The "Food Polymer Science" Approach to Flour Functionality and Ingredient Technology in Biscuit Baking

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SUMMARY: An overview is made on the "food polymer science" approach developed by the authors. The quality and performance of flours for the production of cookies and crackers have been shown to depend upon the major functional polymeric components of flour: gluten protein, damaged starch, and pentosans. Of these, damaged starch and soluble pentosans in soft-wheat flours are detrimental to the commercial production of low-moisture cookies and crackers. The detrimental effects of soluble pentosans in flours can be eliminated through the use of pentosanase enzyme in cookie and cracker doughs. Three commercialized applications of this industrial enzyme technology have been patented by Nabisco. The "food polymer science" approach to baking technology has also been used to study finished-product attributes such as texture, in the context of the thermomechanical properties (e.g. modulus) of glassy solid and rubbery liquid matrices. Results of various studies have clearly demonstrated that products in a glassy solid physical state (at $T < T_g$) are hard and crisp in texture, but upon increasing plasticization by water (such that T_g is depressed below the observation T), are transformed to a rubbery or viscous liquid state, wherein textural hardness (and mechanical modulus) and crispness are dramatically reduced.

We have used the "food polymer science" approach [7,14] to study flour functionality and ingredient technology in biscuit baking[19,24]. Results of our studies have demonstrated that the quality and performance of flours for the production of cookies and crackers depend upon the major functional polymeric components of flour: gluten protein, damaged starch, and pentosans[13,16,18]. Of these, damaged starch and soluble pentosans in soft-wheat flours are detrimental to the commercial production of low-moisture cookies and crackers[2,25]. Soluble pentosans are high-MW, non-starch polysaccharides that have an extremely high water-holding capacity and an ability to form three-dimensional, entangled, viscous, gel-like networks in typical cookie and cracker doughs[16]. Owing to these properties, flours containing higher levels of soluble pentosans require more water to produce machinable doughs, and the water in such doughs is more difficult to remove during baking[18]. The presence of a soluble-pentosan network restricts the spread of cookie doughs and the spring of

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cracker doughs during baking[2,16]. The new AACC Wire-Cut Cookie Method 10-53[4,8] has been used to diagnose such detrimental effects of higher soluble-pentosan contents in flours from Pacific northwest soft white wheats [25]. Alveography (increased P value) and solvent-swelling tests have also been used for similar diagnostic purposes [2,18].

The detrimental effects of soluble pentosans in flours can be eliminated through the use of pentosanase enzyme in cookie and cracker doughs [22]. In three commercialized applications of this industrial enzyme technology, which have been patented by Nabisco[3,20,21], pentosanase enzyme has been used to reduce the viscosities and water requirements of doughs, and to facilitate moisture bake-out and associated cookie spread or cracker spring, thereby: a) controlling the extent of starch gelatinization in a fat-free cracker with optimized texture[3]; b) reducing the extent of color fading in cookies during shelf-life[15,20]; and c) reducing the extent of checking in crackers[21].

The "food polymer science" approach to flour functionality and ingredient technology in biscuit baking has also been used to study finished-product attributes such as texture[15], in the context of the thermomechanical properties (e.g. modulus) of glassy solid and rubbery liquid matrices[23]. Measurements of the glass transition in cookies and crackers, in terms of mechanical modulus as a function of moisture content, have been reported [1].

Modulus has also been correlated with the sensory hardness of cereal-based products[9], and with the development of crispness in cookies during baking[10]. The relationship between the sensory crispness of baked products (or breakfast cereals[11]) and their critical values of relative vapor pressure [6] has been explained on the basis of glass transition temperature (T_g) and the effect of plasticization by water[17]. Experimental evidence for a direct relationship among T_g, water plasticization, and sensory crispness has recently been reported for baked cookies[12] and extruded products[5]. All of these studies have clearly demonstrated that products in a glassy solid physical state (at $T < T_g$) are hard and crisp in texture, but upon increasing plasticization by water (such that T_g is depressed to below the T of observation), such products are transformed to a rubbery or viscous liquid state, wherein textural hardness (and mechanical modulus) and crispness are reduced[15]. Interestingly, it has also been shown[1] that while fat may act as a tenderizing ingredient which reduces the hardness (or modulus) of a cookie matrix, fat does not act as a compatible plasticizer (unlike water), in that it shows no depressing effect on T_g of a cookie matrix.

References

[1] Amemiya, J., and Menjivar, J. A. 1992. Mechanical properties of cereal-based food cellular systems. American Association of Cereal Chemists 77th Annual Meeting, Minneapolis, abs. 207.

[2] Bettge, A.D. 1997. Wheat endosperm texture: genetic, physical, and end-use aspects. At Pacific Northwest Wheat Quality Council Meeting, Coeur D'Alene ID, Jan. 16.

[3] Craig, S.A.S., Slade, L., Levine, H., et al. 1992. Production of crackers with reduced or no added fat, U.S. Patent 5,108,764.

[4] Gaines, C.S., Kassuba, A., and Finney, P.L. 1993b. Instrumental measurement of cookie hardness. IV. Miag multomat mill stream selection. Cereal Chem., submitted.

[5] Karki, M.K., Roos, Y.H., and Tuorila, H. 1994. Water plasticization of crispy snack foods. IFT '94 Annual Meeting, Atlanta, June 29.

[6] Katz, E.E. and Labuza, T.P. 1981. Effect of water activity on the sensory crispness and mechanical deformation of snack food products. J. Food Sci. 46, 403- 409.

[7] Levine, H. and Slade, L. 1988b. Water as a plasticizer: physico-chemical aspects of low-moisture polymeric systems. Water Science Reviews 3:79-185.

[8] Levine, H., and Slade, L. 1993a. The glassy state in applications for the food industry, with an emphasis on cookie and cracker production. In"Glassy State in Food" (J.M.V. Blanshard and P.J. Lillford, eds.), pp. 333-373. Nottingham University Press, Loughborough.

[9] Lillford, P.J. 1990. Structure and properties of solid food foams. In Foams: Physics, Chemistry and Structure (ed. Wilson, A.J.), pp.149-166. Springer-Verlag, London.

[10] Piazza, L. and Masi, P. 1997. Development of crispness in cookies during baking in an industrial oven. Cereal Chem. 74:135-140.

[11] Sauvageot, F. and Blond, G. (1991). Effect of water activity on crispness of breakfast cereals. J. Texture Stud. 22: 423-442.

[12] Seow, C.C., Vasanti Nair, C.K., and Lee, B.S. 1994. Effects of processing on textural properties of food phytosystems. ISOPOW Practicum II, Puebla, Mexico, June 19-24, p. 43. In Food Preservation by Moisture Control, eds. G.V. Barbosa-Canovas and J. Welti-Chanes, Technomic, Lancaster, PA, 1995, pp. 697-728.

[13] Shogren, M.D., Habdas, Z., and Pomeranz, Y., Soluble and total pentosans in flour from various wheat classes, AACC 72nd Ann. Meet., Nashville, 1987, abs. 36.

[14] Slade, L. and Levine, H. 1987b. Recent advances in starch retrogradation. In Industrial Polysaccharides - The Impact of Biotechnology and Advanced Methodologies, eds. S.S. Stivala, V. Crescenzi, and I.C.M. Dea, Gordon and Breach Science Publishers, New York, pp. 387-430.

[15] Slade, L., and Levine, H. 1991a. Beyond water activity: recent advances based on an alternative approach to the assessment of food quality and safety. Crit. Rev. Food Sci. Nutr. 30, 115-360.

[16] Slade, L., and Levine, H. 1991c. Structure-function relationships of cookie and cracker ingredients. In "The Science of Cookie and Cracker Production" (H. Faridi, ed.), pp. 23-141. Van Nostrand Reinhold/AVI, New York (1994).

[17] Slade, L., and Levine, H. 1993a. The glassy state phenomenon in food molecules. In "Glassy State in Food" (J. M. V. Blanshard and P. J. Lillford, eds.), pp. 35-101. Nottingham University Press, Loughborough.

[18] Slade, L. and Levine, H. 1993h. Aspects of soft wheat quality of current interest to a cookie/cracker baker. 40th Annual Research Review Conference, USDA-ARS Soft Wheat Quality Lab, Wooster, OH, April 15.

19) Slade, L., Levine, H., and Finley, J. W. 1989. Protein-water interactions: water as a plasticizer of gluten and other protein polymers. In "Protein Quality and the Effects of Processing" (R. D. Phillips and J. W. Finley, eds.), pp. 9-124. Marcel Dekker, New York.

20) Slade, L., Levine, H., Craig, S., Arciszewski, H., and Saunders, S. 1993. Enzyme-treated low moisture content comestible products, U.S.Patent 5,200,215.

21) Slade, L., Levine, H., Craig, S., and Arciszewski, H. 1994. Reducing checking in crackers with pentosanase, U.S. Patent 5,362,502.

22) Slade, L., Levine, H., Wang, M. and Ievolella, J. (1996). DSC analysis of starch thermal properties related to functionality in low-moisture baked goods, in Recent Advances in Applications of Thermal Analysis to Foods (eds. H. Levine and L. Slade), special issue of J. Thermal Anal. 47:1299-1314.

23) Sperling, L. H. 1986. "Introduction to Physical Polymer Science." Wiley-Interscience, New York.

24) Yamazaki, W.T. and Lord, D.D. (1978). Soft Wheat Products. In Wheat Chemistry and Technology, 2nd edn (ed Y. Pomeranz), St. Paul, AACC, 743-76.

25) Zilberboim, R., Slade, L., Levine, H., Bravo, A., Deming, D., Ievolella, J., Wang, M., and Yost, R. (1997). A baker's preoccupation with soft wheat quality - an invited review. Cereal Chem., in preparation.