Physical and Chemical Attributes and Consumer Acceptance of Sugar-Snap Cookies Containing Naturally Occurring Antioxidants[1]

D. K. HIX,[2] C. F. KLOPFENSTEIN,[2,3] and C. E. WALKER[2]

ABSTRACT

Cereal Chem. 74(3):281–283

The antioxidant compounds, ascorbate (ascorbyl-2-phosphate), α-tocopherol, a combination of ascorbate and α-tocopherol, sodium phytate, and ferulic acid were tested as replacements for butylated hydroxyanisole (BHA) in preserving sugar-snap cookies. The cookies were compared with regard to shelf life, moisture content, width, stacking height, surface score, color, and texture. Following storage at 60°C, the Schaal oven test and gas-liquid chromatographic analysis of headspace gases indicated that ferulic acid and sodium phytate were suitable antioxidants for sugar-snap cookies. At present, sodium phytate is a GRAS substance, whereas ferulic acid is not. Consumer testing showed that cookies containing phytate were as acceptable as those containing BHA.

Synthetic antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG), and *t*-butylhydroquinone (TBHQ) are used widely by the food industry to retard rancidity and preserve freshness. Concern over the safety and utilization of those compounds has led to an interest in using alternative, naturally occurring antioxidants.

The objective of this study was to test the shelf life and other properties of sugar-snap cookies containing ascorbate, α-tocopherol, sodium phytate, and ferulic acid as viable replacements for BHA. Consumer acceptance of a cookie containing sodium phytate as an antioxidant was evaluated.

MATERIALS AND METHODS

Cookie Ingredients

Unbleached cookie flour was supplied by Mennel Milling Co., Fostoria, OH. Proximate flour composition (%) was: protein, 8.80; moisture, 12.97; ash, 0.47; crude fat, 0.42; crude fiber, 0.49. Creamtex partially hydrogenated vegetable oil (soybean, cottonseed) was purchased from Van Den Bergh Foods Co., Joliet, IL. Extra-fine granulated sugar was supplied by Domino Sugar Corp., New York. Cookie formula was the same as the standard method (AACC 1995) sugar-snap cookie formula.

Antioxidants

BHA [2, (3)-*tert*-butyl-4-hydroxyanisole, mixed isomers]; sodium phytate (inositol hexaphosphoric acid dodecasodium salt from corn); and (±)α-tocopherol (95%, prepared from synthetic phytol) were purchased from Sigma Chemical Co., St. Louis, MO. Ascorbate (L-ascorbyl-2-phosphate Mg, Phospitan C) was supplied by Showa Denko America, Inc., New York. Ferulic acid (4-hydroxy-3-methoxycinnamic acid) was purchased from Eastman Kodak, Kingsport, TN.

Antioxidant Incorporation

Antioxidants other than BHA were added at levels of 200, 700, 1,000, 6,000, or 11,000 ppm, based on shortening weight. BHA was added at the legal limit of 200 ppm. Each antioxidant was weighed, added to 25 g of the shortening, and stirred manually. The mixture then was blended with the remaining 375 g of shortening in a Hobart N-50 mixer for 1 min. The shortening-antioxidant combinations were weighed (128 g) into polyethylene containers, tightly capped, and stored (25°C) until required. Replicate cookies were baked within seven to 12 days.

Cookie Production

Three replicates of three sugar-snap cookies each, for each antioxidant-level treatment, were baked randomly during a five-day period using the standard method AACC (1995). The following modifications were employed: 1) the cookies were baked at 400°F (205°C) in a Despatch mini-bake reel test oven for 12 min instead of 10 min; 2) a 5-min cooling period was allowed before transferring cookies from insulated aluminum baking sheets to absorbent paper. After cookie width (*W*) and thickness (*T*) were measured, each cookie was scored using a scale of 1 (no cracks) to 9 very deep, nonuniform cracks) based on a set of actual cookie photographs.

Color Evaluation

Cookie color differences were determined using the Chroma Meter II CR-100 (Minolta Camera Co., Ltd., Marsland Associates, Inc., St. Louis, MO). Values for *L* (lightness on a scale of 100 for pure white to 0 for black), a^+ (red), and b^+ (yellow) were recorded for 12 cookies per batch. Those values were averaged and used to calculate least square means.

Texture Evaluation

The TA.XT2 Texture Analyzer (Texture Technologies, Scarsdale, NY) was used to estimate cookie hardness (25 kg capacity, 1 *g*-force sensitivity, and 0.0025 distance sensitivity). Cookie hardness (*g*-force) was evaluated using a 1.5-mm dia. probe that was inserted through each cookie seven times in a uniform hexagonal pattern ≈1 cm from the outer edge and in the center, and the mean force was calculated. The three-point break (triple-beam snap) was used as an index of cookie hardness, measuring peak force. A speed of 2 mm/sec and a beam separation distance of 4.5 cm were used. All tests were performed in triplicate on whole cookies.

Detection of Rancidity

Lids of half-pint mason jars (Kerr Glass Mfg. Corp., Los Angeles) were fitted with gas-tight septa. Using a 1/8-in. bit, a hole was drilled in the center of the lid flat. A 10-mm single-layer septum (Fisher Scientific Co., Pittsburgh, PA) then was affixed to the white enameled side (bottom) of the flat with GE Silicone Clear Household Glue and Seal (General Electric Co., Waterport, NY). The inverted flat was held in place with a screw band. One day after baking, two cookies (broken in half) from each treatment

[1]Published as contribution 95-373-J, Kansas Agricultural Experiment Station.
[2]Department of Grain Science and Industry, Shellenberger Hall, Kansas State University, Manhattan, KS 66506-2201.
[3]Corresponding author. E-mail: cfk@gizmit.wheat.ksu.edu

Publication no. C-1997-0407-03R.

replicate were sealed in the jars, which were then placed in an oven (model 235-55, Modern Laboratory Equipment Co., New York) and held at 60°C until a rancid odor was detected using the Schaal oven test as described by Joyner and McIntyre (1938), which is commonly used in the baking industry.

The various volatile compounds released during oxidative decomposition of the fat were sampled from the headspace above the samples, then analyzed using a Hewlett-Packard 5880A series gas chromatograph equipped with flame ionization detector (GLC). Volatile compounds were separated on a 5% phenylmethyl silicone cross-linked coated column (25 m long × 0.32 mm i.d. × 0.33 μm film thickness). A water bath was used to warm the samples in the storage jars to 60°C before drawing 1-mL aliquots of gas into gas-tight syringes, then injecting them into the GLC. The retention times for volatile compounds were compared with the GLC retention times of reference standards (method of Bassette and Ward 1975), and major peaks were identified as propanal, butanal, pentanal, and hexanal. Minor peaks identified were methanol, ethanol, 2-methyl propanal, and 3-methyl butanal. Aldehyde reference standards were manufactured by Polyscience Corp., Niles, IL. for distribution by Supelco, Inc., Bellefonte, PA. Data were statistically compared using Proc GLM of the SAS system (SAS 1989). BHA means were compared with individual treatment means using Dunnett's test and separate least significant difference (LSD) tests for each antioxidant-level treatment.

Consumer Acceptance

An affective method of sensory analysis was used to measure consumer acceptance for a control (BHA at 200 ppm) cookie and an experimental treatment (sodium phytate at 11,000 ppm) cookie. One day before the actual consumer testing, cookies were baked and stored at room temperature (25°C).

Testing was conducted at a shopping center in Manhattan, KS. A nine-point hedonic analysis was performed using color-coded ballots to differentiate experimental treatments, with 9 representing the highest degree of liking and 1 the least degree of liking. Consumers (320) reported how much they liked or disliked the sample cookies. Participant gender was nonconspicuously noted at the top of each completed ballot. Degree of acceptance was determined using analysis of variance procedures (SAS 1989).

RESULTS AND DISCUSSION

Effect of Antioxidants on Cookie Dimensions and Moisture Content

Control cookies containing 200 ppm of BHA averaged 180 ± 1.17 g in weight, were 52.9 ± 0.4 mm in diameter, and 5.81 ± 0.20 mm thick. Statistical analysis of the data indicated that cookies containing 200–11,000 ppm of α-tocopherol, ferulic acid, sodium phytate, ascorbate, or ascorbate + α-tocopherol were not different in weight, diameter, or thickness from the control cookies (*data not shown*).

Moisture content of BHA cookies averaged 5.69 ± 0.40. Moisture in cookies containing the test antioxidants ranged from 4.92 for those containing 200 ppm of ascorbate + α-tocopherol to 6.48 for those with 700 ppm of α-tocopherol. In no case was cookie moisture significantly different in test cookies than in the BHA control cookies (*data not shown*).

Effect of Antioxidants On Surface Cracking Pattern

The surface cracking pattern of sugar-snap cookies was scored on a scale from 1.0 (no cracks) to 9.0 (very deep, nonuniform cracks). A score of 5.0 was considered ideal, representing uniform surface cracks. Cookies containing 200 ppm of BHA had a mean score of 5.54 ± 0.09. Mean scores for cookies containing the other antioxidants tested ranged from 4.99 ± 0.46 for cookies containing 1,000 ppm of ascorbate + α-tocopherol to 5.88 ± 0.24 for cookies containing 6,000 ppm of α-tocopherol. It was apparent that all experimental treatments produced cookies very similar in appearance to the BHA cookies.

Color Differences

Color is a matter of visual perception and is an important consideration in food product development, because food color and appearance are usually the first impressions to register in the consumer's mind. Analysis of sugar-snap cookies for lightness (L), red (a^+), and yellow (b^+) characteristics showed that cookies containing ascorbate, α-tocopherol, and ascorbate + α-tocopherol tended to be lighter than those containing ferulic acid or sodium phytate. Red and yellow values tended to increase with increasing antioxidant concentrations. Although the Minolta chromameter was able to detect significant differences in color measurements, the range of *L* values was 64.1–62.6, a difference too small to be distinguished by most observers.

Texture Differences

Texture is very important to the consumer in the determination of cookie quality and can be evaluated by the force required to

TABLE I
Force (*g*) Required to Puncture Sugar-Snap Cookies[a]

	Antioxidant Level (ppm)				
Antioxidant	**200**	**700**	**1,000**	**6,000**	**11,000**
BHA (control)	1,772	. . .	. . .	. . .	. . .
Sodium phytate	1,785	1,749	1,662	1,550	1,688
Ferulic acid	1,935	1,800	1,645	1,562	1,836
Ascorbate	1,589	1,773	1,993	1,565	1,720
Ascorbate +α-tocopherol	2,073* (0.058)	1,806	1,807	1,808	1,616
α-Tocopherol	1,774	1,690	2,022	2,060* (0.069)	1,880

[a] Antioxidant treatment means followed by * are significantly different than the value for BHA at 200 ppm; *P* values are shown in parentheses.

TABLE II
Force (*g*) Required to Snap Sugar-Snap Cookies[a]

	Antioxidant Level (ppm)				
Antioxidant	**200**	**700**	**1,000**	**6,000**	**11,000**
BHA (control)	5,678	. . .	. . .	. . .	. . .
Sodium phytate	5,762	5,402	5,498	5,563	4,861* (0.069)
Ferulic acid	5,466	5,502	4,615* (0.018)	5,255	5,105
Ascorbate	4,999	5,450	5,526	5,191	5,182
Ascorbate +α-tocopherol	5,238	5,570	5,229	5,132	5,056
α-Tocopherol	5,072	5,463	6,100	5,869	5,835

[a] Antioxidant treatment means followed by * are significantly different than the value for BHA at 200 ppm; *P* values are shown in parentheses.

TABLE III
Effect of Antioxidant on Accelerated Shelf Life (Days) of Sugar-Snap Cookies (Schaal Oven Test)[a]

	Antioxidant Level (ppm)				
Antioxidant	**200**	**700**	**1,000**	**6,000**	**11,000**
BHA (control)	53.7	. . .	. . .	. . .	. . .
Sodium phytate	50.3*	33.8	47.0*	55.0*	78.0*
Ferulic acid	37.0	44.0*	45.0*	42.0	65.0*
Ascorbate	39.0	44.0*	42.7	28.7	43.3*
Ascorbate +α-tocopherol	41.3	32.7	29.7	30.7	21.0
α-Tocopherol	36.3	29.3	22.3	21.3	26.7

[a] Antioxidant treatment means followed by * are significantly ≥ value at 53.7 days for BHA at 200 ppm ($P = 0.05$).

TABLE IV
Percent of Propanal (C3), Butanal (C4), Pentanal (C5), and Hexanal (C6) in Headspace of Stored Sugar-Snap Cookies[a]

	Antioxidant Level (ppm)																			
	200				700				1,000				6,000				11,000			
Antioxidant	C3	C4	C5	C6	C3	C4	C5	C6	C3	C4	C5	C6	C3	C4	C5	C6	C3	C4	C5	C6
BHA (control)	12.0	9.6	13.9	46.2																
Phytate	16.2	7.8*	18.8	31.5*	13.5*	13.0	18.6	25.3*	12.5*	11.6*	18.4	23.6*	21.2	7.1*	16.3	25.1*	12.6*	12.6	20.1	26.6*
Ferulic acid	17.2	13.4	17.2	23.5*	8.2*	11.8	18.4	27.5*	19.4	12.4	18.0	17.3*	11.0*	10.1*	19.5	28.3*	9.8*	13.4	18.3	33.8*
Ascorbate	10.8*	15.4	20.6	22.7*	10.7*	11.4*	20.6	26.0*	13.2*	10.0*	18.6	29.7*	9.6*	12.4	20.3	27.3*	14.7	21.5	18.5	24.8*
Ascorbate+ α-tocopherol	12.7*	12.5	18.9	25.5*	12.4*	12.8	17.9	19.8*	9.9*	12.6	17.9	17.2*	10.6*	15.5	18.3	26.6*	9.8*	18.3	21.0	20.6*
α-Tocopherol	19.0	12.4	20.2	24.2*	11.9*	12.9	15.3*	13.7*	12.0*	10.6*	14.8*	24.4*	7.5*	11.4*	18.9	27.0*	9.9*	13.5	16.4	14.1*

[a] Means for each aldehyde (propanal, butanal, pentanal, or hexanal) followed by * are ≤ BHA mean for the same aldehyde.

puncture or fracture a sample. In general, the force required to puncture the test cookies was similar to the force required to puncture the BHA cookies (Table I). Only cookies containing 200 ppm of ascorbate + α-tocopherol and 6,000 ppm of α-tocopherol required higher force to puncture than cookies with 200 ppm of BHA.

The hardness of sugar-snap cookies was evaluated using the triple-beam snap or three-point break test (Table II). The force required to snap the cookies was statistically the same across all antioxidants and levels, except that less force was required for cookies containing 11,000 ppm of phytate or 1,000 ppm of ferulic acid.

Shelf Life Analysis

Three of the test antioxidants (ferulic acid, sodium phytate, and ascorbate) at the 11,000 ppm level preserved the cookies as long or longer than BHA at 200 ppm (53.7 days) (Table III). Ferulic acid and sodium phytate also had a preservative effect at some of the lower levels tested. Cookies containing ascorbate + α-tocopherol, or α-tocopherol became rancid faster than the 200 ppm BHA cookies. Although tocopherol and ascorbate have been reported to have a synergistic antioxidant effect (Schuler 1990), none was observed in this study.

Headspace Analysis by GLC

At the 200 ppm level, ascorbate and ascorbate + α-tocopherol were as effective as BHA in the control cookie at preventing propanal (C3) formation (Table IV). At the 700, 1,000, 6,000, and 11,000 ppm levels of antioxidant addition, nearly all of the antioxidants tested were as effective as BHA in preventing propanal formation. Sodium phytate at the 200, 1,000, and 6,000 levels kept the percent of butanal as low as did BHA at the 200 ppm level. The percent of pentanal was consistently higher for cookies containing all test antioxidants (except α-tocopherol at the 700 ppm level) than for BHA cookies. However, hexanal was higher for the BHA cookies than for any other antioxidant treatment. Pentanal and hexanal are frequently cited as being the two aldehydes most responsible for the development of off-flavors and odors caused by lipid oxidation (Jeon and Bassette 1984). It appears that BHA offers less protection against hexanal production than the other antioxidants tested, whereas the other antioxidants offer less protection against pentanal formation. Some work has shown that higher hexanal in the vapor above some stored products is highly correlated with undesirable sensory characteristics (Boggs et al 1964, Shin et al 1986).

Consumer Acceptance

Cookies containing the antioxidants BHA, ferulic acid, and sodium phytate prolonged cookie shelf life while maintaining the necessary aesthetic qualities. Although it is ubiquitous in nature, ferulic acid does not have GRAS status. BHA does have GRAS status, but the FDC limits its use for human consumption to 200 ppm. Sodium phytate is also common in nature, and it has GRAS status. For those reasons, only BHA at 200 ppm (the control for this analysis) and sodium phytate at 11,000 ppm were selected to assess consumer acceptance.

Consumer test results indicated that there was no significant difference in overall score between cookies containing BHA or sodium phytate. Male acceptance (7.37) and female acceptance (7.51) for cookies was similar. Cookies were more acceptable to those of college-age or less (7.75) and less acceptable to those of working age (7.28) or retired (7.36).

CONCLUSIONS

The Schaal oven test, GLC headspace, instrumental texture analysis and consumer acceptance data indicated that natural antioxidants can be effectively substituted for BHA in sugar-snap cookies. Sugar-snap cookies containing 11,000 ppm of sodium phytate were as acceptable to consumers as those containing BHA. Those sodium phytate cookies had a longer accelerated shelf life than the BHA cookies (65.0 vs. 53.7 days).

LITERATURE CITED

American Association of Cereal Chemists. 1995. Approved Methods of the AACC, 9th ed. Method 10-50D, approved February 1975, revised October 1981, October 1984, October 1991, and September 1992, reviewed October 1994. The Association: St. Paul, MN.

Bassette, R., and Ward, G. 1975. Measuring parts per billion of volatile materials in milk. J. Dairy Sci. 58:428-429.

Boggs, M. M., Buttery, R. G., Venstrom, D. W., and Belote, M. L. 1964. Relation of hexanal in vapor above potato granules during storage of brown rice. J. Food Sci. 29:487-489.

FDA. 1991. Pages 25, 32, 408, 492, 636 in: Code of Federal Regulations. Office of the Federal Register National Archives and Records Administration. U.S. Government Printing Office: Washington, DC.

Jeon, I. J., and Bassette, R. 1984. Analysis of *n*-pentanal and *n*-hexanal as indices of potato chip shelf-life. J. Food Qual. 7:97-105.

Joyner, N. T., and McIntyre, J. E. 1938. The oven test as an index of keeping quality. Oil and Soap. 15:184-188.

Knuckles, B. E., Kuzmicky, D. D., and Betschart, A. A. 1982. HPLC analysis of phytic acid in selected foods and biological samples. J. Food Sci. 47:1257-1258, 1262.

SAS. 1989. Users' Guide. The Institute: Cary, NC.

Shin, M. G., Suk, H. Y., Rhee, J. S., and Kwon, T.-W. 1986. Correlation between oxidative deterioration of unsaturated lipid and *n*-hexanal during storage of brown rice. J. Food Sci. 51:460-463.

Schuler, P. 1990. Natural antioxidants exploited commercially. Chapter 4 in: Food Antioxidants. B. J. F. Hudson, ed. Elsevier Science: New York.

[Received August 26, 1996. Accepted January 15, 1997.]