

Short Communication

Parameters of Texture Profile Analysis

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Although Texture Profile Analysis (TPA) is useful for most solid foods, the misuse of TPA parameters for liquid foods has led to misunderstandings and confusion. Here, we warn of the risk of misuse of TPA parameters for liquid foods.

Keywords: texture profile analysis, cohesiveness, hardness, adhesiveness

Introduction

Parameters observed in the texture profile analysis, hardness, adhesiveness and cohesiveness have been widely used for comparison of the sensory attributes and rheological properties of various foods (Fig.1; Friedman *et al.*, 1963). In the first proposal of texture measurement, a flat faced cylinder is used to compress a sample twice in a reciprocating motion that imitated the action of the jaw. Bourne proposed later that a uniaxial compression is simpler, and most experiments have been performed using this method (Bourne, 1978, 2002). There is no doubt of the usefulness of these parameters for solid foods even though these parameters are, of course, not material constant and depend on measurement conditions such as compression speed, temperature and especially on the strain (the extent to which the sample food is compressed). This is often represented by the clearance indicating the gap between the plunger and the base plane of an Instron type apparatus for the measurement of compression or extension measurement.

TPA analysis has been widely used and is convenient for rapid evaluation of food texture, although the texture can be measured only by humans. In some experiments, liquid samples that cannot keep their shape but flow under gravity are poured into a cup and subjected to uniaxial compression. The obtained parameters are then discussed without considering

the validity or physical meaning of these TPA parameters, hardness, adhesiveness and cohesiveness. Referring to TPA parameters obtained for liquid foods contained in a cup is a “misuse” that the founder of TPA feared in 1998 (Szczesniak and Bourne, 1998).

Some review papers on TPA analysis were published in the Journal of Texture Studies in 1975. All of these papers described the application of TPA analysis for solid foods (Szczesniak and Hall, 1975) and various solid foods in Japan, where this method was most widely used (Tanaka, 1975). For liquid foods, the yield stress and the extensional viscosity are important textural parameters in addition to shear viscosity (Pollen *et al.*, 2004). Recently, Rosenthal (2010) warned of the deviation of some researchers from the original protocol in using TPA for the analyses of liquid foods. The present authors also feel the same danger, particularly in Japan, where semi-solid and thickened liquids for elderly individuals with difficulty in mastication and deglutition are widely evaluated by the TPA method (Consumers Affairs Agency, Japan).

Here, only the most dangerous interpretations are noted. When liquids, such as water, are filled in a cup and subjected to TPA analysis, the calculated cohesiveness becomes one. Let us examine aqueous solutions of xanthan. With increasing concentration of xanthan gum, hardness and adhesiveness increase, and cohesiveness decreases (Table 1). It is recognized that water has a high probability of inducing aspiration because it is the least cohesive, and tends to scatter into smaller portions. Yogurt is widely recommended for

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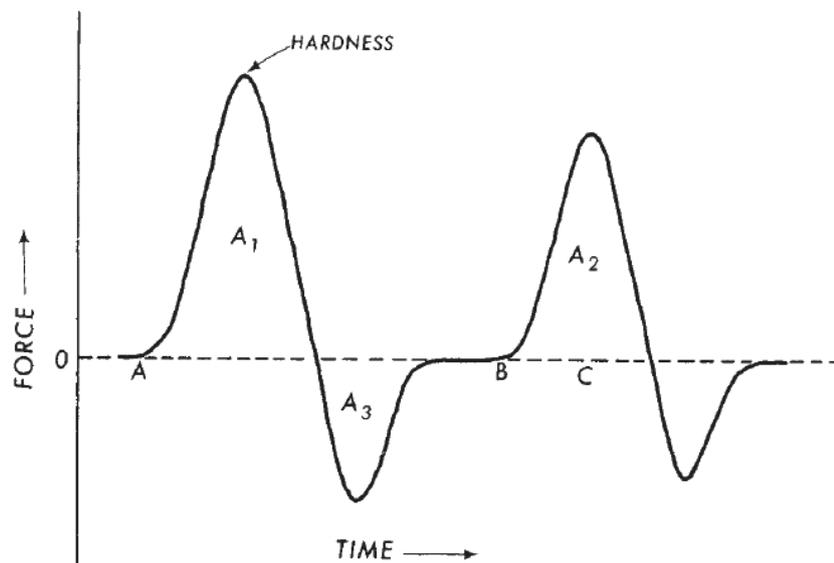


Fig. 1. Typical texture profile analysis (TPA) curve (from Friedman *et al.*, 1963).

Hardness: peak force during the first compression cycle. Adhesiveness: negative force area A_3 for the first bite. Cohesiveness: ratio of positive force area during the second compression to that during the first compression (A_2/A_1).

Table 1. TPA parameters for xanthan gum solutions of various concentrations.

Concentration (%w/w)	Hardness ^a (N/m ²)	Standard regulation ^b	Cohesiveness ^a	Standard regulation ^b	Adhesiveness ^a (J/m ³)	Standard regulation ^b
0	141		1.000	III	12.7	I
0.5	178		0.908	III	33.6	I
1	207		0.863	II	39.6	I
2	387	III	0.831	II	69.0	I
3	1050	II	0.750	II	172	I
4	2180	II	0.736	II	328	I
5	2620	I	0.706	II	364	I
6	2940	I	0.693	II	496	II

a. Mean values of at least triplicate measurements at 20°C.

b. See Table 2 in Appendix.

individuals with difficulty in mastication and swallowing because its texture is believed to be cohesive and does not scatter into small portions in the oro-pharyngeal cavity. The cohesiveness of xanthan gum obtained by a conventional TPA analysis is far smaller than that of water (Table 1). Thus, it is erroneous to extend the concept of the TPA analysis without considering its validity.

As the plunger may correspond to a tongue or a molar, measurement of compression force for liquid foods apparently simulates actual oral processing. What about hardness in this case? For many solid foods, a fracture point can be detected by the maximum force in an instrumental test, but for rubber-like gels such as konnyaku, clay-like foods such as moistened soybean powders, or liquid foods, the force increases steadily with compression distance up to clearance, and then decreases when the plunger stops or is pulled up. This apparent maximum force does not indicate the break-

ing point, and it increases with decreasing clearance. We may sense force during compression of rubber-like gels and liquid, but this should not be referred to as hardness because it depends on both the compression speed and the clearance. Breene (1975) discussed the uncertainty of these TPA parameters by mentioning the critical view of Sherman (1969), who proposed the term firmness rather than hardness. Of course, it also depends on the geometry, i.e., the shape and size of the plunger and the cup that contains the liquid.

What about adhesiveness? This also depends on the parameters mentioned above, and it depends on the surface properties, particularly the wetting behavior of the plunger.

Detailed mathematical analysis of the multiple compression of liquid foods by a plunger may be a future problem, and its physical significance is not fully understood at present. The present authors would like to recommend the observation of viscosity, viscoelasticity and yield stress, and

not the usage of the erroneous misused parameters hardness, cohesiveness and adhesiveness deduced by the inaccurate application of the TPA method for these liquid foods (Kumagai *et al.*, 2011; Nouchi *et al.*, 2012). It should be remembered that it is not possible to directly compare the TPA parameters observed for food samples with different textures, and the physical meaning of TPA parameters cannot be unanimously interpreted in a rigorous sense.

We hope that annular pumping (Bourne, 2002) will be studied and correlated with measurements in sensory tests, and that this test principle will become a widely used method. This method has not yet been exploited, and requires further study.

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Appendix

Consumer Affairs Agency, Government of Japan

Permission of display for foods for special dietary uses since 2009. Method of measurement of texture for foods prepared for individuals with difficulty in swallowing. Measurement of hardness, adhesiveness and cohesiveness Samples should be filled in a cup of 40 mm diameter and 20 mm height (if the sample does not overflow, 15 mm height is also permissible) to a depth of 15 mm.

Using an apparatus that can measure uniaxial compression stress, compression speed should be fixed at 10 mm/s and clearance should be set at 5 mm. A cylindrical plastic plunger of 20 mm diameter and 8 mm height should be lowered and raised twice. The temperature of the measurement should be set at $10 \pm 2^\circ\text{C}$ for foods eaten under cold conditions or at ambient temperature, and $20 \pm 2^\circ\text{C}$ and $45 \pm 2^\circ\text{C}$ for foods eaten after warming.

Table 2. Standard criteria for foods authorized for individuals with swallowing difficulty.

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Parameter	Standard regulation		
	I	II	III
Hardness (N/m ²)	$2.5 \times 10^3 \sim 1 \times 10^4$	$1 \times 10^3 \sim 1.5 \times 10^4$	$3 \times 10^2 \sim 2 \times 10^4$
Adhesiveness (J/m ³)	$< 4 \times 10^2$	$< 1 \times 10^3$	$< 1.5 \times 10^3$
Cohesiveness	0.2~0.6	0.2~0.9	—
Standard regulation I	Serious swallowing difficulty		
Standard regulation II	Moderate swallowing difficulty		
Standard regulation III	Slight swallowing difficulty		