COOKIE BAKING PROPERTIES OF DEFATTED PEANUT, SOYBEAN, AND FIELD PEA FLOURS[1]

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ABSTRACT

Defatted peanut, soybean, and field pea flours were used to replace 10, 20, and 30% of the wheat flour in sugar cookies. Peanut and field pea flours exhibited dough handling properties much like those of the 100% wheat flour controls; soybean flour doughs were drier and more crumbly. Diameter, height, spread characteristics, textural quality (area under curve values), and sensory quality attributes of cookies were not affected adversely by use of peanut flour. Total protein content was increased by about 1.5% with each increment of peanut and soybean flour; cookies prepared with 30% of these flours contained twice as much protein as the 100% wheat flour control. High water-absorptive properties exhibited by soybean flour used at 20 and 30% replacement levels restricted cookie spread and development of a typical top grain during baking; consequently, baking performance and sensory quality attributes of these cookies were affected adversely. Field pea flour cookies did not differ significantly from the 100% wheat flour control in diameter, height, spread ratio, texture measurements, and moisture content. Sensory quality attributes were not affected adversely by use of this flour except at the 30% replacement level where a beany flavor was detected. A follow-up study indicated that addition of water to the formula could improve markedly dough handling, spread characteristics, top grain, and certain sensory quality attributes of sugar cookies containing 30% soy flour; a 2:1 ratio of soy flour to added water produced the best overall results.

Efforts to increase the availability of protein in man's diet have encouraged use of high-protein plant materials as ingredients in a variety of foods. Such wheat-based baked goods as breads, cakes, and cookies are popular foods and provide an excellent means of improving nutritional quality through incorporation of vegetable proteins.

Fortification of wheat flour with nonwheat proteins increases protein quality by improving amino acid profiles (1); however, accompanying adverse changes in such physical qualities as dough character and baking properties have occurred sometimes. For example, nonwheat proteins used in cookie formulas have exhibited greater water retention properties than has wheat flour and thus have possessed a greater capacity for competing for the limited free water in cookie dough (2). Consequently, typical spread and top grain characteristics of cookies containing these types of proteins fail to develop during baking.

Various techniques have been investigated to modify or improve the baking performance of flours from soybeans (2,3), wheat (4), grain sorghum and millet (5), and peanuts (6). These have included addition of surfactants or dough conditioners to bread and cookie formulations and enzymatic or chemical hydrolysis of the protein itself.

The levels at which nonwheat flours could be used to replace wheat flour in cookies also have been investigated. Corn germ flour could replace up to 48% of the wheat flour in chocolate chip and oatmeal cookies without detrimental

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effects on texture and flavor (7). On the other hand, glandless cottonseed could be used only at low levels without adversely affecting physical and sensory qualities of sugar cookies (8). Wheat flour fortified with either 12% whole or dehulled soybean products produced acceptable chocolate chip, coconut, oatmeal, and sugar cookies (3).

The purpose of this study was to investigate the influence of various levels of defatted peanut, soybean, and field pea flours on baking and quality characteristics of sugar cookies.

MATERIALS AND METHODS

Flour Preparation

Defatted flours were prepared from Florunner peanuts (*Arachis hypogaea*), Bragg soybeans (*Glycine max*), and Dixie Cream field peas (*Vigna unguiculata*) as described previously (9). The seeds were coarsely ground and partially defatted with hexane, air dried, reground, reextracted with hexane until the oil content was about 1%, air dried again, and sifted through a 60-mesh screen. The flours were stored in glass jars at 1°C until use.

Analytic Procedures

Moisture content of the flours was determined by vacuum drying 5-g samples for 24 hr at 70°C. Total protein was determined on 0.5-g samples using a modification of the Kjeldahl procedure for peanut products (10). Factors used to convert nitrogen content to protein values were 5.70 for wheat flour, 5.46 for peanut, 5.71 for soybean, and 6.25 for field pea (11). Ash content was determined by the procedure of the American Oil Chemists' Society (10).

Oil content of the flours was determined by weighing 1-g samples on a half sheet of preweighed Whatman 541 filter paper. The filter paper was folded carefully around the sample and clamped with a coiled copper wire. Each sample was placed in a 30-ml glass bottle that had been predried at 132°C for 45 min, weighed, covered with 30 ml of anhydrous ether, capped tightly, and shaken. The samples were shaken periodically over a 48-hr period and uncapped; the folded

TABLE I
Formulation of Sugar Cookies for Replacement of Wheat Flour With Varying Levels of Peanut, Soybean, and Field Pea Flours

Ingredients	% Wheat Flour Replacement			
	0 (g)	10 (g)	20 (g)	30 (g)
Wheat flour (plain, all purpose)	75.5	67.9	60.3	52.7
Peanut, soybean, or field pea flour	0	7.6	15.2	22.8
Sugar (granulated, cane)	75.0	→	→	→
Cream of tartar	1.6	→	→	→
Baking soda	1.0	→	→	→
Salt	0.4	→	→	→
Cinnamon	0.5	→	→	→
Egg (whole, fresh)	24.0	→	→	→
Shortening (hydrogenated vegetable)	47.0	→	→	→

paper containing the flour was removed with tweezers and washed over the sample bottle with 5–10 ml of ether before discarding. The bottles containing both oil and ether were placed under a hood to evaporate the ether, heated in a forced draft oven at 110°C for 1 hr, cooled in a desiccator, and reweighed. Percentage oil was calculated as (oil weight/flour weight) × 100.

Cookie Formulation and Preparation

A 3 × 4 factorial experiment used three defatted legume flours (peanut, soybean, field pea) at three wheat flour replacement levels (10, 20, and 30%), with 100% wheat flour as the control. Formulations are shown in Table I.

Mixing was done by the procedure that Fogg and Tinklin (8) described, except that an Oster Kitchen Center mixer was used. The dough was rolled between sheets of wax-coated freezer paper to a uniform thickness of 9 mm and cut to a diameter of 3.8 cm. Cookies were baked on aluminum cookie sheets at 204° C (400° F) for 9 min in a conventional electric oven. They were cooled for a few minutes before being transferred to absorbent paper.

Baked Cookie Analyses

Baked cookies were weighed and the height and diameter measured with a caliper. Spread ratio was expressed as diameter/height. The same cookies were tested for textural differences with a Food Technology Corp. Shear Press (model TP-1). Operating conditions for the shear press included a standard shear-compression cell, 300-lb transducer ring, 30-sec downstroke speed, and recorder range setting of 100. The area under each texturegram curve was measured with a planimeter and reported as square centimeters per gram.

The crumbs remaining from the texture tests were collected and frozen until analyzed for moisture and protein content. Moisture content was determined on 1-g samples dried in a forced air oven at 110°C for 3 hr. Protein content was determined by the same procedure described previously for analyzing the defatted flours except that the sample weight was 1 g.

The conversion factor for relating Kjeldahl nitrogen content of the cookies to protein content was calculated on the basis of the proportion of total protein provided by each of the three protein-containing constituents. For instance, for each 225 g of dough, the cookies containing 20% peanut flour had:

24.0 g egg @ 12.9% protein in egg[2]	3.1 g egg protein
60.3 g wheat flour @ 10.5% protein in flour[2]	6.33 g wheat protein
15.2 g peanut flour @ 50.9% protein in flour	7.74 g peanut protein
Total	17.17 g protein

When 6.25 is used to convert egg nitrogen to protein, 5.7 for wheat flour, and 5.46 for peanut meal, the weighted factor for the cookie is:

$$(3.1/17.17) \times 6.25 + (6.33/17.17) \times 5.70 + (7.74/17.17) \times 5.46 =$$
$$(.181)(6.25) + (.369)(5.70) + (.451)(5.46) =$$
$$1.131 + 2.103 + 2.462 = 5.696$$

[2]Egg and wheat flour protein percentages estimated from values in USDA Agriculture Handbook No. 8 (12).

Sensory Quality Evaluation

A ten-member panel evaluated sensory qualities of cookies about 4 hr after baking using a rank order test. Only one type of legume flour was tested per day. Whole cookies were arranged on white plates so that a 100% wheat flour cookie was identified as a reference (R) sample; the test cookies were presented in a randomized order. Panelists were asked to use the reference cookie as a basis for determining acceptance by first assigning a score to it and then evaluating each test cookie in comparison to R. Appearance, color, aroma, texture, and flavor were evaluated on a scale of 9 (excellent) to 1 (very poor). For statistical analysis, the original sensory panel data were transformed to a new scale as Amerine et al (13) described so that each scorer's reference was at a level of 9.0.

Statistical Analysis

An overall analysis of variance was run in which the 100% wheat flour controls were pooled and an adjusted error term used. In this analysis, the effects of flour multiplied by level (interaction term) were significant at the 1% level for all comparison items except moisture. For this reason and because the legume flours were tested on separate days, the analysis was rerun to analyze each flour type separately. Each 100% wheat-flour control was treated as a 0 or 4th level, and controls were not pooled in the second analysis. Significance of mean differences was determined by Duncan's multiple range test.

RESULTS AND DISCUSSION

Proximate composition data shown in Table II reveal that the major differences in the flours were in protein and carbohydrate content. Peanut and soybean products were high in protein, while field pea flour was high in carbohydrate. The oil content of all three flours was similar and quite low (0.9–1.5%).

Physical and compositional characteristics and sensory quality scores of sugar cookies prepared with varying levels of peanut, soybean, and field pea flours are shown in Table III. Each flour is discussed separately below.

Peanut Flour

Doughs prepared with various levels of peanut flour closely resembled the 100% wheat flour control in consistency and handling characteristics. This similarity indicates that no modification in formulation would be required to

TABLE II
Proximate Composition of Defatted Peanut, Soybean, and Field Pea Flours

Legume Flour	Moisture (%)	Protein[a] (%)	Oil[a] (%)	Ash[a] (%)	Carbohydrate[a,b] (%)
Peanut	6.8	50.9	1.5	4.5	36.3
Soybean	8.9	46.0	1.1	5.7	38.3
Field pea	13.1	20.9	0.9	3.4	61.7

[a]Wet weight basis (as used in cookie preparation).
[b]Carbohydrate content determined by difference.

TABLE III
Physical and Compositional Characteristics and Sensory Quality Scores of Sugar Cookies Prepared With Varying Levels of Peanut, Soybean, and Field Pea Flours[a]

Legume Flour	Wheat Flour Replacement (%)	Diameter (cm)	Height (cm)	Spread Ratio (diam/ht)	Area Under Curve (cm^2/g)	Moisture (%)	Protein (%)	Sensory Quality Scores[b]				
								Appearance	Color	Aroma	Texture	Flavor
Peanut	0	6.15b	1.06b	5.85ab	.32b	4.54	4.30d	9.0a	9.0a	9.0	9.0	9.0
	10	6.14b	1.15a	5.40c	.35ab	4.42	5.87c	8.7ab	8.9a	8.9	8.6	9.1
	20	6.36a	1.04b	6.15a	.32b	4.13	7.39b	8.2b	8.2b	8.4	8.3	8.5
	30	6.15b	1.11ab	5.56bc	.39a	4.29	8.94a	7.5c	7.9b	8.3	8.3	8.5
(Probability)		(0.01)	(0.05)	(0.01)	(0.05)	(ns)	(0.01)	(0.01)	(0.01)	(ns)	(ns)	(ns)
Soybean	0	6.37a	0.93c	6.85a	.35b	4.30	4.27d	9.0a	9.0a	9.0a	9.0a	9.0a
	10	6.39a	0.96c	6.66a	.40b	4.42	5.74c	9.0a	8.7a	8.6ab	8.5a	8.8a
	20	5.43b	1.32b	4.12b	.50a	4.50	6.97b	6.9b	9.1a	8.4b	7.6b	7.8b
	30	5.18b	1.44a	3.61c	.53a	4.50	8.42a	6.4b	8.0b	7.8c	7.2b	7.2c
(Probability)		(0.01)	(0.01)	(0.01)	(0.01)	(ns)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Field pea	0	6.11	1.11	5.56	.35	3.94	4.16d	9.0	9.0a	9.0a	9.0a	9.0a
	10	6.19	1.02	6.11	.32	3.81	4.67c	8.3	7.7b	8.2bc	8.5ab	8.4ab
	20	6.11	1.01	6.10	.36	3.93	5.10b	9.0	9.0a	8.5ab	8.2b	7.7bc
	30	6.37	0.96	6.89	.35	3.91	5.60a	8.4	8.5a	7.8c	8.1b	7.3c
(Probability)		(ns)	(ns)	(ns)	(ns)	(ns)	(0.01)	(ns)	(0.01)	(0.01)	(0.05)	(0.01)

[a]For each flour type, values within column having no letter in common are significantly different at $P \leq 0.01$ or $P \leq 0.05$ as indicated (ns values are not significantly different).
[b]Scale of 9 to 1, where 9 = excellent, 5 = borderline, and 1 = very poor.

facilitate handling of cookie dough containing this flour. Diameter, height, spread ratio, and texture values (area under curve) of peanut flour cookies were variable and unordered; differences in them therefore should be discounted. Differences in moisture content were not significant.

Protein content was influenced significantly by addition of peanut flour to the sugar cookie formula. Each increment of peanut flour raised the total protein content by about 1.5%, and cookies prepared with 30% peanut flour contained twice as much protein (8.9%) as the control (4.3%). Sensory quality scores show that only appearance and color scores were influenced significantly by increasing the level of peanut flour. These scores decreased slightly as peanut flour level increased because of a slight increase in browning and variation in top grain (Fig. 1). All cookies were rated as acceptable, however. These results indicate that peanut flour could replace at least 30% of the wheat flour in a sugar cookie formula without adversely affecting baking performance, physical characteristics, and acceptability and at the same time could increase substantially the protein content of the finished product.

Soybean Flour

Doughs prepared with 10% soybean flour closely resembled the 100% wheat flour dough in consistency and handling characteristics. At the 20 and 30% replacement levels, however, this flour exhibited high water-absorptive properties. These doughs were much drier and more crumbly than were the control doughs, and therefore more difficult to shape and handle. Cookies containing 10% soybean flour did not differ significantly in diameter, height,

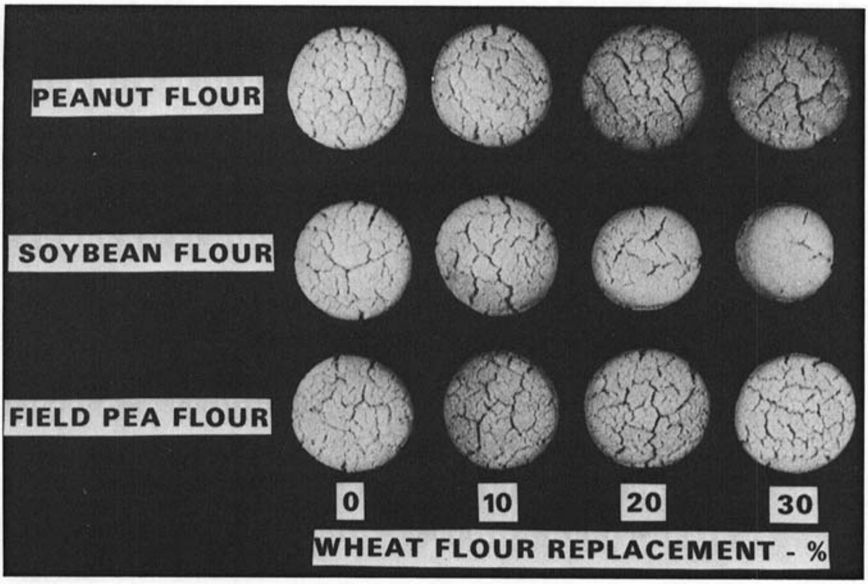

Fig. 1. Representative sugar cookies prepared from defatted peanut, soybean, and field pea flours at 0, 10, 20, and 30% wheat flour replacement levels.

spread ratio, and texture values (area under curve) from the cookies containing 100% wheat flour. Increasing the soybean flour level to 20 or 30%, however, reduced cookie diameter and spread ratios and increased height and toughness (area under curve values).

The mechanism by which cookie spread is reduced by certain wheat flour supplements is not understood completely, but the manner in which water becomes oriented in the dough during mixing appears to be important. Composite flours of wheat and soy apparently form aggregates with increased numbers of hydrophilic sites available for competing for the limited free water in a cookie dough (2). Rapid partitioning of free water to these hydrophilic sites occurs during dough mixing and increases dough viscosity, thereby limiting cookie spread and top-grain formation during baking. Yamazaki et al (14) also found that cookie spread was depressed by increasing the relative quantity of hydrophilic additives in cookie dough. Although surfactants were not used in the present study, they have been used successfully in certain flour products to improve cookie spread (2,4); these dough conditioners delay the gelatinization of flour starch, thereby reducing dough viscosity and allowing cookies to spread before becoming firm or set.

Differences in the moisture content of soybean flour cookies were not significant. On the other hand, protein content was increased significantly by addition of soybean flour to the cookie formula. Each increment of soybean flour raised the total protein content by about 1.4%, and cookies prepared with 30% soybean flour contained almost twice as much protein (8.4%) as the control (4.3%).

Results of sensory quality evaluations show that most organoleptic attributes of soybean flour cookies were not affected adversely until 20 or 30% soybean flour levels were used. Taste panelists commented that cookies containing these levels of soybean flour received low appearance, texture, and flavor scores because of their thickness, hardness, beany flavor, and poor spread characteristics. The spread-restriction properties that the soy flour exhibited also prevented development of a typical top grain (Fig. 1) during baking. Therefore, these results show that even though addition of soybean flour increased significantly protein content of sugar cookies, dough handling, baking performance, and sensory quality attributes were affected adversely when 20 or 30% soybean flour was used to replace wheat flour. The need for modifying cookie formula for use with this type of flour was implicated.

Field Pea Flour

Doughs prepared with various levels of field pea flour closely resembled the 100% wheat flour control in consistency and handling characteristics. No modifications would be required therefore in formulation to facilitate handling of cookie dough containing this flour. The physical characteristics of the baked products containing field pea flour also closely resembled the 100% wheat flour control; differences in diameter, height, spread ratio, texture (area under curve values), and moisture content were not significant. Addition of field pea flour to the cookie formula slightly increased protein levels—about 0.5% with each increment of field pea flour.

The baking performance of field pea flour was much like wheat flour; cookies containing this flour spread uniformly during baking and developed a typical top grain (Fig. 1). This was reflected in sensory quality scores for appearance when no significant difference was noted between the control and test samples. Color and aroma scores were variable and unordered, indicating that these differences should be discounted. Texture scores showed only a slight decrease as field pea flour level increased, but the decrease in flavor scores was more marked. Taste panelists detected an undesirable beany flavor in cookies containing high levels of field pea flour. One means of reducing raw, beany flavors in legume flours to be used as ingredients in sugar cookies and other baked goods might be exposing the materials to moist heat; other studies (15,16) have shown this to be an effective flavor-modifying technique for use with plant proteins.

These results show that field pea flour could replace at least 30% of the wheat flour in a sugar cookie formula without adversely affecting baking performance or altering the physical characteristics of the end product. A slight increase in protein content occurred with use of this flour. Most sensory quality attributes of cookies containing field pea flour were not influenced adversely until the 30% wheat flour replacement level was reached.

Alteration of Soy Flour Cookie Dough Consistency

Results of these baking studies indicated that no major modifications in formulation would be required when using peanut or field pea flour to replace a portion of the wheat flour in sugar cookies; these flours exhibited satisfactory dough handling and baking performance. By contrast, soy flour used at 20 and 30% wheat flour replacement levels produced drier, more crumbly doughs that were difficult to shape and handle. Because of the high water-absorptive properties that soy flour exhibited, cookies prepared with high levels of soy flour failed to spread properly or develop a typical top grain during baking. Therefore, the formula for the cookie containing 30% soybean flour (Table I) was modified to incorporate additional water to investigate its influence on dough handling and cookie spread. Four test batches were prepared as follows:

% Wheat Flour Replacement	*Ratio of Soy Flour to Added Water*
0 (Control)	...
30 (Soy)	0
30 (Soy)	2:1
30 (Soy)	1:1

For those batches with adjusted water levels, the water was incorporated by blending it with the beaten egg. Spread characteristics (diameter, height, spread ratio) and sensory quality attributes were determined as previously described; results are shown in Table IV and Fig. 2.

Dough consistencies varied according to water level; the 100% wheat flour control and the dough containing a 2:1 ratio of soy flour to added water had similar consistencies and optimum dough handling characteristics. The soy flour dough without added water was dry and crumbly, while that containing a 1:1 ratio of soy flour to added water was wet and sticky; both doughs were difficult to handle.

TABLE IV
Influence of Water Adjustments Made in Sugar Cookie Formulations Containing Soybean Flour on Spread Characteristics and Sensory Quality Scores[a]

% Wheat Flour Replacement	Ratio of Soy Flour to Added Water	Dough Consistency	Diameter (cm)	Height (cm)	Spread Ratio (diam/ht)	Sensory Quality Scores[b] Appearance	Color	Aroma	Texture	Flavor
0 (Control)	...	Optimum	6.24b	0.96c	6.55a	9.0a	9.0a	9.0a	9.0	9.0a
30	0	Dry, crumbly	5.18c	1.36a	3.83c	5.7b	6.5b	7.2b	8.3	7.3b
30	2:1	Optimum	6.25b	1.06b	5.90b	9.2a	9.2a	8.3ab	8.7	7.8b
30	1:1	Wet, sticky	6.55a	0.97c	6.74a	8.9a	8.8a	8.5a	8.8	7.2b
	(Probability)		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.05)	(ns)	(0.01)

[a]Values within column having no letter in common are significantly different at $P \leqslant 0.01$ or $P \leqslant 0.05$ as indicated (ns values are not significantly different).
[b]Scale of 9 to 1, where 9 = excellent, 5 = borderline, and 1 = very poor.

Cookies that most closely resembled the 100% wheat flour control in diameter measurements were those prepared with a 2:1 ratio of soy flour to water. In height and spread ratio measurements, however, doughs containing a 1:1 ratio of soy flour to added water produced cookies most like the control. Cookies prepared from soy flour doughs with no added water were least like the control; they were smaller in diameter and spread ratio but thicker than the other test samples. The taste panelists also preferred them least because of their poor spread, failure to develop a typical top grain (Fig. 2), darker color, and overcooked aroma. Even though baking time was identical for all samples, cookies prepared from soy flour with no added water were decidedly browner than were the other test samples.

The appearance, color, and aroma scores of cookies containing either a 2:1 or 1:1 ratio of soy flour to added water did not differ significantly from the control. Differences in texture scores of control and soy flour test samples were not significant. Flavor scores of all soy flour samples regardless of water level were

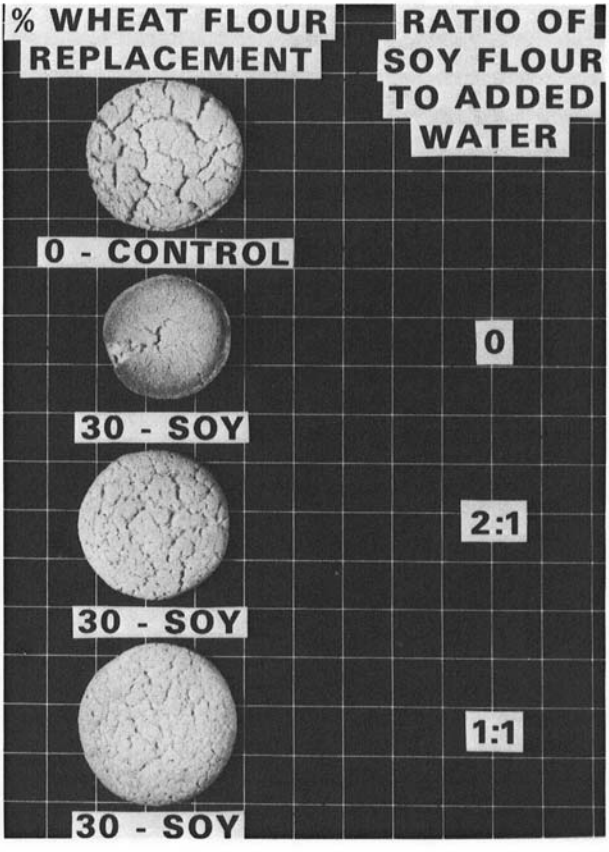

Fig. 2. Influence of water adjustments made in sugar cookie formulations containing 30% soy flour on top grain and spread characteristics.

similar to but poorer than the 100% wheat flour control.

Considering overall physical and organoleptic qualities of soy flour cookies, those prepared with a 2:1 ratio of soy flour to added water were most like the control. The benefits of manipulating water level to improve dough handling and spread characteristics of cookies containing a high water-absorptive capacity flour (eg, soy flour) were clearly demonstrated.

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