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Children's Acceptance, Nutritional, and Instrumental Evaluations of Whole Grain and Soluble Fiber Enriched Foods

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ABSTRACT: **The Dietary Guidelines for Americans 2005 report recommends 3 or more daily ounce-equivalents of whole grains (WG), and the FDA suggests consumption of 25 g of total dietary fiber (TDF) and 6 g of soluble fiber (SF) for a 2000-calorie diet. Efforts to increase the consumption of WG and SF among elementary school-aged children are needed. The objectives of this study were to examine the consumption of WG- and SF-enriched burritos and cookies among elementary school-aged children and to perform a quality evaluation of all products. Children in grades K to 6 from a local elementary school consumed control (CTR) products made with refined flour along with the test products (TRT) over a 13-wk period. TRT burritos and cookies contained 51% and 100% WG, respectively. CTR and TRT products were served on 3 and 4 different Fridays, respectively. Children's consumption was determined via plate waste. Quality parameters such as texture, color, water activity, weight, and product dimensions were also measured. No significant differences in consumption between CTR and TRT burritos and cookies were found (36% and 90%, respectively). Texture (area) was higher for CTR burritos compared with TRT burritos (1.31 and 0.66 kg-s, respectively). CTR burritos were lighter than TRT burritos with *L** values of 80.04 and 64.61, respectively. CTR cookies required a higher breaking force (3.14 compared with 0.58 kg), were lighter than TRT cookies (63.18 compared with 50.27), and had lower water activity (0.5 compared with 0.71).**

Keywords: children, plate waste, school lunch, soluble fiber, whole grain

Introduction

Currently, in the United States, 1 in 8 children has 2 or more risk factors for heart disease (Sloan 2006). In addition, 30% to 50% of new child diabetes cases are classified as type 2, and 31% of children are at risk of or are overweight (Sloan 2006). Zanzola (1996) reports that children fail to meet the existing recommendations for fiber intake. Thus, it is important to reformulate foods to make them nutrient dense.

The Dietary Guidelines for Americans 2005 report (USDA 2006) supports greater consumption of whole grains and dietary fiber to reduce the risk for chronic disease. Considerable scientific evidence indicates that consuming whole grains daily can significantly reduce the risk for heart disease (Bazzano and others 2003; Jensen and others 2004; Mellen and others 2007), type-2 diabetes (Fung and others 2002; Montonen and others 2003; Hodge and others 2004), and obesity (Newby and others 2003; Bazzano and others 2005; Esmaillzadeh and others 2005). Whole grains are important sources of fiber, vitamins, minerals, lignans, sterols, phytins, sphingolipids, and other phenolic compounds (Miller and others 2000). These potent protective components in whole grains may work individually or synergistically to reduce disease risk (Slavin and others 1999). Despite these potential benefits, only 10% of children consume 3 ounce-equivalents of whole grain as recommended by the Dietary Guidelines for Americans 2005 report and Healthy People 2010 Objective (U.S. DHHS 2000).

According to the FDA and DHHS (2002), 25 g of total dietary fiber is recommended daily along with 6 g of soluble fiber in a 2000-calorie diet. This amount is based on the ratio of soluble fiber to total dietary fiber that naturally occurs in fruits, vegetables, legumes, and grains. The average fiber intake in the United States is only about 14 g/d (Arndt 2006).

With the passage of the Healthy Meals for Healthy Americans Act, which required school meals to adhere to the Dietary Guidelines for Americans in terms of the limits on total fat, saturated fat, and moderate amounts of sodium, the USDA took action to improve the nutritional quality of school meals (Healthy Meals of Americans Act 1994; Swanson 2006). Although the level of whole grains served was not provided, it was reported that 12.2% of states and 49.7% of districts require schools to offer students 5 or more foods containing whole grains each week (Wechsler and others 2001).

Plate waste has been used to examine the consumption of fruits and vegetables (Adams and others 2005), skim milk (Wechsler and others 1998), and soy (Endres and others 2003). However, there is only 1 study to assess the consumption of whole grain foods. Chan and others (2008) observed the acceptability of partially substituting refined-wheat flour in pizza with white whole wheat flour. Results showed no difference in consumption and liking between the 50:50 blend and the refined-wheat flour pizza. However, results showed that children in the lower grades ate significantly less pizza than children in the 6th grade.

The introduction of whole grain wheat and barley flours into familiar grain products such as burritos and cookies may potentially

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increase dietary fiber and whole grain consumption in elementary school-age children. According to Friedman and Hurd (1995), preliminary sensory research suggests that children accepted the white whole wheat-based experimental foods containing fiber. In another study, children preferred the taste of bread made with white whole wheat compared with the red whole wheat (Ludkow and others 2004).

Quality measurements are an important factor to consider when trying to understand the acceptability of a certain food product. To find an acceptable level of whole flour in tortillas, Friend and others (1992) conducted a study with tortillas prepared from different mixtures of red and white wheat flours that were both whole and refined (0%, 25%, 50%, 75%, 100%). Dough that contained whole wheat flour had higher water absorption. The additional water requirement during preparation of tortillas made with whole wheat flour may be due in part to the higher pentosan content of the whole wheat flour. Adequate absorption is important for optimization of dough handling and finished product quality. Other research has been done to evaluate quality parameters of grain foods (Hatcher and others 2005).

There has been no published research that examines children's consumption of a blend of whole grain barley flour and whole wheat flour used in traditional grain foods such as bean and cheese burritos and chocolate chip cookies served in a school cafeteria setting. Data comparing the quality of whole grain foods and their refined flour counterpart is limited. This study had several objectives: (1) to examine the acceptance of whole grain products via plate waste; (2) to examine quality differences between the control and treatment products; (3) to estimate whole grain and soluble fiber intake consumed during the time of the study; and (4) to test the nutritional content of the control and treatment products.

Materials and Methods

Product selection and manufacturing

Burritos and chocolate chip cookies were selected for the study based on information provided on the school menus from January to June 2006. These 2 items were served frequently (at least twice per month). To control for errors from days-of-week effect, the study was conducted on the same of the day of the week (Fridays). Burritos and cookies were served on 7 Fridays between March and June. Burritos and cookies were always accompanied with green salad, canned peaches, canned corn, a Granny Smith apple, and choice of the type of milk. The treatment cookies, termed "treatment" (TRT), contained 1.2 g of β-glucan soluble fiber from Prowashonupana barley (Sustagrain®, ConAgra Foods Inc., Omaha, Nebr., U.S.A.) and contained 8 g of whole grains/serving. The treatment burritos, termed "treatment" (TRT), contained 1.4 g of β-glucan soluble fiber in the tortilla and were made with 25% Prowashonupana barley flour and 26% white whole wheat flour (Ultragrain®, ConAgra Foods Inc.) flour basis and contained 19 g of whole grains/serving. Prowashonupana is a proprietary waxy, hulless barley variety that contains at least 30% total dietary fiber (12% β-glucan soluble fiber, 18% insoluble fiber).

Children's acceptance

Subjects/setting. Children who participated in the study were in Kindergarten (K) to 6th grades at Neil Armstrong Elementary School in the Pomona Unified School District (PUSD). See Table 1 for ethnicity and lunch distribution breakdown of children at Armstrong Elementary School. In the 2005/2006 school year, there was a total enrollment of 466 students. As of October 2005, student enrollment included 45% Hispanics, 23% Whites, 14% Asians, 9% Blacks, and 8% Filipinos. About 240 meals are served daily in the cafeteria, which represents approximately 52% participation in the school lunch program. Twenty-three percent (23%) of the total students qualified for the federal free and reduced lunch program (Lunch Distribution Report 2006). This percentage would indicate that the rest of the children are coming from higher income households where exposure to whole grains is more likely (Marquart 2006, personal communication).

This project was approved by the PUSD Board of Education and the Institutional Review Board of California State Polytechnic Univ. (Pomona, Calif., U.S.A.).

Plate waste. Obtaining accurate measurements of children's consumption of a particular food is challenging. Twenty-four-h recalls and observations could be used to measure dietary intake, however, problems with self-reports and observers overestimating consumption often proves to be less valid in this population. Therefore, the most precise method for dietary assessment may be measuring pre- and postweight of the children's plate waste (Kirks and Wolff 1985). Plate waste has been shown to be an effective method to examine the acceptance of healthier meals among children in Elementary School cafeterias. According to Head and others (1977), plate waste results, which reflect the amount consumed, is of particular interest to school lunch administrators, nutrition educators, and researchers.

Plate waste procedures were based on methods previously used by other researchers (Chan and others 2008). Grade levels were grouped into 4 grade groups, which consisted of K, 1st and 2nd (denoted as Group 1), 3rd and 4th (denoted as Group 2), and 5th and 6th (denoted as Group 3). A research assistant assigned to the serving line, counted the number of burritos and cookies taken by the students using a hand tally counter (S90189, Fisher Scientific Inc., Pittsburgh, Pa., U.S.A.), and to ensure accuracy, a 2nd research assistant verified the number of items served with another hand tally counter. After consuming their meal, children handed their tray to the research assistants, and their uneaten portions of burrito and cookie were weighed separately using a scale (SK-20KWP, AND Engineering Inc., Milpitas, Calif., U.S.A.). Two training sessions were conducted with all research assistants to ensure that proper counting and weighing procedures were followed.

Calculations. During the time the burritos were served, they were held at an average temperature of 67 °C in a holding cabinet equipped with a data logger (TP125, Dickson, Addison, Ill., U.S.A.), which allowed temperature tracking during the time the burritos

Table 1 — Ethnicity and lunch distribution breakdown of children at Armstrong Elementary School.

		Nr	%
Ethnicity[a]	American Indian or Alaskan	0	0
	Asian	64	14
	Pacific Islander	1	0
	Filipino	39	8
	Hispanic	211	45
	Black not of Hispanic origin	42	9
	White not of Hispanic origin	109	23
	Multiple or no response	0	0
	Total enrollment	**644**	**100**
Lunch distribution[b]	Free lunch	83	18.08
	Reduced lunch	23	5.01
	Paid lunch	353	76.91
	Total enrollment	**459**	**100**

[a]Source: PUSD Ethnic Distribution of Enrollment of Students (as of October 2005) handout given by Jane Stallings of PUSD on June 22, 2006.
[b]Source: Lunch Distribution Report (6/1/2006) handout given by Jane Stallings of PUSD on June 22, 2006.

were heated, transported to the school cafeteria, and served during the lunch period. The research assistants randomly selected 10 burritos from the holding cabinet before lunch and another 10 burritos from the burrito serving tray right after lunch was concluded. Ten cookies were selected at random from the tray after being defrosted for about 3 h and another 10 were selected right after lunch. Both the burritos and cookies were individually weighed using a balance (PM6000, Mettler Instrument Corp., Hightstown, N.J., U.S.A.). Average weight was calculated based on the weight of 20 burritos and cookies, respectively. The total weight of the burrito and cookie served for each grade group was determined by the mean weight of 1 serving of burrito and cookie multiplied by the total number of burritos and cookies served to the children within the particular grade group. Calculations for the total weight of burritos/cookies served (g); total consumption of burritos/cookies (g), mean burrito/cookie consumption per person (g), and percent of consumption are as follows:

$$\textbf{Total weight of burritos/cookies served(g)} = \text{average weight of burritos/cookies(g)} \times \text{nr of burritos/cookies served}$$

$$\textbf{Total consumption of burritos/cookies(g)} = \text{total weight of burritos/cookies served(g)} - \text{plate waste for burrito/cookie(g)}$$

$$\textbf{Mean burrito/cookie consumption per person(g)} = \text{total consumption of burritos/cookies(g)/nr of burritos/cookies served}$$

$$\textbf{Percent of consumption} = \text{(total consumption of burritos/cookies(g)/total weight of burritos/cookies served(g))} \times 100\%$$

Nutritional analysis

Whole grain and soluble fiber determination. To establish the whole grain and soluble fiber intake of the children before the study, menus from March through June during the time the experiment took place were analyzed. The menus were generated using the NutriKids software (LunchByte Systems Inc., Rochester, N.Y., U.S.A.). The nutritional analysis generated by this software included data on vitamins, minerals, fats, and dietary fiber, but did not include data on soluble fiber and whole grain. For calculation of dietary fiber intake, food items that were either cereal based and/or contained a total dietary fiber greater than 0.5 g were selected. Soluble fiber values were obtained from several sources (Anderson and Bridges 1988; Li and others 2002; Northwestern Univ. Nutrition Facts Sheet on Dietary Fiber 2007; and/or from manufacturers' information). Whole grain products were selected by evaluating the ingredient statements. If the statement noted whole grain as the 1st or 2nd ingredient, manufacturers were contacted to determine the specific amount of total and soluble dietary fiber and values were tabulated. For products where soluble fiber information was unavailable, chemical analysis was conducted (USDA, Western Regional Research Center, Albany, Calif., U.S.A.) using the AOAC method 45.4.09.

Chemical analysis. Analysis of the control (CTR) and treatment (TRT) burritos and cookies were conducted using AOAC methods: total fat analysis (AOAC 996.06), moisture (AOAC 950.46), ash (AOAC 923.03), cholesterol (AOAC 994.10), protein (AOAC 992.15), minerals by ICP (AOAC 984.27), total and soluble dietary fiber (AOAC 991.43), vitamin A (AOAC 2001.13), vitamin C (AOAC 984.26), and sugars (AOAC 977.20).

Product quality determinations

Color, product dimensions, and internal temperature measurements of CTR and TRT products were collected at the elementary school site. Texture, and water activity measurements were carried out at the Cal Poly Pomona Product Development laboratory (Pomona, Calif., U.S.A.).

Texture

Burritos. Fifteen to 25 random samples were selected for texture determinations with a texture analyzer (model TA.XT plus, Texture Technologies Corp., Scarsdale, N.Y., U.S.A./Stable Micro Systems, Godalming, Surrey, U.K.) equipped with a stainless steel plate and a 3-mm stainless steel cylinder probe (TA-53). The force-deformation curve for each burrito provided data on area under the curve of force (load) compared with deformation. Settings included pretest speed of 5 mm/s, test speed of 3 mm/s, posttest speed of 10 mm/s, distance of 28 mm, and trigger force of 50 g. Burritos had an average surface temperature of 42 ± 32.3 °C.

Cookies. Fifteen to 25 random samples were selected for texture measurements with a texture analyzer (model TA.XT plus, Texture Technologies Corp.) equipped with a 3-point bend attachment (TA-92), a heavy-duty platform (TA-90), and a stainless steel blade (TA-92). The base's internal adjustable gap was set at 50 mm. The force-deformation curve for each cookie provided data on maximum peak force, rupture distance, and gradient or Young's modulus of elasticity. Settings included pretest speed of 5 mm/s, test speed of 3 mm/s, posttest speed of 10 mm/s, distance of 20 mm, and trigger force of 50 g.

Color (burritos and cookies). CIELab color was measured using a Minolta Chroma Meter (CR-400, Konica Minolta Sensing Americas Inc., Ramsey, N.J., U.S.A.), which had been calibrated using a Minolta white calibration plate nr 17333240 for CR-200/CR-300/CR400 with 2° OBSERVER to measure lightness (L^*), red/green (a^*), and yellow/blue (b^*) color values. Readings were collected from the center of each burrito and cookie. A total of 5 burritos and 5 cookies were randomly chosen and tested each day plate waste data were collected.

Water activity (cookies). Water activity of the cookies was determined on 5 randomly selected samples at 25 ± 0.2 °C using a water activity meter (AquaLab 3TE, Decagon Devices Inc., Pullman, Wash., U.S.A.).

Weight and dimensions

Burritos. Twenty and 10 randomly selected burritos were weighed using a before and after plate waste data collection, respectively. Five burritos were randomly taken from the 20 and measured for internal temperature (°C), length (cm), width (cm), and thickness (mm) using a digital caliper (Dial Metric Caliper Cat. nr 134160001, Bel-Art Products, Pequannock, N.J., U.S.A.).

Cookies. Five cookies were randomly selected before plate waste data collection and measured for diameter (cm), rotated 90° and remeasured for diameter and then measured for thickness (mm) using a digital caliper.

Statistical analysis

Average consumption per student (g), percent consumption, and all quality parameters for both the burritos and cookies were analyzed using a generalized linear model in SAS (version 9.1; SAS Inst., Cary, N.C., U.S.A.). Least significant differences (LSD) were evaluated at the 95% confidence interval.

Results and Discussion

Children's acceptance

Burritos. See Table 2 for results. Comparisons among the average burrito consumption among the different grade groups (Kindergarten [K], 1st to 2nd grades [GG1], 3rd to 4th grades [GG2], and 5th to 6th grades [GG3]) for each treatment showed that, K consumed significantly less ($P < 0.05$) control (CTR) burritos (21%) than GG1 (36%), GG2 (36%), and GG3 (37%). However, all grade levels consumed similar amounts of the treatment (TRT) burritos (39%). When examining the effects of both treatments on all grades, no differences in the total consumption of burritos were observed. Both CTR and TRT burritos were consumed at similar amounts (36%).

A potential factor contributing to the low-percent consumption of burritos might have been a low preference for these burritos by the participating children. Despite the low percentage, consumption was consistent throughout the study. When observing the effects of treatments within the individual grade groups, results showed that K (32%), GG1 (36%), GG2 (39%), and GG3 (37%), all consumed similar amounts of CTR and TRT burritos, as well (Table 2). Regarding average TRT burrito consumption per student (g), K, GG1, GG2, and GG3 showed values of 51, 56, 62, and 58 g, respectively (Figure 1).

Cookies. K consumed less CTR cookies (68%, $P < 0.05$) compared to GG1 (85%), GG2 (90%), and GG3 (95%). Similar results were observed for the TRT cookies, where K consumed 42%, compared to GG1 (81%), GG2 (82%), and GG3 (90%) (Table 2). Results also showed no differences between the total consumption of CTR and TRT cookies (90%), which contrasted with the low consumption of CTR and TRT burritos (36%). When comparing the effects of treatments within the individual grade groups, both CTR and TRT cookies were consumed at similar amounts for GG1 (85%), GG2 (90%), and GG3 (95%). However, differences were observed in the consumption percentage between CTR and TRT cookies for K, where CTR cookies were consumed at a greater level (68% compared with 42%) (Table 2).

Table 2—Average consumption of control (CTR) and treatment (TRT) burritos and cookies.

	Burrito (%)		Cookie (%)	
	CTR	TRT	CTR	TRT
All grades	35.6^{ax} (1.1)	34.6^{ax} (3.3)	89.7^{ax} (1.0)	83.8^{ax} (4.0)
K	20.5^{ay} (6.3)	32.0^{ax} (23.6)	68.2^{ay} (6.1)	42.2^{by} (18.2)
GG1	35.6^{ax} (1.3)	33.0^{ax} (4.4)	85.3^{ax} (0.9)	81.2^{ax} (6.0)
GG2	36.1^{ax} (5.8)	38.5^{ax} (2.8)	89.8^{ax} (3.3)	82.2^{ax} (4.0)
GG3	36.6^{ax} (1.8)	32.1^{ax} (4.7)	94.7^{ax} (3.3)	89.5^{ax} (4.4)

^{abc}Values with different superscripts are significantly different ($P < 0.05$) between the treatments CTR and TRT and among the individual grade groups for a given product. ^{xyz}Values with different superscripts are significantly different ($P < 0.05$) between the grade groups (K, GG1, GG2, GG3) for a given treatment (CTR and TRT). K = Kindergarten; GG1 = 1st and 2nd grade; GG2 = 3rd and 4th grade; GG3 = 5th and 6th grade. Values for each grade are shown as means and those in parentheses are standard deviations.

In terms of the average amount of cookie (g) consumed per student, there were no differences in the total average consumption of cookies when all grade groups were combined (28 g) (Figure 2). Results also showed that K consumed more CTR cookies than TRT cookies (21 g compared with 13 g). For the other grade groups, CTR and TRT cookies were consumed at similar levels of 26, 27, and 29 g for GG1, GG2, and GG3, respectively (Figure 2). Chan and others (2008) found that 1st grade children consumed 10 g of white whole wheat flour pizza while 6th grade children consumed about 13 g. In addition, Harnack and others (2003) reported that whole grain intake steadily increased with age with preschool aged-children consuming 0.8 serving per day to adolescents consuming 1 serving per day.

Chase and others (2004) showed that the most important factors contributing to enhanced consumer desirability for whole grain products were good taste and favorable palatability. Burgess-Champoux and others (2006) stated that gradually incorporating whole-grains into familiar food products and providing samples of the new foods would provide an effective vehicle to increase whole-grain intake and acceptance. Others factors affecting plate waste could be attributed to product quality and handling, room environment, staff's friendliness and cooperativeness, and the time available to eat lunch among others (Jansen and Harper 1978; Ralston and others 2003). In this study, proper food handling to ensure food safety and quality was carried out by placing the burritos in a holding cabinet including a data logger to record the cabinet's temperature. Regarding the time available to eat lunch, studies have shown K to 12th grade students taking an average time between 7 and 10 min, however, a reasonable lunch schedule is considered to be 20 min (Conklin and others 2005). During this study, students were given 20 min to receive and eat their lunch. In addition to time constraints, meals are generally rushed by children when lunch is scheduled before recess (Ralston and others 2003). Data show that 40% of elementary schools reported scheduling recess immediately after lunch (Wechsler and others 2001).

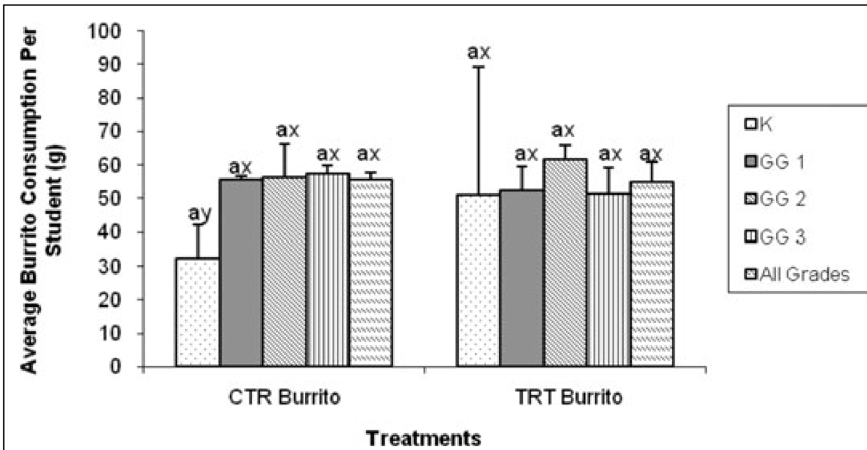

Figure 1—Average burrito consumption (g). ^{ab}**Values with different letters are significantly different ($P < 0.05$) between control (CTR) and treatment (TRT) and among individual grade groups, K, GG1 (1st and 2nd), GG2 (3rd and 4th), GG3 (5th and 6th) for a given product.** ^{xy}**Values with different letters are significantly different among grade groups and within CTR and TRT treatments for a given product.**

Nutritional analysis

Whole grain and soluble fiber determination. The daily average of total dietary fiber (TDF), soluble fiber (SF), and whole grains (WG) contained in the Pomona Unified School District (PUSD) lunch menu from March to June of 2007 ranged from 4.4 to 7.8 g, 0.3 to 1.7 g, and 0 to 5.9 g, respectively (Table 3). Although lunch is considered only a 3rd of the meals eaten in a day, estimated amounts of TDF, SF, and WG were lower than the daily recommendations of 8.3, 2, and 16 g, respectively.

Nutritional analysis of burritos. Per 163 g serving, the TRT burrito contained 19 g of WG, it contained 10.2 g TDF, 2.8 g of SF, and 1.1 g of β-glucan SF, which corresponded to over a 3rd (1/3) of the daily recommended amount of TDF and SF (Table 4). This burrito also had significantly higher amounts of TDF, monounsaturated and polyunsaturated fats, calcium, phosphorous, potassium, total fat, and moisture than the control burrito, while it also contained significantly lower amounts of sodium and iron.

Nutritional analysis of cookies. Per 30 g serving, the TRT cookie contained 8 g of WG, 2.6 g of TDF, and 1.2 g of SF (Table 4). This cookie also contained 0.96 g of β-glucan soluble fiber per serving. This cookie also had significantly higher amounts of TDF, SF, protein, polyunsaturated fat, phosphorous, ash, and moisture than the CTR cookie.

Product quality determinations

For burritos, quality parameters such as texture (area or work required to bite into the burrito), CIELab color, weight (g), length (cm), width (cm), and thickness (cm) were obtained. For cookies, texture (force, distance, and gradient), water activity, CIELab color, weight (g), diameter (cm), and thickness (cm) were obtained (Table 5 and 6).

Texture

Burritos. Texture expressed as area (kg-s) was higher for CTR burritos compared with TRT burritos (1.31 compared with 0.66 kg-s, $P < 0.05$), which meant that CTR burritos required more work

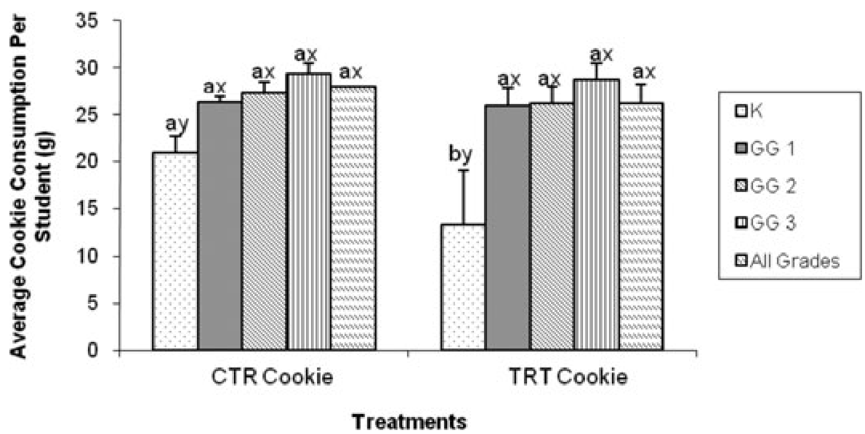

Figure 2—Average cookie consumption (g). [ab]**Values with different letters are significantly different ($P < 0.05$) between control (CTR) and treatment (TRT) and among individual grade groups, K, GG1 (1st and 2nd), GG2 (3rd and 4th), GG3 (5th and 6th) for a given product.** [xy]**Values with different letters are significantly different among grade groups and within CTR and TRT treatments for a given product.**

Table 3—Daily average of total dietary fiber (TDF), soluble fiber (SF), and whole grain (WG) in the lunch menu not including the whole grain products used in the study.

Weeks[a]	Daily average of TDF intake at lunch (g)[b]	1/3 of the daily recommended amount of TDF (g)[bc]	Daily average of SF intake at lunch (g)[ba]	1/3 of the daily recommended amount of SF (g)[bc]	Daily average of WG intake at lunch (g)[b]	1/3 of the daily recommended amount of WG (g)[bd]
March 2007						
1 to 2 ($n = 2$)	5.02 ± 3.13[b]	8.33	0.61 ± 0.40[b]	2	0.0	16
5 to 9 ($n = 5$)	7.79 ± 2.81	8.33	1.61 ± 0.85	2	1.8	16
12 to 15 ($n = 4$)	6.10 ± 4.63	8.33	1.54 ± 1.43	2	0.0	16
19 to 23 ($n = 5$)	5.24 ± 1.73	8.33	0.95 ± 0.59	2	1.0	16
26 to 29 ($n = 4$)	7.45 ± 1.41	8.33	1.36 ± 0.73	2	2.3	16
April 2007						
2 to 5 ($n = 4$)	7.20 ± 2.59	8.33	1.64 ± 1.36	2	2.3	16
16 to 20 ($n = 5$)	4.39 ± 2.76	8.33	0.95 ± 0.92	2	0.0	16
23 to 27 ($n = 5$)	6.32 ± 1.20	8.33	1.70 ± 0.90	2	1.0	16
May 2007						
1 to 4 ($n = 4$)	6.21 ± 3.59	8.33	1.69 ± 1.25	2	0.0	16
7 to 11 ($n = 5$)	6.21 ± 2.68	8.33	1.37 ± 0.88	2	0.0	16
14 to 17 ($n = 4$)	5.82 ± 0.64	8.33	1.38 ± 0.49	2	2.3	16
21 to 25 ($n = 5$)	5.80 ± 1.54	8.33	1.15 ± 0.72	2	5.6[e]	16
29 to 30 ($n = 2$)	5.10 ± 0.77	8.33	1.07 ± 0.45	2	0.0	16
June 2007						
1 ($n = 1$)	4.38	8.33	0.31	2	0.0	16
4 to 8 ($n = 5$)	5.14 ± 2.15	8.33	1.12 ± 0.95	2	5.9[e]	16
11 to 15($n = 2$)	4.74 ± 2.40	8.33	1.21 ± 0.82	2	0.0	16

[a]Data do not include March 16, March 30, April 6, May 18, and May 31 due to Manager's Choice menu and May 28 due to a Holiday.
[b]Mean ± standard deviation.
[c]Recommendations made by FDA and DHHS (CFR 101.77b3) and divided by 3 to indicate only lunch.
[d]2005 Dietary Guidelines recommend consuming 48 g of whole grains per day (3 servings of 16 g each) divided by 3 to indicate only lunch.
[e]Values were supplied by the manufacturers, but some appear somewhat high.

Table 4—Chemical analysis[A] results comparing control (CTR) and treatment (TRT) burritos and cookies.

		Burrito (163 g/serving)		Cookie (30 g/serving)	
Components	**Units**	**Control**	**Treatment**	**Control**	**Treatment**
Energy	**Kcal/serving**	**408.61[a]**	**422.86[b]**	**148.29[a]**	**145.93[a]**
Total dietary fiber[B]	g/serving	7.07[a] (0.75)	10.15[b] (0.77)	0.68[a] (0.14)	2.63[b] (0.28)
Soluble fiber[B]	g/serving	2.06[a] (0.38)	2.80[a] (0.62)	0.22[a] (0.05)	1.16[b] (0.10)
β-glucan[C]	g/serving	0	1.12	0	0.96
Sugars	g/serving	3.37[a] (0.24)	2.67[a] (0.03)	12.30[a] (0.11)	11.69[a] (0.45)
Protein	g/serving	18.11[a] (0.32)	18.68[a] (0.36)	1.61[a] (0.10)	1.98[b] (0.05)
Total fat	g/serving	14.38[a] (0.03)	15.70[b] (0.07)	7.37[a] (0.18)	7.69[a] (0.25)
Sat. fat	g/serving	5.85[a] (0.09)	5.85[a] (0.01)	1.19[a] (0.06)	1.22[a] (0.34)
Trans. fat	g/serving	0.55[a] (0.06)	0.57[a] (0.00)	0.01[a] (0.01)	0.01[a] (0.00)
Cholesterol	mg/serving	16.81[a] (0.68)	17.21[a] (1.96)	9.61[a] (0.10)	8.80[a] (0.96)
MUFA	g/serving	3.68[a] (0.06)	4.16[b] (0.02)	4.10[a] (0.11)	4.16[a] (0.11)
PUFA	g/serving	3.60[a] (0.04)	4.38[b] (0.05)	1.74[a] (0.05)	1.96[b] (0.12)
Calcium	mg/serving	203.96[a] (1.24)	216.30[b] (1.66)	10.32[a] (3.69)	6.08[a] (0.27)
Iron	mg/serving	3.59[a] (0.07)	3.31[b] (0.01)	0.57[a] (0.04)	0.80[a] (0.15)
Phosphorus	mg/serving	289.42[a] (1.16)	346.28[b] (8.34)	26.20[a] (0.17)	49.96[b] (1.89)
Potassium	mg/serving	461.22[a] (3.53)	514.75[b] (15.56)	52.19[a] (10.42)	66.17[a] (3.17)
Sodium	mg/serving	1095.77[a] (18.14)	1020.84[b] (8.41)	64.36[a] (2.42)	67.06[a] (3.00)
Vitamin A	IU/serving	471.89[a] (8.06)	497.97[a] (61.09)	<20[a] (0.00)	<20[a] (0.00)
Vitamin C	mg/serving	<0.10[a] (0.00)	<0.10[a] (0.00)	<0.10[a] (0.00)	<0.10[a] (0.00)
Ash[B]	% per serving	4.51[a] (0.09)	4.50[a] (0.05)	0.33[a] (0.02)	0.39[b] (0.01)
Moisture[B]	% per serving	74.30[a] (1.38)	77.60[b] (2.16)	1.81[a] (0.10)	2.74[b] (0.34)

[A]Chemical analysis conducted by ConAgra Foods Inc. Values of components are shown in means, and those in parentheses are standard deviations.
[B]Additional data were obtained from Medallion Laboratories (Minneapolis, Minn., U.S.A.).
[3]β-glucan was calculated according to the amount of Prowashonupana barley (Sustagrain™, ConAgra Foods Inc.) in the burrito and cookie.

to be masticated than TRT burritos. According to Springsteen and others (1977), increased levels of whole wheat flour in cake dough caused a faster relaxation of the dough due to the bran particles disrupting the gluten matrix, which in turn led to a weaker dough structure and a softer product.

Cookies. CTR cookies required a higher breaking force (3.14 compared with 0.58 kg) or were harder than TRT cookies. The distance (mm) and gradient (kg/s) were greater for the CTR cookie compared to the TRT cookies (30.38 compared with 12.57 mm, and 2.50 compared with 0.26 kg/s, respectively), which indicates that the TRT cookies were less stiff than the CTR cookies. Hatcher and others (2005) conducted a study to evaluate the suitability of roller-milled flours from 8 genotypes of hulless barley (HB) as a blend for yellow alkaline noodles (YAN). Results showed that the addition of 40% of HB flour required less work input compared to the 20% HB flour blend noodles. This was probably due to a higher water absorption, which probably caused the noodles to soften. Klamczynski and Czuchajowska (1999) evaluated 3 cultivars of barley flour (1 nonwaxy and 2 waxy barleys). Results showed that freshly baked quick breads made from wheat flour were the hardest (3.92 N), followed by those containing nonwaxy barley (2.72 N) and then those with waxy barley (2.28 N). The results were primarily attributed to starch properties. The barley variety used in our study was waxy.

Table 5—Quality parameters of control (CTR) and treatment (TRT) burritos.

	Color			Texture
Treatments	***L***	***a***	***b***	**area (kg-s)**
CTR	80.04[a] (2.87)	−1.31[a] (0.44)	16.55[a] (1.81)	1.31[a] (0.68)
TRT	64.61[b] (6.53)	2.02[b] (0.57)	20.26[b] (2.40)	0.66[b] (0.23)

		Dimensions		
Treatments	**Weight (g)**	**Length (cm)**	**Width (cm)**	**Thickness (cm)**
CTR	156.89[a] (6.27)	13.04[a] (0.62)	5.58[a] (0.45)	3.00[a] (0.49)
TRT	159.77[b] (4.14)	12.45[b] (0.52)	5.20[b] (0.49)	2.71[b] (0.16)

[abc]Values with different superscripts are significantly different ($P < 0.05$) between the treatments (CTR and TRT). Color ($n = 5$); texture ($n = 15$ to 25); weight ($n = 20$); dimensions ($n = 5$). Values of treatments are shown in means, and those in parentheses are standard deviations.

Water activity (cookies). Results showed that CTR had a lower water activity compared to TRT cookies (0.50 compared with 0.71, $P < 0.05$). From observation and chemical analysis results, TRT cookies were moister compared to CTR cookies (Table 4). Friend

Table 6 – Quality parameters of control (CTR) and treatment (TRT) cookies.

Treatments	Color			Water activity	Texture		
	L	A	b	(aw)	Force (kg)	Distance (mm)	Gradient (kg/s)
CTR	63.18[a] (4.01)	2.60[a] (1.38)	26.47[a] (2.31)	0.50[a] (0.03)	3.14[a] (2.77)	30.38[a] (9.37)	2.50[a] (2.14)
TRT	50.27[b] (5.88)	6.80[b] (1.83)	28.94[b] (3.87)	0.71[b] (0.05)	0.58[b] (0.16)	12.57[b] (4.36)	0.36[b] (0.12)

Treatments	Weight (g)	Dimensions		
		Diameter 1 (cm)	Diameter 2 (cm)	Thickness (cm)
CTR	30.91[a] (1.25)	8.03[a] (0.33)	7.78[a] (0.38)	1.49[a] (0.12)
TRT	31.79[b] (1.74)	6.40[b] (0.38)	6.43[b] (0.37)	1.36[b] (0.12)

[abc]Values with different superscripts are significantly different ($P < 0.05$) between the treatments. Color ($n = 5$); water activity ($n = 5$); texture (n =15 to 25); weight ($n = 20$); dimensions ($n = 5$). Values of treatments are in means, and those in parentheses are standard deviations.

and others (1992) indicated that the addition of whole wheat flour to a tortilla formulation affected dough water absorption. Unlike dough prepared with refined flour, dough containing whole wheat flour required more water. Bhatty (1997) stated that waxy hulless barley flour resulted in a higher mixograph water absorption and water-holding capacity than regular hulless barley milled under identical conditions due to the higher β-glucan content. As noted previously, TRT cookies also required smaller breaking force than CTR cookies.

Color (burritos and cookies). Control burritos were lighter than TRT burritos with L^* values of 80.04 and 64.61 ($P < 0.05$), respectively. Control cookies were also lighter than TRT cookies with L^* values of 63.18 and 50.27, respectively. The bran portion contributes to the darker pigment in whole grains (Atwell 2001), thus products made with refined flours like the CTR burritos and cookies are lighter. Control burritos had a lower a^* value compared to TRT burritos (–1.31 compared with 2.02), which means that TRT burritos displayed more red color than CTR burritos. A lower b^* value was observed in CTR burritos compared to TRT burritos (16.55 compared with 20.26), indicating that TRT burritos were closer to the yellow color than the CTR burritos. Again, lower a^* and b^* values were also seen in CTR cookies compared to TRT cookies with a^* values of 2.6 and 6.8 and b^* values of 26.47 and 28.94, respectively. Friend and others (1992) reported darker and redder flour tortillas when they included whole wheat flour, which partly agreed with our results. In contrast, their whole wheat flour tortillas were less yellow compared to our whole grain products that were yellow. Hatcher and others (2005) reported that hulless barley flours were equivalent to or surpassed the brightness (L^*) of whole wheat flour, were equivalent to whole wheat flour in flour redness (a^*), but lower in yellowness (b^*).

Weight and dimensions. Both CTR burritos and cookies were significantly lighter ($P < 0.05$) than TRT products. Control and TRT burritos were 157 and 160 g, respectively; while CTR and TRT cookies were 31 and 32 g, respectively. Ereifej and others (2006) showed similar results where an increase in the percent of barley flour in Balady bread also increased the loaf weight. This was partly attributed to the wider and larger loaf diameter, and pocket formation in the loaves. Consistent with our findings, Chan and others (2008) reported that although their refined wheat pizza or control and the 50:50 blend pizza indicated the same weight when provided by the manufacturer (132.4 g); when they measured the actual mean weights of 10 samples of these pizzas, the 50:50 blend pizza was higher in weight (144 g) than the refined wheat pizza (128.9 g). In our study, there were also differences in dimensions between CTR and TRT burritos (length [13.04 compared with 12.45 cm], width [5.58 compared with 5.20 cm], and thickness [3 compared with 2.71 cm]); and between CTR and TRT cookies (diameter 1 [8.03 compared with 6.4 cm], diameter 2 [7.78 compared with 6.43 cm] and thickness [1.49 compared with 1.36 cm]).

The CTR burritos were longer, wider, and thicker than the TRT burrito; and the CTR cookies were larger in diameter and thicker than the TRT cookies. Potential factors contributing to the smaller dimension of TRT burritos and cookies may include the lower amounts of starch and higher amounts of fiber in the waxy barley flour used in this study. According to Swanson and Penfield (1988), yeast-leavened bread made with 20% barley flour had a smaller volume and poorer crumb structure. In Klamczynski and Czuchajowska's (1999) study, when 3 cultivars of barley flour (1 nonwaxy and 2 waxy barleys) were evaluated, results showed that sugar snap cookies made from nonwaxy barley had a greater diameter than cookies from waxy barley. In addition, quick breads baked from nonwaxy barley had a similar loaf volume to that of wheat bread, but waxy barley bread had a smaller loaf volume. This was attributed to the poor cellular structure in the waxy barley bread because it lacked amylose and was not able to hold the structure of the quick bread.

Conclusions

Overall, the study results show potential for both whole grain and soluble fiber enriched products to be incorporated into the school menus, particularly chocolate chip cookies. The high level of consumption of the whole grain chocolate chip cookie may have been due to the product type. Since children may have consumed the chocolate chip cookie regardless of whether they were made with whole grain or not due to the popularity of this snack item.

It is noteworthy that the main entrée, a whole grain and high fiber burrito, was consumed in equal amounts to a control burrito by young children (many of whom may be picky eaters).

Future studies will include the acceptance of other whole grain enriched products such will be incorporated into a variety of popular food products such as chicken nuggets, pizza, pasta, and so on, which may be well accepted by students, as well as the examination of acceptance of whole grain products supplemented with nutrition education.

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