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Food Texture Characterization Techniques Tailored to Specific Structural "Types:" A Review

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Foods can generally be categorized by physical structure and organization. Solid foods can be divided into elastic, plastic, or brittle categories, with each group encompassing porous/cellular or nonporous conformations. Each food type has a characteristic deformation behavior that gives rise to a characteristic sensory texture.

Deformation behavior can be mathematically described using stress-strain models that are appropriate to the particular macrostructure and that yield quantitative mechanical parameters. Structural/organizational properties can be measured using a variety of imaging and other techniques. Correspondingly, sensory characteristics can be evaluated using descriptive and statistical methodologies. The associations among structure—which is influenced by process and formulation parameters—and mechanical or sensory texture can thus also be quantitatively determined and used as predictive tools.

Investigations encompassed the following food categories: (1) elastic"gel-like" materials—specifically, processed meat and eggs; (2) "porous-plastic" materials—specifically, baked products; and (3) "porous-fracturable" materials—specifically dried extruded products. The mechanical properties of these foods were quantified by compression testing and appropriate mathematical description of stress-strain functions.

For gel-like materials, in which volume is maintained during compression, determination of elastic modulus accommodated the increase in cross sectional area that occurs during deformation (Barrett *et al.* 1997a, 1998; Nussinovitch *et al.* 1990). Exponential force-deformation relationships were converted into linear stress-strain relationships for modulus calculation by

$$E = \text{“corrected” stress / Henky's strain} = F(t)(H_0 - H(t))/A_0H_0] / \ln(H_0/(H_0 - H(t)))] \quad \text{(Eq. 1)}$$

where F = compressive force, H = specimen height, t = time, and A_0 and H_0 are original specimen cross-sectional area and height, respectively.

For bread, which exhibits a deformation model characteristic of spongy materials, that is, accommodating an intermediate nonrising or lower-slope region caused by plastic deformation of cell walls, a three parameter model was used:

$$\text{stress} = [C1*\text{strain}] / [(1 + (C2*\text{strain}))*(C3 - \text{strain})] \quad \text{(Eq. 2)}$$

(Barrett *et al.* 1997b, Swyngdeau *et al.* 1991), in which the fitted constants C1 and C2, respectively, indicate compressive resistance and plasticity.

And for fracturable foods, fractal and Fourier analysis can describe the rugosity of stress-strain curves (Barrett *et al.* 1992, 1994a). Similarly, analysis of the distribution of fracture intensities using an exponential function,

$$\text{frequency} = C\exp(-b(\text{fracture intensity})) \quad \text{(Eq. 3)}$$

(in which C and b are fitted coefficients) provides indices of fracturability (Barrett *et al.* 1994b).

Different structures were obtained in each instance by varying formulations (i.e., water activity and fat level in meat, hydrocolloid usage in eggs, humectant level in bread, plasticizer level in extrudates) and process parameters (i.e., conventional vs. microwave-assisted freeze-drying of eggs, low-shear versus high-shear formation of bread, mechanical energy input in extrusion). Physical/structural properties were evaluated by bulk property analysis, by image analysis (to determine the distribution and quantity of fat particles in meat and cell structure in porous foods), by water-binding measurement (to determine relative water-holding capacity in rehydrated eggs), and by colorimetry (to determine extent of darkening in meat).

The products were sensorially evaluated by a trained panel who employed magnitude estimation methodology to quantify pertinent textural properties. Using this technique, panelists expressed their perceptions of relative differences among attribute intensities using a ratio scale.

Predictive sensory–instrumental relationships were obtained for each food tested. For example, sensory "firmness" strongly correlated with the elastic modulus of processed meat, with the fitted C1 coefficient (from Eq. 2) of bread, and with the extent of water binding in rehydrated freeze-dried eggs. Furthermore, the relative correspondence of each sensory profile to a panel-developed "ideal" profile was used to rank samples according to preference, permitting identification of optimal process/formulation parameters.

In each system, effects of process/formulation parameters on mechanical behavior, structure, and functionality were elucidated. For bread, reduced formation shear (effected via both process technique and plasticizer content) resulted in a more expanded and more deformable gluten network. For eggs, reduced thermal exposure (effected by microwave-assisted rather than conventional freeze-drying) resulted in less firm rehydrated structures with increased water holding capacity. For emulsified processed meats, firmness was maximized at an intermediate fat content.

Established relationships among process/formulation parameters, structure, and texture in each system enabled optimization of product functionality and acceptance.

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