available that discuss the rheology of foods. Mostly they are limited to liquid and liquid-like food products. Furthermore, there are several good books that discuss food texture and how to measure it using instruments and/or human panels. In some of these books, some aspects of fracture mechanics are also discussed. In addition, there are various books on fracture mechanics of engineering materials and/or polymer systems. However, as discussed above, for a profound analysis of the mechanical properties of many food products, one needs a basic understanding of rheology and fracture mechanics as well as the ability to combine concepts from both science fields. With this book, I have attempted to provide basic knowledge of both rheology and fracture mechanics to enable the readers to gain a profound understanding of the mechanical behavior of various classes of food products. Moreover, a discussion is given on the relation between mechanical properties and the structure of food products at various length scales. In the last chapter, a short discussion is given on the relation between rheological and fracture characteristics of foods and texture perception.

The book can be used as a course book for food science majors and for students with a minor in food engineering. I realize that for both purposes, a selection has to be made of the topics discussed to let the content fit better with the background of the students following the course. The book is primarily written as a textbook; a second aim is that it can be used as a reference book by people working in the field of food research and development. I have tried to keep the mathematics at a relatively low level (no tensor calculus). In places where a derivation is given for a relatively complicated equation, I have tried to do so in such a way that one can understand the most important steps in this derivation without being able to follow the mathematics in detail.

For several chapters, I used parts of the chapter on rheology that I wrote together with Hans Lyklema for volume IV of his book, *Fundamentals of Interface and Colloid Science*. In addition, extensive use was made of the numerous lectures that I have given as part of the courses on rheology and fracture behavior of foods for undergraduate, graduate, and postdoctoral students at Wageningen University and abroad and for industries.

As mentioned above, I have made no attempt to cover all aspects of rheology and fracture mechanics of foods. Had I done so, the size of this book would have doubled at least. Self-evidently, the selection of the topics is colored by my experience and opinions and the extent to which topics have been discussed in the literature. This is especially the case for the choice of examples illustrating the relation between food structure and their rheological and fracture behavior.

Acknowledgments

Several colleagues have contributed to this book in a direct or indirect way. First of all I am indebted to the late Prof. Pieter Walstra for the many discussions we had on rheology and fracture mechanics of foods. I also want to especially thank Prof. Tiny van Boekel, Wageningen University, who has read and commented on all chapters. I am likewise grateful to Prof. Allen Foegeding, Raleigh, North Carolina, USA, who scrutinized several chapters and provided good suggestions that improved the manuscript. Without the contributions of my PhD and postdoctoral students and coworkers to the development of various parts of the knowledge discussed in this book, I would never have been able to write it.

I am greatly indebted to Marlies Meijer for all the computer work she did, which was necessary to enhance the figures from the basic ones I prepared. And last, but not least, I am very grateful to my wife, Willemien, for her understanding, love, and support.

Author

Ton van Vliet graduated with a degree in food technology from Wageningen University in 1973. He earned his PhD in physical chemistry and colloid sciences from the same university in 1977. After a post-doctoral fellowship at the Weizmann Institute of Science in Israel, he became an assistant professor at Wageningen University in the Food Physics Group, and in 1984 he became an associate professor. From 1998 until his retirement in 2010, he worked as a project leader at the Top Institute Food and Nutrition (TIFN).

His main research interest is rheology and fracture mechanics of food systems, in terms of their composition, structure, and physical stability. In his research, a range of rheological techniques were used in addition to techniques such as microscopy, permeametry, x-ray diffraction, and pulse nuclear magnetic resonance (NMR). He tries to bridge the gap between fundamental and predominantly curiosity-driven research and research resulting from problems in the food industry.

At TIFN, Dr van Vliet was the project leader of large projects on the stability of emulsions and foams, crispy/crunchy behavior of cellular solid foods, and effects of water migration in solids.

During his career, he has worked with scientists from various disciplines, and has published about 300 scientific papers on many topics in the field of food physics in a wide variety of journals. He taught at the university holding lectures for undergraduate and graduate students, and was responsible for establishing experimental courses, and thesis supervision for many MSc and PhD students. He also conducted various post-doctoral courses at the university as well as in industry on a contractual basis both in the Netherlands and abroad.

Dr. van Vliet served as the editor of the *Journal of Texture Studies* for 14 years. In 2008, he received the Carl Wilhelm Brabender award from the American Association of Cereal Chemists (AACC) for his outstanding contribution to the field of rheology as applied to the milling and baking industry (this award is presented every 3 years), is listed by Thomson ISI as a highly cited researcher, and is an elected member of the International Academy of Food Science and Technology (IAFoST).

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Introduction