Effect of Variability in Sugar Granulation on the Evaluation of Flour Cookie Quality[1]

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ABSTRACT

The effects of sugar particle size on the evaluation of soft wheat flour quality were determined by a sensitive cookie-baking method. Sugars with different particle-size distributions varied in ability to differentiate two flours with contrasting qualities. Optimum performance of the test was obtained using sugar with a mean size range of 250 to 200 μ. Ten varietal flours were tested with monosized sugar fractions from sieve separations on 10 screens ranging from 24 to 200 mesh per in. Cookie spread and top-grain scores increased with decreasing mean particle size of sugar, and differentiation improved with sugars in the through 48-mesh to over 80-mesh (295 to 175 μ). Natural distributions of sugars were truncated at 32-, 35-, and 48-mesh cutpoints, with each finer separate exhibiting improved cookie spread and appearance. Monosized sugar fractions were blended to give normal distributions about mean sizes of 240, 185, and 155 μ, respectively. Cookie performance and overall differentiation among flours from several wheat varieties were improved progressively with decreasing mean particle size of the sugar blends within the limits of the conducted trials.

The effectiveness of laboratory test baking in a continuing quality evaluation program depends to a great extent upon standardization of techniques and uniformity of materials. A part of the cumulative quality bias in "crop year differences" may be caused by undetected or uncontrolled differences in properties of baking ingredients purchased in the open market over a period of time. Particle-size variability in sugar, a major ingredient, can introduce problems in the sugar-snap cookie test. Particle-size analysis of sugars used in the cookie test indicates a shift toward coarse granulation, with distributions skewed far from the normal curve for an "ideal" sugar, defined many years ago (1). Finney et al. (2) have shown the marked effects of variable sugar and leavening concentrations on cookie-baking performance. This report covers a basic study of the influence of sugar granulation at fixed concentration on cookie spread, W/T ratio, and top-grain appearance.

MATERIALS AND METHODS

The Wooster cookie test (3), originally designated "Micro-Method III", has been in use at this laboratory since its development some 25 years ago. The test differs at many points from AACC Approved Method 10–50 (4). Some of the significant

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departures include use of: 40 g. of flour to produce two cookies, rather than 225 g. for six units; a nonrecording pin-type micro dough mixer rather than a Hobart[3] C-100 with 3-qt. bowl, for both stages of mixing; and a minimum dough-mixing time, rather than 2 min. The Wooster formulation contains slightly more sugar and shortening than Method 10-50 and uses ammonium bicarbonate as the principal leavening agent, which is added in the form of ammonium chloride and sodium bicarbonate solution (3) rather than sodium bicarbonate only. In addition, it retains the use of nonfat dry milk solids and does not include dextrose as specified for Method 10-50.

Most of the above deviations contribute to increased cookie spread, since the Wooster formula was originally balanced for maximum differential spreading among flours of different quality. The greater quantity and availability of the leavening render the test sensitive to both flour differences and ingredient variations. The Wooster cookie test (3) was used in this baking study essentially as published.

In all figures and tables, cookie diameters refer to the sum of diameters of two cookies from each dough; top-grain score is based on a range of 9 for an excellent, uniform surface break-up to 0 for a poor, minimal-grain formation. All data are the means of replicated bakes. Standard deviations for cookie diameter were ±0.2 cm. and for top-grain score were ±1.3 units.

Samples of six commercial cane sugars ranging from coarse granulated to "baker's special" grades were obtained for comparison. Quantities of the "baker's special" sugar were reduced in particle size by either one pass through a Hobart coffee mill at No. 3 setting, or by one pass through the Alpine[3] pin mill at 9,000 r.p.m. Particle-size distributions were obtained by a 5-min. Ro-Tap[3] separation of 200-g. samples of sugar on a nest of Tyler[3] sieves of 48, 65, 100, 150, and 200 mesh. Cookies were prepared from straight-grade Comanche (HRW) flour and from a commercial SRW straight grade using each sugar sample.

In the second phase, two granulated sugars were selected for separation into ten particle-size ranges by Ro-Tap sieving. A coarse granulated sugar gave fractions over 24-, 28-, 32-, 35-, and 48-mesh screens. A "baker's special" type resulted in seven separates: overs of 35, 48, 65, 80, 100, 150, and throughs of 150 mesh, respectively. Multiple separations were made and separates pooled until a minimum of 500 g. was available for all ranges. Cookies were baked from all separates of both sugars using the cookie standard and nine varietal straight-grade flours, Allis-milled from wheats grown near Urbana, Ill.

The effects on cookies of truncating the natural distribution of a regular granulated sugar at 32-, 35-, and 48-mesh cut-off points were studied using a cookie standard and five varietal flours. Finally prepared and tested were three synthetic particle-size populations, each with normal distribution about the respective mean: over 65, over 80, and over 100-mesh separates. The last-mentioned distribution corresponded to the approximate analysis of "ideal" "baker's special" (1).

For convenience, sieve sizes are identified by the mesh per inch. Actual size of mesh openings for the sieves used in the study are given in the following table:

[3]Hobart is a trademark of Hobart Mfg. Co., Troy, Ohio. Alpine is a trademark of Alpine Aktiengesellschaft, Augsburg, W. Germany. Ro-Tap and Tyler are trademarks of W. S. Tyler Co., Mentor, Ohio.

Mesh/in.	Opening μ	Mesh/in.	Opening μ
24	701	65	208
28	589	80	175
32	500	100	149
35	417	150	105
48	295	200	74

RESULTS AND DISCUSSION

Early editions of the Official Methods of the AACC (1) specified a sieve analysis for particle size of "baker's special" sugar. Size analysis data presented in Table I indicate that particles of the "ideal" sugar were nearly normally distributed, whereas distributions of actual sugars 3 through 7 were truncated or skewed. The current edition of AACC Approved Methods (4) retains the following specification in Cookie Method 10–50: "Sugar should be free-flowing granulated, with not more than 5% retained on a 48-mesh Tyler sieve." This statement implies recognition of detrimental effects of coarse sugar particles but it may be difficult to obtain a continuing supply of sugar which complies with the requirement. From Table I it is clear that none of samples 3 to 7 met the specification; most entries contained many times the limit of particles over 48 mesh.

Data for pin milling (sugar No. 1) are included as an example of extremely fine sugar resembling confectioner's grade but without added starch. Hobart grinding of "baker's special" grade sugar (No. 2) resulted in a significant reduction in the estimated mass median diameter. The process was erratic in producing variable amounts of very fine particles which tended to cling to larger crystals, giving occasional anomalous results in particle size and baking tests. Only one premium-priced sugar, "V-fine," was found to approach or exceed the "ideal" distribution.

TABLE I. COMPARISON OF "IDEAL" BAKER'S-SPECIAL SPECIFICATION WITH PARTICLE-SIZE DISTRIBUTION OF MODIFIED (1 AND 2), AS RECEIVED (3–8), AND SIZE-BLENDED (9–11) SUGARS

	Particle-Size Distribution (%)							
	Overs of mesh							
Sugar Number and Type	48	65	80	100	150	200	Through 200	MMD[a] μ
"Ideal" baker's special (specification)	2	18	...	45	19	12	4	165
1) Pin-milled (sugar 5)	0	0	0	1	22	38	38	80
2) Hobart-ground (sugar 5)	40	29	11	5	9	1	5	245
3) Granulated	77	15	4	1	2	1	0	315
4) Coarse granulated	95	3	1	0	1	0	0	345
5) "Baker's special"	57	24	9	4	5	1	0	310
6) "Extra fine"	56	25	8	3	6	1	1	310
7) "V-fine" lot I	13	46	18	5	16	1	1	220
8) "V-fine" lot II	0	29	31	20	11	5	0	180
9) 65-mesh Mean blend[b]	30	40	25	5	0	0	0	240
10) 80-mesh Mean blend[b]	5	25	40	25	5	0	0	185
11) 100-mesh Mean blend[b]	0	5	25	40	25	5	0	155

[a]MMD = Mass median diameter estimated by graphical means.

[b]Synthetic distributions prepared by thorough mixing of stated proportions (by weight) of the stated sieve-separate of sugar.

Baking Responses with Parent Sugars

The effects of six sugars on cookie dimensions and appearance are given in Fig. 1. Sugar No. 1 (pin-milled "baker's special") gave the greatest differentiation between the flours in diameter, width/thickness (W/T), and appearance. The top grain was abnormally bold and unsuitable for test purposes. Sugar No. 2 (Hobart-ground "baker's special") produced normal top grain and gave excellent differentiation between the flours. That specific sugar was used for cookie-quality evaluation and was the control in the present study.

Sugar No. 3 (regular granulated) decreased diameter and W/T differences, and produced poorer top grain patterns. Sugar No. 4 (coarse granulated) minimized size, spread factor, and appearance differentiation. Sugar No. 5 (contemporary "baker's special") gave particle-size data and cookie characteristics about equal to those of granulated sugar No. 3. Cookies from sugar No. 6 ("extra fine") were similar to No. 3 and No. 5 and thus were omitted from the photograph.

Sugar No. 7 ("V-fine") compared most favorably in both particle-size distribution and in cookie results with control sugar No. 2. Results of this survey suggest that diameter differences and top-grain patterns are optimized by sugar particle size in the 250 to 200 μ MMD range.

Figure 2 presents the W/T-cookie diameter relationship for the preceding series of cookies. Since W/T is seldom obtained with the two-cookie micro-method (3), it is of interest that good linear regression was found over the wide range of cookie

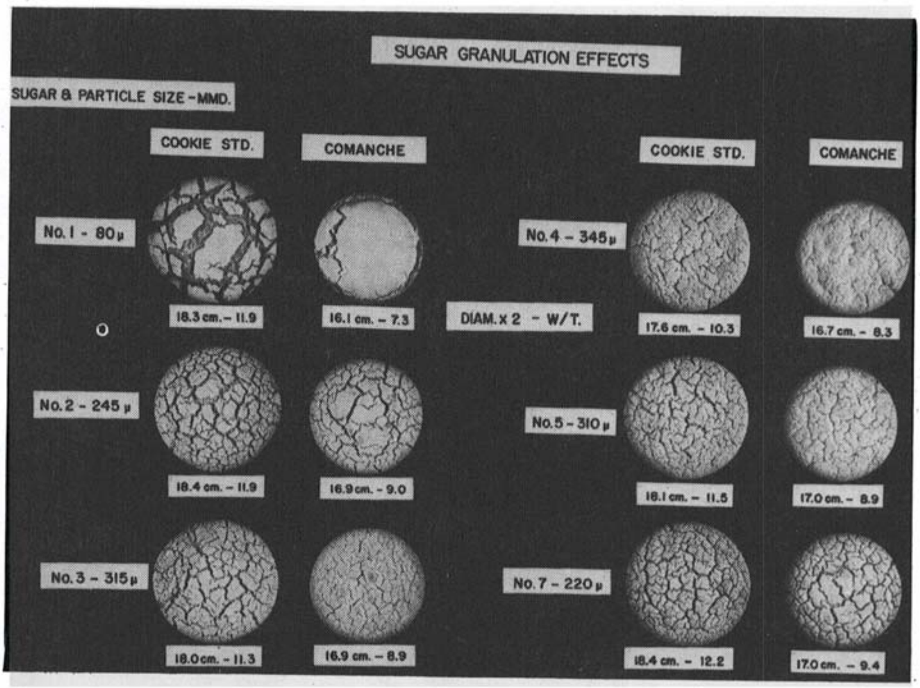

Fig. 1. Relative differentiation of a good and a poor quality cookie flour by sugars having a wide range in granularity.

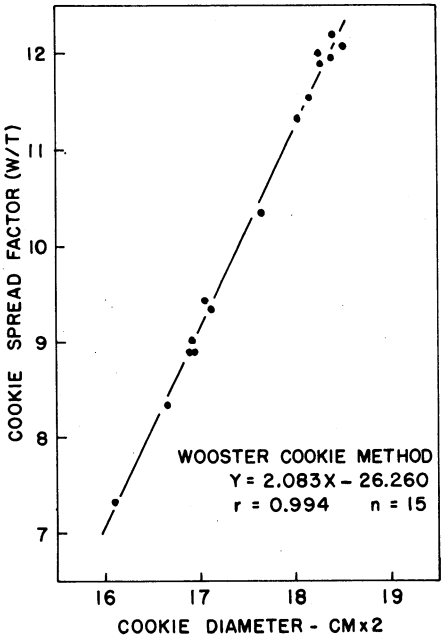

Fig. 2. Relationship of cookie spread factor (W/T) and mean diameter of two cookies as measured in the Wooster cookie method.

quality represented here. The high correlation of the two measurements suggests that either is satisfactory in describing cookies, although the concept of dimension is lost in the W/T ratio.

Baking Responses with Sugar-Sieve-Separates

Cookie data for the second particle-size study involving the coarse (No. 4) and fine (No. 6) parent sugars and their separates are summarized in Tables II and III, the latter a continuation of the former. Mean data are given for cookies from sugar separates of both parents in the overlap range of 35- and 48-mesh sieves. Both cookie spread and top-grain scores increased with decreasing sugar particle size and maximized at the through 48/over 80-mesh levels. Continued increase in fineness resulted in cookies with increasingly bold top grain (A type), with no significant increase in diameters from those containing 48/80-mesh sugars.

The overall cookie-spread response to decreasing particle size of sugar fractions is summarized in Fig. 3. Coarse particles were clearly detrimental to the spreading ability of cookie flours and tended to reduce varietal differentiation on the basis of both measurement and appearance (Tables II and III). Relatively monosized sugar in the through 48/over 80-mesh range appeared to maximize the quality factors and differences among the flours studied.

From Table I, it is seen that the commercial sugars, No. 3 to No. 6, contained only 4 to 33% of particles in the 48/80-mesh range. Extending the range to include sizes over 100 mesh would increase yields to a range of 4 to 37%. Bulk sifting of

TABLE II. COOKIE DIAMETERS AND TOP-GRAIN SCORES OBTAINED WITH COARSE GRANULATED SUGAR (NO. 4) AND SIEVE SEPARATES. DATA FOR 35- AND 48-MESH SEPARATES ARE MEANS FROM BOTH COARSE (NO. 4) AND FINE (NO. 6) PARENT SUGARS

			Sugar Sieve Separates—Size Range (mesh) and MMD (μ)									
	Parent Sugar No. 4		Ov-24 (650 μ)		Ov-28 (575 μ)		Ov-32 (490 μ)		Ov-35 (435 μ)		Ov-48 (350 μ)	
Flour Variety	Cookie diam. cm.	Score	Cookie diam. cm.	Score	Cookie diam. cm.	Score	Cookie diam. cm.	Score	Cookie diam. cm.	Score	Cookie diam. cm.	Score
SRW-Standard	17.2	2	17.2	1	17.3	2	17.9	3	18.2	4.5	18.1	5.8
Comanche	17.2	1	16.9	1	17.1	1	17.4	2	17.6	2.5	17.8	3.3
Purkof	17.1	1	16.9	1	17.1	1	17.6	1	17.6	3.3	17.8	3.8
Clarkan	17.1	1	16.9	1	17.1	1	17.6	2	17.8	3	18.0	3.5
Trumbull	17.2	1	17.1	1	17.3	1	17.9	1	17.8	3	18.1	3.5
Fairfield	17.2	1	17.0	1	17.3	1	17.7	1	17.8	3	18.0	4.5
Thorne	17.4	1	17.2	1	17.5	1	17.8	2	18.0	3.8	18.2	4
Avon	17.4	2	17.7	3	17.9	4	17.9	4	18.5	6.8	18.6	6.8
Blackhawk	17.8	2	17.3	1	17.8	2	18.0	3	18.4	4.3	18.6	5.9
Am. Banner	17.8	2	17.4	2	17.9	3	18.3	5	18.6	6.8	18.7	7.4
Mean	17.3	1.4	17.2	1.3	17.4	1.7	17.8	2.4	18.0	4.1	18.2	4.9

TABLE III. COOKIE DIAMETERS AND TOP-GRAIN SCORES OBTAINED WITH FINE SUGAR (NO. 6) AND SIEVE SEPARATES

			Sugar Sieve Separates—Size Range (mesh) and MMD (μ)									
	Parent Sugar No. 6		Ov-65 (240 μ)		Ov-80 (185 μ)		Ov-100 (150 μ)		Ov-150 (115 μ)		Through-150 (90 μ)	
Flour Variety	Cookie diam. cm.	Score	Cookie diam. cm.	Score	Cookie diam. cm.	Score	Cookie diam. cm.	Score	Cookie diam. cm.	Score[a]	Cookie diam. cm.	Score[a]
SRW-Standard	18.2	6	18.3	7.5	18.2	7	18.2	6	18.3	7	18.3	8
Comanche	17.6	3	17.8	3.5	17.9	4.5	17.8	5	17.7	4	17.7	6
Purkof	17.8	3	18.0	4	17.9	4.5	18.2	6	17.8	4A	18.0	5A
Clarkan	18.0	3	18.1	4	18.1	4	18.1	4	18.1	5.5	18.2	6A
Trumbull	18.0	2.5	18.2	5	18.3	5.5	18.5	7	18.3	7	18.0	6
Fairfield	18.2	4	18.5	5	18.3	5	18.7	6	18.4	7.5A	18.4	7A
Thorne	18.0	4	18.5	7	18.3	6	18.3	8	18.5	7.5A	18.7	7A
Avon	18.6	8	18.8	9	18.7	8	18.4	8	18.6	7A	18.8	6A
Blackhawk	18.3	6.5	18.6	7.5	18.2	6	18.4	7	18.6	7A	18.3	8
Am. Banner	18.5	8	18.9	8.5	18.8	8.5	18.7	9	18.7	8A	18.9	8A
Mean	18.1	4.8	18.4	6.1	18.3	5.9	18.3	6.6	18.3	6.5	18.3	6.7A

[a]A = Bold top grain.

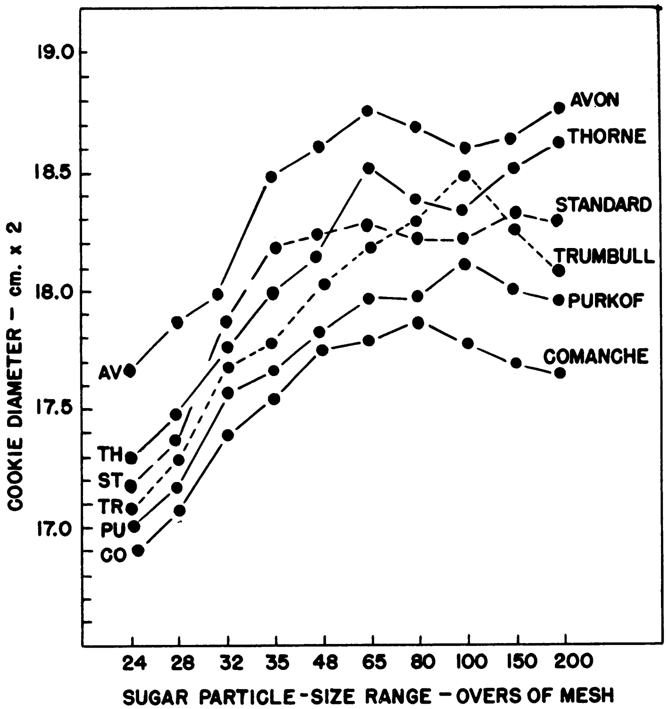

Fig. 3. Response of cookie spread (Wooster method) to decreasing particle size of sugar sieve separates. Pure variety straight-grade flours from Avon (AV), Thorne (TH), Trumbull (TR), Purkof (PU), and Comanche (CO) and a commercial cookie standard (ST).

sugars 3, 5, and 6 to obtain the fraction between through 48 and over 100 mesh would be a method of marginal economy for obtaining favorable particle size from ordinary commercial sugars.

Sugar No. 7 appeared to be satisfactory in fineness and performance. A measure of particle-size variability between lots of sugar was obtained by testing a second sample (sugar No. 8) purchased after an 8-month interval. Although Lot II was finer than Lot I and somewhat coarser than the "ideal" specification, it was satisfactory for test baking purposes.

Baking Responses with Truncated Distributions

A quantity of granulated sugar (No. 3) was separated by Ro-Tapping on a 32-mesh screen. Coarse and fine separates were compared for effect on cookie quality using a commercial straight-grade flour and five Allis-milled varietal flours. Sugar-particle distributions were also truncated at two finer cutpoints, using 35- and 48-mesh screens. Baking data from all separates are compared with performance for the parent granulated sugar (Table IV).

For every separation, cookies produced from overs of the stated screen were smaller than, or equal to, cookies from the granulated controls. Top-grain scores for all products of the coarse fractions were lower than the controls. In every case,

TABLE IV. COOKIE DIAMETERS AND TOP-GRAIN SCORES OBTAINED WITH REGULAR GRANULATED SUGAR (NO. 3) AND WITH COARSE AND FINE SEPARATES FROM 32-, 35-, AND 48-MESH SIEVES, RESPECTIVELY

Flour Variety	Parent Sugar No. 3		Parent Sugar Separated by Sieve of Stated Mesh: 32-Mesh, Overs		32-Mesh, Throughs		35-Mesh, Overs		35-Mesh, Throughs		48-Mesh, Overs		48-Mesh, Throughs		V-Fine Control	
	Cookie diam. cm.	Score	Cookie diam. cm.	Score	Cookie diam. cm.	Score[a]	Cookie diam. cm.	Score	Cookie diam. cm.	Score	Cookie diam. cm.	Score	Cookie diam. cm.	Score[a]	Cookie diam. cm.	Score[a]
SRW-Standard	17.7	7	17.5	3	18.2	9	17.5	3	17.9	8.5	17.5	4.5	18.1	8.5	18.0	8A
Purkof	16.7	1.5	16.6	1	17.0	2.5	16.5	1	16.9	3	16.7	1	17.5	6.5	17.2	6
Thorne	17.4	5	17.3	2	17.8	6	17.1	2	17.7	6.5	17.3	3	17.8	8	18.0	8
Avon	17.6	7	17.4	4	17.8	8A	17.5	5	17.8	8.5	17.6	6.5	17.8	7A	17.8	8A
Blackhawk	17.5	7	17.2	2	17.6	6.5	17.2	2	17.9	8	17.5	5	17.8	8.5	17.9	8.5
Monon	17.4	4	17.2	2	17.6	4.5	17.4	3	17.7	5	17.2	4	17.7	5	17.7	7.5
Mean	17.4	5.3	17.2	2.3	17.7	6.1	17.2	2.7	17.7	6.7	17.3	4.0	17.8	7.3	17.8	7.6

[a]A = Bold top grain.

TABLE V. COOKIE DIAMETERS AND TOP-GRAIN SCORES OBTAINED FROM SYNTHETIC SUGAR BLENDS WITH PARTICLE-SIZE DISTRIBUTIONS GIVING MMD OF 240, 185, AND 155 μ

Flour Variety	Parent Sugar No. 3		Synthetic Sugar Blends: MMD 240 μ		MMD 185 μ		MMD 155 μ		V-Fine Control	
	Cookie diam. cm.	Score	Cookie diam. cm.	Score[a]	Cookie diam. cm.	Score[a]	Cookie diam. cm.	Score[a]	Cookie diam. cm.	Score[a]
SRW-Standard	17.7	7	18.3	8.5	18.3	7A	18.2	7A	18.0	8A
Purkof	16.7	1.5	17.0	3	16.8	5.5	16.7	3A	17.2	6
Thorne	17.4	5	17.8	8	17.9	7	17.9	8A	18.0	8
Avon	17.6	7	17.8	8A	18.1	7A	17.5	4A	17.8	7.5A
Blackhawk	17.5	7	17.6	8	17.8	7.5A	17.8	7.5A	17.9	8.5A
Monon	17.4	4	17.9	6	18.2	8	17.8	7.5A	17.7	7.5
Mean	17.4	5.3	17.7	6.9	17.9	7.0A	17.7	6.2A	17.8	7.6

[a]A = Bold top grain.

cookies from sugar particles passing through the stated mesh were larger, and top-grain scores approximately equal to or higher than the corresponding control from whole granulated parent sugar. In most cases the fine sugar fractions were equal to the performance obtained with "V-fine" control (sugar No. 7). Relative differentiation among the flours appeared to be maintained regardless of the mean quality level imposed by the sugar used.

Baking Responses with Synthetic Particle-Size Distributions

Sugars with particles normally distributed about mean sizes of 240, 185, and 155 μ, respectively, were prepared by blending together appropriate quantities of the required size separates. Table I lists the particle-size compositions of synthetic sugar blends Nos. 9, 10, and 11, and Table V gives comparative cookie data for the sugars, and for coarse and fine controls. All three blends produced cookies substantially larger than the granulated control and there was a tendency for the SRW cookie standard, Avon, and Monon to exceed the spread for products of the fine control. Overall differentiation was increased with all three size blends.

Sugar particle size has been shown capable of controlling spread and top-grain appearance in the sugar-snap cookie. Gross variation in sugar granulation within or between years may result in anomalous and misleading data in evaluation and quality-control programs.

The mechanism whereby coarse sugar particles are detrimental to cookie spread may be related to the flour-sugar-water ratio in the dough and to the time-rate of solution. In order to be handled, rolled, and cut, sugar-snap cookie dough must be kept in a water-deficit condition. There is competition between sugar and flour for available water during the brief period of mixing and handling. In processing, sugar particles are coated with fat (creamed mass) and are further impeded from solution. As sugar particle size increases, less surface is available in the system and surface area thus becomes a limiting factor in achieving dough viscosity and ultimate spread potential.

It has been noted that significant particle-size differences can occur within generic-named sugars. For critical applications, such as research and quality-control baking, an index such as a particle-size distribution profile is of value both for selection of sugar for a test application and for maintaining continuity in properties of replacement materials.

From the baking series with sieve separates, it appeared that sugar particles ranging from throughs of 48 mesh to overs of 100 mesh were most suitable for use in the Wooster sugar-snap cookie test. In situations where available as-received sugars deviate from the optimum size range, satisfactory improvement can be made by a simple truncation and removal of coarse particles at the 48-, 35-, or 32-mesh cutpoint, whichever gives acceptable yield and performance for the operation in question.

Baking results obtained with synthetic blends of normally distributed sugar particles confirm the superiority of the "ideal" baker's-special specification over sugars with other particle-size distributions for use in the sugar-snap cookie baking test for flour quality characterization.

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