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Determination of Yogurt Quality by Using Rheological and Textural Parameters

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Abstract. Sensory and textural parameters of yogurt are known to have an important impact on food quality and acceptability. The emphasis in this article is to summarize the rheological and textural parameters of yogurt. Viscosity, hardness, adhesiveness, cohesiveness, and springiness are considered the most important descriptors for the textural perception of yogurt. Factors affecting textural properties of yogurt and the possible defects are also discussed in this paper.

Keywords: Yogurt, rheology, texture

1. Introduction

Yogurt is a very popular functional dairy product which is produced by acid fermentation of milk with the thermophilic homofermentative lactic acid bacteria *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus.* The manufacturing processes of yogurt differ depending on the country, but it always comprises a lactic fermentation that brings milk to gelification due to destabilization of the protein system. It is normally retailed in one of the three physical states, namely set (undisturbed gel in the retail pot), stirred (the acid gel formed during incubation in large fermentation tanks is disrupted by stirring) or fluid (drinking yoghurt). Most of the basic plain yogurts are set yogurts, which are fermented in the container that they are eventually sold in, while most fruit-flavored yogurts are stirred yogurts, because flavors and fruit added after fermentation need to be properly dispersed in the yogurt matrix (Tamime and Robinson, 1999; Chandan, 2006; Tamime 2006).

2. Rheological and Textural Parameters of Yogurt

Texture is one of the most essential components of yogurt quality. *Texture*, which comes from Latin *textura (cloth), is* a vocable used initially to describe the cross-linking style of weave threads. It now defines disposition and arrangement for the different parts of a system. For food products, according to the International Standard Organization, texture represents all the rheological and structural attributes perceptible by means of mechanical, tactile, and, when appropriate, visual and auditory receptors. Rheology and structure of a product evaluated by instrumental methods also give relevant information on its textural properties (Ramaswamy and Basak, 1991; Borwankar, 1992; Foegeding et al. 2011; Fisher and Windhad, 2011).

The texture of yogurt or any type of fermented milk product is important with regard to the quality of the products. It is related to sensory perception of food product. The textural characteristics of yogurt are generally studied in the cup, using a spoon, or in the mouth by sensory methods. The most common sensory attributes relating to yogurt texture are thickness /viscosity, smoothness (opposite to lumpiness, graininess, grittiness), and sliminess (or ropiness). Determination of the yogurt texture usually includes sensory,

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structure and rheology analyses (Sodini et al. 2004; Walstra et al. 2006). Generally textural properties of yogurt can be assessed following methods:

Instrumental Analysis: Rheology and Texture

- Small-amplitude oscillatory rheology (SAOR)
- Large-amplitude oscillatory shear
- Penetrometry
- Texture profile analysis
- Viscometry

Instrumental Analysis: Structure

- Visual observation of gel microstructure and indirect evaluation of network homogeneity by measurements of water-holding capacity (WHC)
- Scanning or transmission electron microscopy
- Confocal scanning laser microscopy
- Permeability of drainage test

Sensory Analysis

- Smoothness: lumpiness, graininess, grittiness; sliminess or ropiness

2.1. Rheological Methods

Food rheology is the study of deformation and flow of food materials. Milk gels are visco-elastic, thus yogurt's rheological properties can be characterized using both the viscous and elastic components. Visco-elastic indicates that the material has some of the elastic properties of an ideal solid and some of the flow properties of an ideal (viscous) liquid (Steffe, 1996; Rao, 1999; Lee and Lucey, 2010).

Small Amplitude Oscillatory Rheology

Small amplitude oscillatory rheology (SAOR) has been used to characterize the rheological properties of yogurt during the gel formation process (fermentation) without damaging the weak gel network. Small deformation is defined as a small relative deformation (strain or change in dimension) (e.g. ≤1%), when its applied it does not disrupt the development of the network structure. SAOR testing involves applying an oscillatory (sinusoidal) stress/strain and measuring the strain/stress responses (Ross-Murphy, 1995; Steffe, 1996; Rao, 1999; Lee and Lucey, 2010). The following rheological parameters determined in a SAOR test.

Elastic or storage modulus (G′) expresses the measure of energy stored per deformation cycle and indicates the solid-like properties.
Viscous or loss modulus (G″) indicates the magnitude of energy lost as viscous dissipation per cycle of deformation and reflects the liquid-like properties.
Loss tangent (LT) is defined as ratio of loss modulus to storage modulus (G″/G′) and indicates the type of visco-elastic properties in a material.

In simple terms G′ represents the elasticity whereas G ″ indicates the viscous or liquid character of the gel network. A high LT value (i.e., G″ >G′) means that the material has liquid-like behavior.

Large Deformation Rheology

Large deformation characteristics of food gels are related to functional properties including shaping, cutting/slicing and eating characteristics (van Vliet and Walstra, 1995). Rheological parameters that can be obtained from this type of test include yield stress (σ yield) and yield strain (γ yield), which are defined as the point when the shear stress begins to decrease. A low **σ** yield value implies that the yogurt gel has weak network, while a low value of **γ** yield implies that it is a brittle or short textured gel. The strength of protein-protein bonds, the number of bonds per cross-section of the strand, relaxation times for the network bonds, and the orientation of strands in the matrix all contribute to the yield properties of gels (Steffe, 1996; Lucey et al.1997; Ozcan et al. 2011).

2.2. Texture Profile Analysis (TPA)

Some textural parameters are determined by using Texture Profile Analysis (TPA) with mechanical compression of a food. All TPA measurements are carried out with two-cycle uniaxial compression instruments (Fig. 1). Classification of food texture into primary, secondary or tertiary characteristics are summarized in Fig. 2. (Sherman 1969; Chen and Stokes 2012).

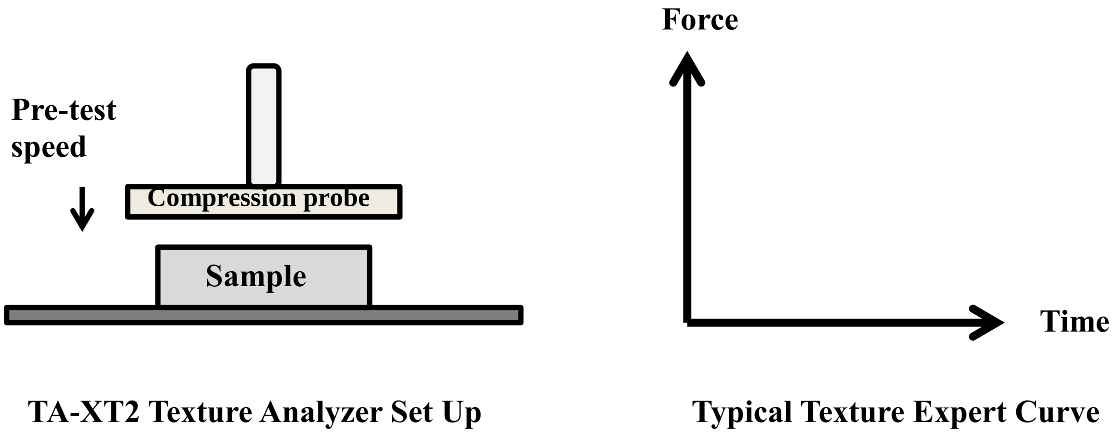

Fig. 1. Uniaxial compression test of sample during texture profile analysis

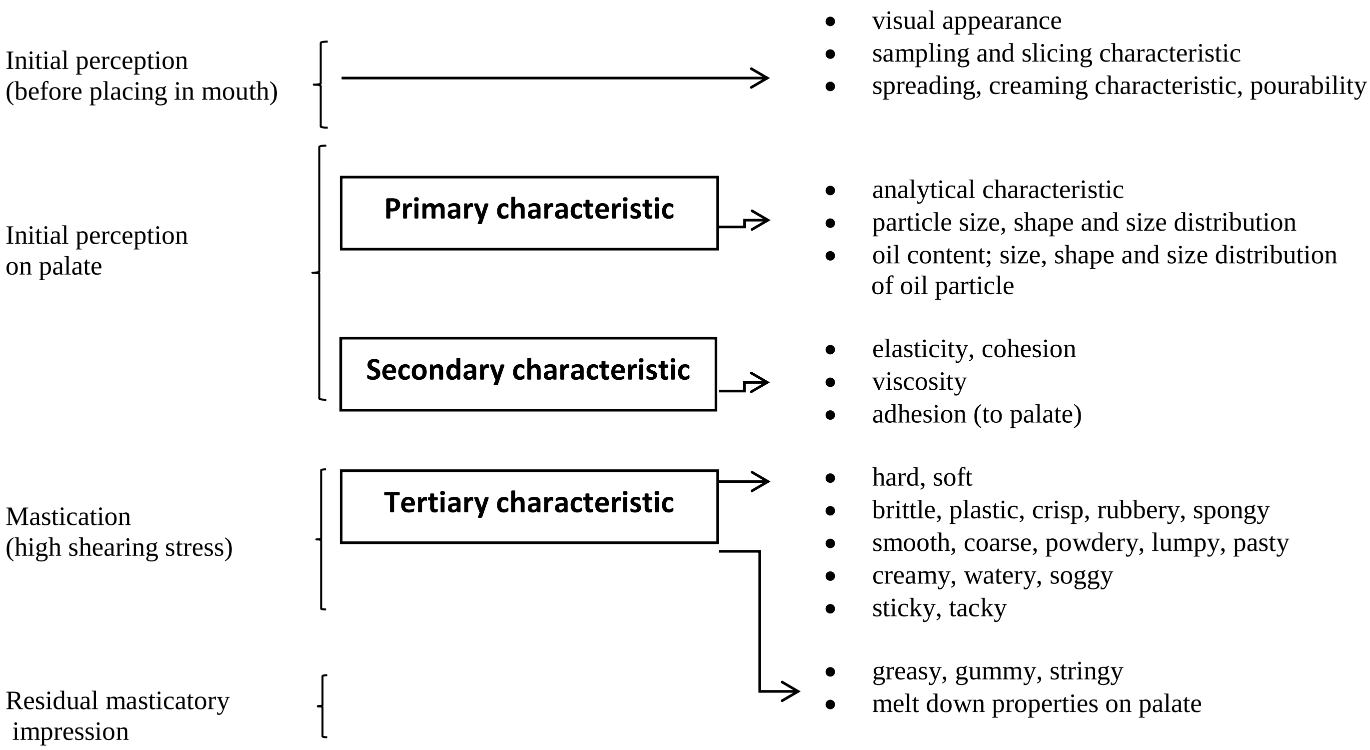

Fig. 2. Classification of food texture into primary, secondary or tertiary characteristics

Texture profile measurements are originally carried out using double-bite compression tests (Fig. 3). In practice, force (stress) and deformation (strain) are the two fundamental parameters for texture characterization. TPA measures parameters such as chewiness, gumminess, cohesiveness, adhesiveness and firmness (Bourne 1978; Chen and Stokes 2012).

- The peak force during the first compression cycle is defined as **hardness** or **firmness.**
- The ratio of the positive force area during the second compression cycle to that during the first compression cycle (area 2/area 1) is originally defined as **cohesiveness.**
- The negative force area of the first compression cycle (area 3), **adhesiveness.**
- The length to which the sample recovers in height during the time that elapses between the end of first compression cycle and start of the second compression cycle is defined as **springiness** (originally called elasticity).
- **Gumminess** is defined as the product of hardness time's cohesiveness, and **chewiness** is defined as the product of hardness time's cohesiveness time's springiness.

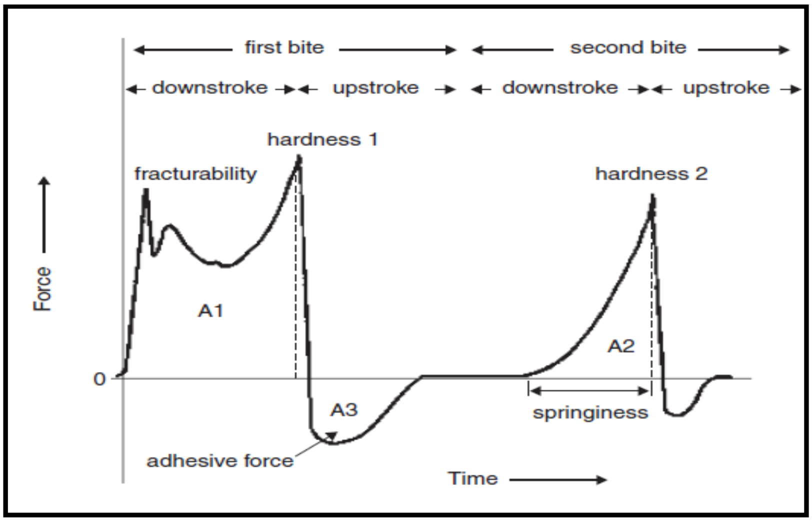

Fig. 3. Typical stress trend during double-bite compression test, from which parameters are calculated

2.3. Factors Affecting Textural Properties of Yogurt

Yogurt exhibits a variety of non-Newtonian effects, such as shear-thinning, yield stress, viscoelasticity and time-dependency (Benezech and Maingonnat, 1994; Steffe, 1996). One of the most important attributes for yogurt quality is texture. The main processing parameters influencing the yogurt texture are fortification level and material(s) used, stabilizers type and usage levels, fat content and homogenization conditions, milk heat treatment conditions, starter culture (type, rate of acid development and production of EPS), incubation temperature (influences growth of starter cultures, gel aggregation, bond strength), pH at breaking, cooling conditions, handling of product post manufacture (e.g. physical and temperature abuse) (Lucey and Sing,1997; Lucey, 2004; Sodini et al. 2004).

The gel strength of yogurt is related to the total effects of chemical interactions. During denaturation β-lactoglobulin interacts the binding of β-lactoglobulin with the κ-casein on the casein micelle surface by disulfide bridging is responsible for the increase of gel strength and viscosity of yogurt (Dannenberg and Kessler, 1988; Lucey et al. 1997). The physical properties of yogurt gels including gel stiffness and permeability, rearrangement of protein particles in gel network, and structure breakdown of stirred-type yogurts are important factors that influencing the physical and structural properties of yogurts (Lee and Lucey, 2010). An understanding of the mechanisms involved in the formation of texture in yogurts and impact of the processing conditions on texture development helps to improve the quality of yogurt. Important approaches to modify the texture of yogurt and decrease textural defects include (Lucey 2001; Lucey 2004; Ozcan et al. 2011):

a. Use of novel stabilizers and various types of milk-derived ingredients
b. Use of various types of membrane concentrate methods
c. Specific cultures (e.g. producing a specific exopolysaccharide (EPS), type and content)
d. Enzymatic cross-linking of milk proteins, (e.g. transglutaminase)
e. Use of high hydrostatic pressure (e.g.>200 MPa) to the milk to cause denaturation of whey proteins or of the yoghurt to prevent post acidification
f. Use of very high pressure homogenization
g. Increasing gel stiffness (elastic modulus) and yield stress

3. Conclusion

Fermented dairy products such as yogurt have long been known for their functional value, particularly in managing intestinal disorders such as lactose intolerance or acute gastroenteritis. The application of each treatment (addition of probiotics, prebiotics, different food ingredients and process) potentially influences rheology and texture properties of yogurt. In terms of health, although technology has been applied with almost complete success to produce low - fat, low calorie and functional yoghurt with sufficient rheological properties, still there is need for product optimization.

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