Prediction of Cookie Quality from Dietary Fiber Components[1]

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ABSTRACT

Water-soluble pentoses, pectin, water-insoluble hemicellulose, cellulose, and lignin contents of a commercial wheat bran, oat bran, corn bran, navy bean hulls, and soy hulls were measured, and their quantities related to physical and sensory characteristics of sugar-snap cookies in which cookie flour was replaced with 0 or 20% of these dietary fiber sources. Top grain, spread, color, percentage moisture, and all sensory characteristics were significantly affected by fiber source. Ninety-seven percent of the variability in cookie spread was predicted based on fiber components. Hemicellulose was a factor in all of the prediction equations, indicating that variation in the hemicellulose components in cereal and legume brans affects the quality of cookie products.

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The relationship between low levels of dietary fiber and certain noninfectious diseases such as diverticulosis (Painter and Burkitt 1971), atherosclerosis (Trowell 1972), and colonic cancer (Burkitt 1971) has been studied extensively. For this reason, interest has arisen in increasing fiber in the diet. Baked products have proved to be acceptable carriers of fiber from various sources (Brockmole and Zabik 1976, Gorczyca and Zabik 1979, Pomeranz et al 1977, Shafer and Zabik 1978, Vratanina and Zabik 1978).

The quality of the final product has been found to differ according to the source of the fiber added. Many of the differences in cake quality were found to relate to the quantity of the individual fiber constituents (Shafer and Zabik 1978). In this study, cookies containing various sources of cereal and legume brans were evaluated to determine differences in cookie quality and whether such differences could be related to individual fiber constituents.

MATERIALS AND METHODS

Materials

Sources of dietary fiber included commercial wheat bran, oat bran, corn bran, and soy hulls. These materials were from the same

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common lot used by Shafer and Zabik (1978), and were taken from frozen storage for use in this study. A sample of navy bean hulls was obtained from Texas A&M University (Aguilera et al 1982). The control flour was a standard cookie flour (70% extraction) donated by Mennel Mills, Fostoria, OH. The flour continued 8.9% protein, 0.41% ash, and 13.4% moisture.

Cookie Preparation

Cookies were prepared containing either 0 or 20% of the fiber sources, based on flour weight. Preparation of cookies was in accordance with a modification of the micro-III method (Finney et al 1950) as described by Vratanina and Zabik (1978). Preliminary testing set the level of liquid at 4 ml of vanilla plus deionized water to equal a total of 6 ml of liquid for the control and 10 ml of liquid for the cookies containing bran. The experiment was performed as a completely randomized design with four replications.

Cookie Evaluation

Cookies were evaluated as outlined by Vratanina and Zabik (1978) for surface color, spread, tenderness, breaking strength, moisture content, and top grain. Characteristics evaluated by a trained sensory panel included surface shape, color, and characteristics, interior cell size and shape, cell distribution, color, and texture. The cookies were not evaluated for taste because of problems caused by oxidation of some of the stored brans.

Fiber-Component Analyses

The amounts of individual fiber components including water-soluble pentoses, pectin, water-insoluble hemicellulose, cellulose, and lignin of all materials except the navy bean hulls were previously reported (Jeltema and Zabik 1979). Navy bean hulls were analyzed by the same separation and quantitation scheme (Jeltema and Zabik 1980).

Statistical Analyses

Analysis of variance was used to examine each cookie quality characteristic. Duncan's multiple range test (Duncan 1957) was used to test differences among brans. The components of the brans were related to cookie quality through the simple correlations. Equations to predict cookie quality using fiber components as the independent variables were developed using stepwise (addition) multiple regression. All first- and second-order terms involving bran components were candidates to be added to the model by stepwise regression.

RESULTS AND DISCUSSION

Cookie Quality

The Soft Wheat Quality Laboratory (Wooster, OH) evaluates the quality of wheat flour to be used in the production of sugar-snap cookies by examining top grain characteristics and spread of the cookies. Cookies having large spread and shallow, narrow cracks are considered the most desirable (Finney et al 1950, Kissell et al 1971). For both of these characteristics, the control and the cookies containing navy bean hulls scored highest, with scores that were not significantly different ($P<0.05$). Scores decreased progressively for the cookies containing oat, soy, wheat, and corn bran (Table I).

Surface color of cookies was affected by bran color. The darkest bran was wheat bran, and cookies containing wheat bran were significantly darker and less yellow than the other cookies tested. The a-values (redness) showed similarities among cookies in this color range.

The tenderness scores separated the cookies into two categories of hardness. The corn, wheat, and soy cookies were significantly more tender than the control, navy bean, and oat cookies (Table I). Crispness of the cookies was measured and recorded as breaking

TABLE I
Objective Measurements of Cookies Made with Various Cereal Brans[a]

Variable	Top Grain	Surface Color[b] L	Surface Color[b] a	Surface Color[b] b	Spread	Allo-Kramer Reading: Tenderness (lb/g)	Allo-Kramer Reading: Breaking Strength (lb/cm)	Moisture (%)
Control	8.5 a	65.2 a	10.1 a	25.5 a	12.3 a	9.2 a	3.5 a	2.6 c
Corn	4.8 c	62.7 bc	10.3 a	25.0 a	8.2 e	8.1 b	3.1 a	3.8 a
Wheat	6.5 b	54.7 e	10.4 a	18.9 c	9.0 d	7.9 b	2.9 a	3.2 b
Navy bean	8.3 a	61.7 c	10.6 a	25.3 a	11.9 a	9.5 a	3.2 a	3.2 b
Oat	7.3 ab	64.2 ab	7.1 b	22.2 b	10.5 b	9.0 a	3.7 a	3.0 bc
Soy	6.5 b	57.9 b	8.3 b	22.2 b	9.8 c	8.0 b	3.3 a	3.5 ab
SEM[c]	1.8	5.2	1.8	3.3	2.1	0.9	0.4	0.5

[a]Means are based on four replications. Averages followed by the same letter are not significantly different at $P<0.05$ (Duncan 1957).
[b]Values from Hunter color difference meter, in which L = lightness, a = redness, and b = yellowness.
[c]Standard error of the mean.

TABLE II
Sensory Scores of Cookies Made with Various Cereal Brans[a]

Variable	Surface Appearance: Shape	Surface Appearance: Color	Surface Appearance: Characteristics[b]	Interior Appearance: Cell Distribution	Interior Appearance: Cell Size and Shape	Interior Appearance: Color	Interior Appearance: Texture
Control	5.2 c	5.7 b	6.7 ab	5.2 a	5.2 a	5.7 a	5.3 a
Corn	5.5 bc	5.4 bc	5.3 b	4.6 b	4.4 b	3.9 b	5.8 a
Wheat	5.8 ab	3.5 e	6.1 ab	4.5 b	3.9 b	3.4 b	5.4 a
Navy bean	6.3 a	6.4 a	7.6 a	5.4 a	5.3 a	5.9 a	5.3 a
Oat	6.2 a	5.1 c	6.8 ab	5.7 a	5.2 a	5.2 a	5.6 a
Soy	5.1 c	4.1 de	5.6 b	4.6 b	4.3 b	3.8 b	5.0 a
SEM[c]	0.6	1.4	1.1	0.7	0.8	1.4	0.4

[a]Means of four replications, six-member taste panel, maximum points possible for optimum quality for each parameter is 7. Averages followed by the same letter are not significantly different at $P<0.05$ (Duncan 1957).
[b]Number and size of island and width and depth of cracks.
[c]Standard error of the mean.

strength (Table I). This measurement showed no significant differences among any of the brans.

Moisture levels of the raw doughs were not significantly different from each other (except for the control, which contained less liquid than cookies containing bran). After the cookies were baked, there was slightly more distinction between the variables for percentage moisture (Table II). Cookies containing corn bran retained significantly more moisture ($P<0.05$) than cookies containing navy bean hulls, wheat bran, or oat bran.

A trained panel measured both external and internal sensory characteristics (Table II). Surface characteristics (top grain) of the cookies were judged good for all variables, with little distinction among the different brans. These results differ somewhat from those obtained by the experimenter (Table I). Although results obtained by both measurements were highly correlated (0.82), the sensory panel found fewer significant differences. Difficulties the panel encountered included use of a small sample (half cookie) and less experience in evaluating surface cracking. The sensory-panel evaluation of surface shape placed cookies containing soy and the control lower than other cookies.

Cookies with a light color were more acceptable than dark cookies. Both external and internal color were most acceptable for control cookies or for those containing navy bean hulls, and least acceptable for cookies containing soy or wheat bran.

Interior cell distribution was significantly better for cookies containing oat and navy bean bran, and for the control cookies. Findings for the size and shape of the cookies were identical. The panelists apparently were unable to distinguish between these two characteristics.

No significant differences in textural quality were found among the various cookies (Table II). Texture is closely related to mouthfeel; therefore, the panelists probably found it difficult to detect differences without tasting the samples.

Fiber Components

The dietary fiber components of all but the navy bean hulls were reported previously (Jeltema and Zabik 1979). These values, repeated in Table III, are compared with those for navy bean hulls. Values for individual fiber components varied substantially. The legume hulls (soy and navy bean) were much higher in pectin than were the nonlegume brans. However, whereas soy was highest in cellulose (36%), navy bean was low in cellulose (5.8%). Oat bran was low in most fiber components. Corn bran was highest in water-insoluble hemicellulose, followed by wheat bran.

TABLE III
Dietary Fiber Components of Various Plant Materials

Source	Water-soluble Pentose (%)	Pectin (%)	Water-insoluble Hemi-cellulose (%)	Cellulose (%)	Lignin (%)
Wheat bran[a]	0.44	0.61	28.49	8.40	5.35
Corn bran[a]	0.30	0.56	45.62	14.99	2.02
Oat bran[a]	0.93	1.11	8.20	2.92	3.36
Soy hulls[a]	0.89	6.92	17.57	36.19	3.10
Navy bean hulls[b]	1.13	8.96	18.00	5.81	1.03

[a]Four replications (Jeltema and Zabik 1979).
[b]Three replications.

Correlation Between Cookie Quality and Fiber Components

Most cookie properties were significantly ($P<0.01$) correlated with fiber components (Table IV). Most (47–97%) of the variation in quality could be predicted by fiber components, for which the percent of variation predicted is measured by the R^2 value (Table V).

Of the fiber components, hemicellulose was significantly correlated with most of the cookie properties measured. The hemicellulose fraction is composed of three fractions: uronic acids, hexoses, and pentoses. Of these fractions, the uronide portion was more highly correlated with cookie properties than the total hemicellulose value or any other fraction.

Spread showed the highest simple correlation with fiber components. The hemicellulose fractions were most highly correlated with spread (r = −0.80 to −0.89), followed by lignin (r = −0.62), for which an increase in either component correlated with decreased spread. Hemicellulose components have a high water-holding capacity (Eastwood 1973), and cookie spread decreases in the presence of components that bind water (Kissell and Yamazaki 1975, Vratanina and Zabik 1978). Lignin, however, has never been attributed with a high water-holding capacity. The simple correlation cannot be regarded as indicating the absolute effect of these substances on the property measured because of possible interactions among components. Some evidence suggests that lignin content parallels hemicellulose content (Gaillard 1962); however, the two were not significantly correlated in the brans used in this study.

Ninety-seven percent of the variation in spread was accounted for by application of a model containing the bran components lignin, hemicellulose, and pectin (Table V). Hemicellulose alone was associated with 68% of the variation, whereas linear terms in hemicellulose and lignin were associated with 85% of the variation. The uronide portion of hemicellulose was most highly correlated with spread, and could be used alone to predict 80% of the variation. This is of interest because pectin was not significantly correlated with spread. Both navy beans and soy were high in pectin, yet cookies prepared with navy bean hulls showed good spread (11.9); cookies that contained soy hulls had a much lower spread (9.8). Yamazaki (1955) previously reported that several hydrophilic materials (ie, agar, hydroxyethyl cellulose, tailings, and acid-precipitated xylan) reduced cookie diameter when 39 g of cookie flour was blended with 1 g of the substance before cookie preparation.

Other aspects of cookie quality were also significantly correlated with hemicellulose and, in some cases, with cellulose or lignin

TABLE IV
Significant Simple Correlation[a] Coefficients of Fiber Components with Cookie Properties

	Cookie Properties						
Measured Quantity	Toughness	Top Grain	Moistness	Shape	Cell Distribution	Cell Size	Spread
Cellulose	−0.51	···	···	−0.50	−0.49	···	···
Lignin	−0.56	···	···	···	···	−0.61	−0.62
Water-insoluble hemicellulose	−0.49	−0.69	0.68	···	−0.55	−0.57	−0.82
Uronic acid	−0.59	−0.74	0.68	···	−0.62	−0.64	−0.89
Hexoses	···	−0.70	0.62	···	−0.53	−0.51	−0.82
Pentoses	···	−0.66	0.68	···	−0.54	−0.56	−0.80
Water-soluble pentose	···	···	···	···	···	···	0.59
Spread	0.68	0.76	−0.64	···	0.56	0.66	···

[a]Significant at $P<0.01$.

TABLE V
Prediction Equations for Cookie Properties[a]

Cookie Property	Prediction Equation[b]	R^2
Toughness	$y = -0.0277\, X_{Cel} + 0.0032\, X_{Hem} - 0.0096\, (X_{Hem})(X_{Lig}) + 9.4574$	57
Top grain	$y = -0.0782\, X_{Hem} + 8.5308$	47
Moistness	$y = +0.0194\, X_{Hem} + 0.0125\, X_{Cel} + 2.6697$	56
Shape	$y = -0.0346\, X_{Cel} + 1.2524\, X_{WSPent} + 0.0199\, X_{Hem} + 4.8247$	63
Cell distribution	$y = -0.0107\, X_{Hem} + 0.7568\, X_{WSPent} - 0.0238\, X_{Cel} + 4.9610$	55
Cell size	$y = -0.0251\, X_{Cel} - 0.4217\, X_{Lig} + 0.4173\, (X_{Lig})(X_{WSPent}) + 5.3680$	69
Spread	$y = -0.1417\, X_{Hem} - 0.6425\, X_{Lig} - 0.0043\, X_{Hem} - 0.0726\, (X_{Pect})(X_{Lig}) + 12.1481$	97

[a]Components added if the partial correlation was significant at $P < 0.05$.
[b]X_a = Quantity of a. Cel = Cellulose, Hem = hemicellulose, Lig = lignin, Pect = pectin, WSPent = water-soluble pentose.

(Table IV). Evenness of internal and external color correlated with variation in fiber components; however, this correlation was probably indirect, because correlation was better with characteristics such as cell size, cell distribution, and spread, which influence color. Although the direction of the correlation of water-soluble pentose components to cookie characteristics was always opposite that of the insoluble-hemicellulose components, the correlation was only significant between spread and water-soluble pentoses, in which water-soluble pentose content correlated with increased spread. This differs from cake-quality measurements, in which water-soluble pentose content was often significantly negatively correlated with quality (Shafer and Zabik 1978).

In general, an increase in fiber components significantly correlated with an increase in tenderness and moistness, decreased spread, and poorer top grain and cell characteristics.

Predicting Overall Cookie Quality from Spread

Whereas the major portion of variation in cookie quality was associated with fiber components, particularly water-insoluble hemicellulose content, spread was significantly correlated with all other cookie-quality measurements. Large spread correlated with drier, tougher cookies, and better top grain, cell size, and cell distribution.

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