THE UNIVERSITY OF MANITOBA

RATIO SCALING OF SWEETNESS AND TEXTURE IN THREE HYDROCOLLOID GELS

by

ROBERTA KATHLEEN YORK

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

DEPARTMENT OF FOODS AND NUTRITION

WINNIPEG, MANITOBA
AUGUST, 1972

ABSTRACT

Ratio scaling was used as the technique to study the pattern of sweetness and texture perception in three experiments using gelatin, low-methoxyl pectin (LMP) and xanthan gum-locust bean gum (XLB) gels with glucose as the sweetening agent. Ratio estimation values from a five-member, trained sensory panel were compared to physical texture dimensions from the General Foods Zenken Texturometer through both the linear function ($T = nC + k$) and Stevens' power law ($T = k\ C^n$). Sweetness perception in gels followed the power law with the exponent, n, for each gel the same as that for the corresponding glucose-water solutions in that experiment. The sweetness log intercept decreased as the concentration of hydrocolloid increased. Sensory measurements of firmness by mouth and touch were related to physical measurements of hardness through the power law for gelatin and LMP. The exponent was $n = 1.2$ and the log intercept seemed to be hydrocolloid specific. There was no linear or exponential relationship between sensory and physical measurements of cohesiveness and adhesiveness. Melting time of gelatin was related to hydrocolloid concentration by a linear function ($n = 1$ for the power function). Through the use of a specially designed back-extrusion cell with the Allo-Kramer Shear

Press, differences in particle size among levels of gelatin and XLB were demonstrated.

ACKNOWLEDGEMENTS

Special acknowledgements are due to three people: Dr. Howard Moskowitz, Prof. Marion Vaisey and Prof. Ruth Diamant. The study was performed as a cooperative project with Dr. Moskowitz of the U.S. Army Natick Laboratories, Natick, Massachusetts, who programmed and performed the computer analysis of the data. The study was designed with the help of Dr. Moskowitz, Prof. Vaisey and Prof. Diamant. Many thanks go to Mrs. Diamant also for all of her help and encouragement during the research for and the preparation of this thesis.

The author wishes to thank Mrs. B. Thompson, Miss E. Dale, Sister A. Gillis, Prof. R. Berry, Mrs. C. Schwartz-Biggar, Miss M. Latta, Mrs. E. LeBlanc, Miss C. McLandress and Mr. L. Burtnick for their conscientious attendence of panel sessions in one or more of the hydrocolloid series; and Mrs. A. Watkins for her valuable assistance in conducting the panel sessions.

The author also wishes to thank Chas. Tennant and Co., Ltd and Sunkist Growers, Inc. for their donations of hydrocolloids used in this study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

Taste-texture interactions is an area that has been of interest to investigators since the 1950's. A limited number of papers have been published on the topic, all pointing to the fact that changing the texture of a food will affect the way the basic tastes are perceived when the food is taken into the mouth.

One of the kinds of agents used to vary the texture of foods are the many hydrocolloids currently used in the food industry. The wide use of these in formulated products makes it desirable to know as much as possible about the way they affect the perception of taste. The study of the way the use of different gels affects the texture is another area of importance.

Recently ratio scaling has been used in the study of taste, texture and taste-texture interactions in both foods and model systems of food products. Through Stevens' power law, it is often possible to demonstrate a relationship between the perception of a stimulus and a measurement of its physical intensity.

The purpose of this study is to examine the use of the power law to describe sweetness and several sensory dimensions of texture in three hydrocolloid gels and to examine the taste-texture interactions that occur.

REVIEW OF LITERATURE

Perception of Sensory Dimensions

Before one can consider the relationship between sensory and physical measurements of taste and texture, one must examine the physiological basis of the perception of these dimensions.

Taste Perception - Sweetness

The sensation of taste has been defined by Beidler (1966) as being the sensation produced when food is taken into the mouth and stimulates the receptors of the taste cells.

The general structure of the sense organs for taste has been described by Hellekant (1969). Taste perception in mammals is by "specific structures, the taste buds, in the epithelium of the tongue. Each taste bud is composed of several elongated cells, the chemoreceptors, which, by means of microvilli are in contact with the fluid on the surface of the tongue. The basal parts of these cells establish synaptic contiguity with several nerve fibres. These nerve fibres join and form nerve bundles which mediate the gustatory sensation to the brain."

The perception of taste is divided into four primary modalities: sweet, salt, sour and bitter. No one receptor cell responds only to one type of stimulus. That is, each taste bud responds to all of the taste substances but with differing sensitivities (Beidler, 1966). The areas of particular sensitivity have been established by electrophysiological readings. Sweetness is perceived mainly in the area of the tip of the tongue with sensitivity decreasing towards the base of the tongue. It is the simultaneous stimulation of a group of taste cells of varying sensitivities that results in the perception of taste quality of a given stimulus (Beidler, 1966).

Many studies have been done to observe and attempt to explain taste perception and its relation to the molecular structure of its stimuli. The strongest theory explaining sweetness perception at the molecular level seems to be the AH,B system put forth by Shallenberger (1963), Shallenberger _et al._ (1965), Shallenberger and Acree (1967) and Shallenberger _et al._ (1969).

This theory describes a stereochemical relationship between two types of groups which, when present together, cause the sweetness response to be elicited. The theory suggests that the saporous unit of all sweet-tasting compounds is a bifunctional group made up of an acidic (AH) and a basic (B) moiety with the A-H proton to B distance of about 3 Å.

Within the AH,B system, AH moieties which have been found are -OH, -NH, $-NH_4^+$, ArH and in special cases, -CH.

The B moieties which have been found are -O-, =O, Cl, -C=C-, and COO^-. The interaction between the sweet compound and the receptor site is said to be a hydrogen bond in which the AH,B of the sweet compound forms two simultaneous bonds with the AH,B unit in the receptor site (Shallenberger et al., 1969).

The stereic nature of this receptor site has been studied. Both D- and L- forms of monosaccharides elicit approximately the same response in sweetness scores. It seems that any individual sugar -OH group can act as either an AH or B unit. In amino acids, L-amino acids with an R group larger than the ethyl radical do not elicit the same sweetness response as do their D-forms. This has led Shallenberger et al. (1969) to suggest a spatial barrier which restricts access of those amino acids to the taste bud receptor site.

A study was performed by Birch et al. (1970) to test Shallenberger's theory. Although the theory explained sweetness perception most plausibly, the fact that there would have been isomerization of the sugar crystals when dissolved in the saliva, placed some doubt on the evidence for the theory. They used two stable, non-reducing glucosides, α,α-trehalose and α,D-glucopyranoside, the configurations of which would not change during the experiment. They found a molar proportionality between the two sugars and were thus able to support the theory.

Other support for this theory comes from the work of Dastoli (1968) and Dastoli and Price (1966). These workers have reported the isolation of a sweet-sensitive protein from extracts of bovine taste buds. This protein will combine and form complexes with sugars and other sweetening agents in a direct relationship to the concentration in solution. The strength of the bonds in the complexes was between 1 to 4 Kcal. per mole which is similar to the energy in hydrogen bonding (1 to 2 Kcal. per mole). Also, the protein discriminated among sugars in the same order of sweetness found with human subjects. The protein had a high lysine content and this amino acid would form a suitable AH,B receptor site.

Texture Perception

The perception of texture in the mouth is a complex relationship of the responses of the many structures present there.

The tongue functions to position the food for chewing and to break up the food by tongue-to-palate pressure. The tongue also responds to the various stimuli of taste, touch and temperature (Yeatman, 1972).

The sense organs for the perception of the mechanical properties of food have been roughly divided into three groups by Oldfield (1960):

1) those in the superficial structures of the mouth (the hard and soft palate, tongue and gums),

2) those around the roots of the teeth (in the peridontal membrane) and,

3) those in the muscles and tendons used in mastication.

Two types of nerve endings are found in the soft structures of the mouth. A network of free endings located there are thought to respond to touch and light pressure and probably thermal, chemical and mechanical stimuli at pain intensities. Organized structures present respond to deeper pressure, distortion by stretch and to cold. Nerve endings which are part of the dental nerves in the tooth pulp and in the peridontal membrane have been found to be sensitive to small pressures.

There is little known about the sensory mechanisms of skin by which mechanical properties of substances are assessed. Even less is known about the specific sensory mechanisms of the specialized structures of the mouth (Oldfield, 1960).

Measurement and Classification of Texture Dimensions

The correlation of physical and sensory measurements of texture is an important problem. The task is made more difficult because there is still lacking a good understanding of the sensory and motor functions involved (Oldfield, 1960). In addition to this there is the problem that the human is more sensitive and far more complex than the machine. The human can learn to perceive qualities which cannot be expressed in analytical terms without extensive and expensive research (Yeatman, 1972).

Texture has an important influence on consumers' attitudes towards foods. Studies done in the United States and Japan have indicated that not only is texture an important attribute in foods, but in some products it may be more important than flavor (Szczesniak, 1971; Yoshikawa *et al*., 1970). In both studies, the most common attributes mentioned were degrees of hardness, cohesiveness, and moisture content (Szczesniak and Kahn, 1971). Using word-association tests, Szczesniak and Kleyn (1963) found that consumers are generally highly aware of texture in foods. However, they are not always conscious of this awareness.

In a study of consumer awareness of texture in foods Szczesniak and Kahn (1971) found the following. Consumers seem to have difficulty in visualizing the concept of texture in foods. Flavor overshadows texture at the conscious level. Texture is taken for granted, considered an integral part of the nature of the food. Texture awareness is easily brought to the conscious level by defining the concept and using examples of specific foods. However, consumers can not distinguish between texture and consistency in foods.

Szczesniak and Bourne (1969) found, in a study of perception of firmness by untrained judges simulating consumers, that firmness could be one of several things depending on the degree of firmness. In soft foods, firmness is consistency (e.g. puddings), in the intermediate range it is deformation and in the higher range it is puncture or flexure.

A clear definition of texture is critical to a study of the sensory and physical attributes of texture. Until recently, there had not been a satisfactory definition of texture in foods. While several workers have proposed definitions (Kramer, 1959; Amerine et al., 1965; and Szczesniak, 1963a), none of these was entirely successful.

One of the main problems seemed to be that language provides too many adjectives which come to mind when a definition of texture is attempted. The problem is compounded by individual interpretations of each adjective in terms of previous sensory and social conditioning to foods (Corey, 1970).

In the introduction to a recent symposium on texture Kramer (1972) has proposed a broadly applicable definition of texture as "the disposition or manner of union of particles of a body or substance". This definition is further limited so that texture is defined as "that one of the three primary sensory properties of foods which relates entirely (or in addition to the other primary properties) to the sense of touch or feel and is, therefore, at least potentially capable of precise measurement objectively by mechanical means in units of mass or force". This definition has the advantage of identifying texture as a primary sensory property of food (along with flavor and appearance), specifying the method of perception by human subjects, and suggesting the general means of physical measurement of this property.

There are two principal reasons for measuring texture: 1) to establish quality control standards and, 2) to develop generalizations and hypotheses of a theoretical kind (Scott Blair, 1960). It is this second reason which is the subject of this section.

Because the relationship between descriptions of textural dimensions and physical measurements is still vague, one of the current objectives in texture measurement is the more accurate quantifying of sensory and objective tests currently used (Morrow, 1972). The use of psychophysical analogues is a technique for the study of basic physical measurements. This can be defined as "a model system which attempts to explain the relationship between psychological and physical measurement". This definition is vague but "it is basically believed to be the very core of food texture measurement" (Morrow, 1972).

The first system for the definition and classification of textural characteristics was put forth by Szczesniak (1963a). Textural characteristics were grouped into three catagories: mechanical, geometrical, and other (mainly fat and moisture content). The mechanical characteristics were reactions of the food to stress and were further divided into five primary dimensions and three secondary dimensions.

The five primary mechanical characteristics as defined by Szczesniak (1963a) are:

1) Hardness - the force necessary to attain a given deformation;

2) Cohesiveness - the strength of the internal bonds making up the body of the product;

3) Viscosity - the rate of flow per unit of force;

4) Elasticity - the rate at which a deformed material returns to its original condition when the deforming force is removed; and,

5) Adhesiveness - the work necessary to overcome attractive forces between the surface of the food and the surface of the other materials with which the food comes in contact e.g. teeth, tongue, palate.

Two of these characteristics, elasticity and cohesiveness, are machine-significant terms which are difficult to perceive organoleptically (Szczesniak, 1965).

The three secondary dimensions are:

1) Brittleness - the force with which material fractures. It is related to hardness and cohesiveness and is characterized by low cohesiveness.

2) Chewiness - the energy required to masticate a solid food to a form ready for swallowing. It is related to hardness, cohesiveness, and elasticity.

3) Gumminess - the energy required to disintegrate a semisolid food product to a form ready for swallowing. It is related to hardness and cohesiveness and is characterized by low hardness.

The idea behind using these dimensions for texture profiling was that texture was perceived in the mouth as a number of different sensations that could be perceived individually and integrated into a composite impression. The objective measurements of texture must do this also if they are to correlate with sensory analyses (Szczesniak, 1968)

The sensory characteristics have been related to physical measurements of texture taken from graphs obtained from the texturometer (Szczesniak et al., 1963). The texturometer has been described by Friedman et al. (1963). It consists of four basic units:

1) an articulator with a strain gauge sensing plate and fitted with plungers of varying diameters;

2) a fast-response pen recorder;

3) a variable-voltage power supply; and

4) a Wheatstone bridge circuit with balancing potentiometer for zero adjustment.

The interpretation of the graphs produced is given in Figure 1.

In sample testing the deformation in the texturometer is not strictly compression since the head of the plunger is not parallel to the sample platform. As the plunger moves down in an arc, an edge and then the rest of the plunger contacts the surface of the food. This sequence reverses as the plunger moves upward. The curves obtained are not taken to be direct measurements of texture but rather are measured for various features e.g. ratios of areas under the curves. These are used as the physical measurement of the texture characteristics used in the sensory analysis of texture.

Szczesniak _et_ _al_. (1963) evaluated the texture profile scales on the texturometer and found good agreement i.e. a linear relationship between the dimensions of chewiness, adhesiveness and gumminess and a curvilinear relationship between hardness, brittleness, and viscosity. The samples used as points of the scale had been selected as examples suitable to the scale, so good correlation would be expected.

Brennan _et_ _al_. (1970) reported on work with the