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Gradual Incorporation of Whole Wheat Flour into Bread Products for Elementary School Children Improves Whole Grain Intake

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Please note that this study was published before the implementation of Healthy, Hunger-Free Kids Act of 2010, which went into effect during the 2012-13 school year, and its provision for Smart Snacks Nutrition Standards for Competitive Food in Schools, implemented during the 2014-15 school year. As such, certain research may not be relevant today.

ABSTRACT

Purpose
Whole grain intake is associated with health benefits but current consumption by children is only about one-third of the recommended level. The purpose of this study was to test the feasibility of an innovative approach whereby the whole wheat content of bread products in school lunches was gradually increased to increase whole grain intake by children.
Methods
A convenience sample included children in K-6th grade from two elementary schools in a Midwestern city. Whole red and white wheat flour content of buns and rolls served twice weekly was increased from 0% to 91% in 16 and 7 incremental levels, respectively over the school year. Red wheat products were served in one school and white wheat products in the other. Plate waste methods were used on a whole school basis to estimate consumption. ANOVA procedures were used to determine whether whole grain and modified bread product intake differed by level of whole wheat flour and menu entrée category.
Results
Mean consumption of whole grain (g/child) increased as the level of red and white whole wheat flour increased in modified bread products. Consumption of modified bread products did not differ statistically from baseline (0% whole grain flour) until the 72% level for red and 67.5% level for white wheat was served. Consumption of buns and rolls varied with type of accompanying menu items regardless of wheat type or level.
Application to Child Nutrition Professionals
A gradual increase in whole wheat content in menu items resulted in favorable whole grain consumption by children. This approach may allow school foodservice directors to gradually introduce acceptable whole grain products into school menus.

INTRODUCTION

Recent reviews of scientific evidence indicate that whole grain intake reduces the risk of various chronic diseases such as coronary heart disease (Flight & Clifton, 2006; Jacobs & Gallaher, 2004; Mellen, Walsh, & Herrington, 2008; Seal, 2006) and type 2 diabetes (Kaline, 2007; Priebe, van Binsbergen, de Vos, & Vonk, 2008; Qi & Hu, 2007). Recent U.S. national dietary intake data, Continuing Survey of Food Intake by Individuals (CSFII) 1994-1996, showed that children and adolescents 6-19 years of age consumed 0.8-1.0 mean servings of whole grain products per day (Harnack, Walters, & Jacobs, 2003). These levels are only about one-third of the amount recommended by U.S. Dietary Guidelines for Americans, 2005 (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2005).

School nutrition services can play an important role in facilitating an improved intake of whole grain foods by offering children more whole grain bread products through school meals. However, some attributes of whole grain products present challenges in increasing intake of whole grain foods by children. Most whole grain bread products, particularly yeast breads are made with red whole wheat flour which generally produces a darker colored product and a bitter taste compared to refined grain foods (Atwell, 2002). Focus group results with children indicated that familiarity, appearance and the taste of new foods such as whole grain foods were important factors that influenced acceptability (Burgess-Champoux, Marquart, Vickers, & Reicks, 2006). The genetic variation in sensitivity to bitterness is thought to play a role in the acceptance and rejection of bitter-tasting vegetables (Bell & Tepper, 2006; Cowart, 1981) and may play a role in whole grain acceptance as well based on the bitter taste of some whole grain products (Atwell, 2002).

To address the potential issue of bitterness and appearance of whole wheat foods, wheat products made with white whole wheat have recently been introduced. The lack of darker pigment in the bran portion of white whole wheat flour is mainly responsible for the lighter color of these grain products (Atwell, 2001). While the color may differ, red and white whole wheat flours have similar macro- and micronutrient content (Syms & Cogswell, 1991). Similar to red wheat, white wheat has a high protein content, strong gluten and high water absorption which makes it a good choice for breads and related products (Atwell, 2001). Children preferred bread made with 100% white whole wheat flour two and one-half times more for appearance and two times more for taste compared to bread made with 100% red whole wheat flour (Lukow, Guinard, & Adams, 2004). Preliminary studies by Chan, Burgess-Champoux, Vickers, Reicks, and Marquart (2008) showed that serving school children pizza crust made with a 50:50 blend of white whole wheat and refined flour resulted in consumption levels similar to those observed when pizza crust made with 100% refined wheat flour was served. Limited studies have evaluated the acceptance of products made with red and white wheat. Further studies are needed to incorporate grain products made with red and white whole wheat into the school meal setting.

Gradual modifications in product formulations have been made successfully by food companies over time (Dubow & Childs, 1998). This gradualist approach to improving nutritional quality of food products has been referred to as “stealth nutrition” (Spittler, 2007) and represents an approach that parents and school foodservice personnel may find acceptable to improve diet quality of children. Examples include a step-wise approach in the 1960s to reduce the amount of caffeine in Coke and gradual reductions in sodium and fat in canned goods and savory snack products (Dubow & Childs, 1998). No reports in the literature document the effectiveness of a systematic approach to gradually incorporate higher levels of whole grain into products to allow consumers to adapt to the variations in taste, texture and appearance.

The objective of this study was to test the feasibility of incrementally increasing the levels of red and white whole grain flour in bread products over the course of a school year to determine if whole grain intake increased as red or white whole wheat flour content increased, and differed by menu category based on accompanying foods.

METHODOLOGY

Subjects

Participants were Kindergarten through 6th grade children from two suburban elementary schools (selected by the district food service administration) having a total student population of approximately 600 students each in a large Midwestern metropolitan area. The schools had fairly equal numbers of boys and girls. In both schools, about one-fifth were minority children and one-fifth were eligible for free or reduced price school meals. The school district research committee and the University of Minnesota Institutional Review Board approved the study.

Procedures

Modified red whole wheat products were served in one school and modified white whole wheat products in the other. A preliminary study used difference threshold testing to establish the concentrations (levels) of red and white whole wheat flour as a percentage of the total flour content

used to prepare the bread products (Delk & Vickers, 2007). Trained adult panelists (n=25) made judgments through ascending forced-choice tests; where the threshold step level was determined when 50% of the subjects could detect a difference based on the color, texture and taste of the sample rolls. Test results established 15 levels between 0 and 91% for products made with red whole wheat flour and 7 levels between 0 and 90% for products made with white whole wheat flour. Because participants could mor
e easily detect differences in levels for products make with increasing concentrations of red whole wheat flour (possibly due to the color), there were more levels for these products than for those made with white whole wheat flour.

Bread products (buns-2 oz and dinner rolls-1.5 oz) were prepared by a local bakery (Great Northern Bakery, Minneapolis, MN) based on a method adapted from Finney (Finney, 1984) and a recipe provided by the bakery. Quantities of whole wheat flour used to make bread products to the specified levels were measured to the nearest 0.001 grams on scales calibrated weekly. The level of refined flour decreased and the amount of water increased as the level of red or white whole wheat flour was increased as a percentage of the total flour content of the products. The concentrations of all other ingredients were held constant except that gluten was increased as the levels of whole wheat flour increased. To maintain optimal quality, hamburger buns were baked, sliced, and frozen about two weeks prior to delivery to the school on the day they were served. Rolls were prepared as frozen shaped dough pieces, then thawed, proofed and baked at the school on the day they were served.

For the first two weeks of the 2005-2006 school-year, a baseline level of consumption was established by serving buns and rolls made with 100% refined wheat flour as a percentage of the total flour content of the product. Bread products prepared at each subsequent level of red and white whole wheat flour were served an average of 3.8 times and 7.6 times, respectively. Based on the school district menus, modified bread products were substituted when rolls or hamburger buns were already being served. Buns were typically served as part of the main dish for a meal while research staff placed the roll on the child's tray to make sure that children were exposed to these products. Acceptance was monitored throughout the study by examining consumption (based on plate waste) at each level. Products made with the next incremental level of whole grain flour were served if overall consumption did not fall below 75% of values observed at baseline when products containing no whole wheat flour were served.

Each time the bread products were served over the course of the school year, the weight of the product served was calculated by multiplying the mean weight of 10 conveniently selected product samples by the total number served to children. Trained observers were present in the school cafeteria to help children discard uneaten bread product waste at the end of the meal. The amount consumed was calculated as a percentage of the difference between the amount discarded and the amount served based on an actual count of the buns or rolls served daily (Comstock & Symington, 1982). The amount consumed was corrected to account for the weight of residue such as condiments and sandwich fillings remaining on the buns. Intake of whole grain (g/child) from the modified bread products was determined based on calculations using Nutrition Data System for Research software (Nutrition Coordinating Center, University of Minnesota, 2006) to determine whole grain content of bread products. Together with bread product consumption data derived from plate waste data, grams of whole grain consumed per child were calculated.

Data analysis

Consumption data were analyzed as grams of whole grain consumed per student and as percentage of modified bread products consumed based on the difference between the amount served and the amount collected as waste on a school wide basis. Prior to data analysis, consumption data were tested for normality and found to be normally distributed. One-way ANOVA (Statistical Analysis System, SAS Institute, Cary, NC, Version 9.1, 2002-2003) was used to determine if mean whole grain consumption (g/child) differed according to the level of whole wheat flour in the products. ANOVA was also used to compare differences in consumption of bread and rolls on a school wide basis according to level of whole wheat flour in the bread products. Observations from lower levels were collapsed into one value (pairs) to increase the number of observations per level. Differences in

consumption were also examined by bread type (bun or roll) and 5 menu entrée categories based on characteristics of the entrée. These categories included: 1) bun served with a meat patty; 2) bun served with a meat mixture; 3) roll served with a meat or cheese/pasta dish; 4) roll served with a breaded piece(s) of meat or fish; and 5) roll served with a plain meat item and gravy. The level of significance was set at $p<0.05$.

RESULTS AND DISCUSSION

As the content of whole wheat flour was gradually increased in bread products over the course of the school year, the mean grams of whole grain consumed per child increased from 0 to 12.9 grams and 10.7 grams for red and white wheat products respectively (Table 1). These results indicated that whole grain consumption per child met almost one full serving of whole grain according to the school food service requirement (14.75 grams) (U.S. Department of Agriculture-Food and Nutrition Services, 2001).

Table 1. Mean whole grain consumption - grams per child [1]

Level of red whole wheat flour (% of total flour content)	Mean whole grain consumption - g per child (times served)	Level or white whole wheat flour (% of total flour content)	Mean whole grain consumption - g per child (times served)
0	0^{a} (5)	0	0^{a} (7)
1	0.2^{ab} (3)	11	1.5^{b} (7)
2	0.3^{ab} (4)	23	3.5^{c} (8)
5	0.8^{ab} (4)	32	4.1^{c} (5)
7	1.1^{ab} (3)	45	6.2^{d} (7)
10	1.5^{ab} (4)	67.5	7.7^{e} (12)
14	2.2^{bc} (3)	90	10.7^{f} (7)
21	3.6^{cd} (4)		
26	4.2^{de} (4)		
32	5.6^{e} (5)		
38	5.7^{e} (4)		
47	2.8^{e} (4)		
59	8.6^{f} (5)		
72	10.0^{f} (5)		
91	12.9^{g} (8)		

[1] Values not sharing the same superscript letters are significantly different ($p<0.05$ according to GLM procedure).

Mean consumption of buns and rolls at the baseline for both schools (0% whole wheat) was ~75% (Table 2). Intake of bread products did not differ significantly from the baseline level up to the 59% level of red whole wheat and 45% level of the white whole wheat. The consumption of products made with 72% and 91% for the red whole wheat flour and the 67.5% and 90% levels for white whole wheat flour was significantly lower than intake at the baseline level (Table 2). The range of consumption for dinner rolls made with red whole wheat flour was 57% to 77% while white whole wheat flour was 50% to 78% (Table 2). Buns were not served enough times at each level to compare bun consumption to the baseline level. However, the range of consumption for buns throughout the school year for red whole wheat was 51% to 67% and 54% to 67% for white whole wheat (data not shown).

Table 2. Percent consumption of bread products made with whole red and white wheat [1]

Level of red whole wheat flour (% of total flour content)	Consumption[2](%) for all products (times served)	Consumption[2](%) for rolls (times served)	Level of white whole wheat flour (% of total flour content)	Consumption[2](%) for all products (times served)	Consumption[2](%) for rolls (times served)
0	73 ± 7^{a} (5)	76 ± 5^{ab} (4)	0	74 ± 8^{a} (7)	78 ± 6^{a} (5)
1-2	64 ± 17^{ab} (6)	77 ± 10^{a} (3)	11	66 ± 14^{ab} (7)	78 ± 5^{a} (1)
5-7	71 ± 11^{ab} (6)	75 ±12^{ab} (4)	23	66 ± 6^{ab} (8)	68 ± 6^{a} (3)
10-14	70 ± 10^{ab} (6)	75 ± 9^{ab} (4)	32	66 ± 13ab (5)	74 ± 3^{a} (3)
21-26	70 ± 10^{ab} (7)	73 ± 10^{ab} (5)	45	68 ± 5ab (7)	68 ± 6^{a} (3)
32-38	69 ± 8^{ab} (7)	71 ± 7^{abc} (4)	67.5	57 ± 9b (12)	51 ± 5^{b} (5)
47-59	65 ± 6^{ab} (7)	64 ± 7^{abc} (5)	90	59 ± 10b (7)	50 ± 5^{b} (3)
72	60 ± 10^{b} (6)	62 ± 11^{bc} (4)			
91	59 ± 7^{b} (8)	57 ± 8^{c} (5)			
p-value	0.12	0.02	p-value	0.009	<0.001

[1] Values with different superscript letters in the same column are significantly different ($p<0.05$).
[2] Consumption was calculated by taking the total weight of product served and subtracting plate waste. Total weight served was determined by multiplying the number of served products by the mean weight (based on 10 conveniently selected products).

Consumption of the bread products was also compared based on 5 entrée categories. Mean consumption of all bread products containing red and white whole wheat flour when served in the 5 menu entrée categories ranged from ~56% to 74% and 55% to 69% (respectively) (Table 3). Buns served with a patty (such as hamburger or chicken), rolls served with pasta/sauce, and rolls served with sliced meats/gravy were consumed in amounts significantly higher than buns served with mixed meat (such as sloppy Joes and BBQ pork) and rolls with breaded meat (such as chicken nuggets and shrimp poppers). It is possible that the flavor of whole wheat was masked by bun fillings and condiments while rolls were generally consumed plain. In support of this concept, others

have shown that for a trained panel, a combination of tomato sauce and soy protein caused a suppression of the bitter, harsh and astringent tomato flavors and that the soy protein flavor was less distinguishable (McDaniel & Chan, 1988). Stevens (1996) quantified the conditions for taste masking based on the strength of one taste (masker) and the concentration of the masking target. While it doesn't appear that this quantification has been done for masking the bitter taste of whole grain with other flavors, it may be important to complete these studies to assist in menu planning in schools. Another factor that could have contributed to acceptance of the modified bun product was that it was always served as part of the entrée and the entrée food group has been shown to be consumed at a high level by children in school meals in the past (Getlinger, Laughlin, Bell, Akre, & Arjmandi, 1996).

Table 3. Percent consumption by menu entrée category [1]

Category	Total percent consumption red wheat (times served)	Total percent consumption red wheat (times served)
1- Buns with patty (chicken or hamburger)	67 ± 6[a] (9)	69 ± 3[a] (8)
2- Buns with mixed meat (sloppy joe or BBQ pork)	55 ± 7[b] (10)	55 ± 9[b] (9)
3- Rolls with pasta (spaghetti with sauce, lasagna)	69 ± 9[a] (15)	65 ± 9[a] (12)
4- Rolls with breaded meat (chicken or shrimp poppers)	59 ± 11[b] (7)	55 ± 10[b] (7)
5- Rolls with whole meat (Salisbury steak/gravy or turkey/gravy)	74 ± 9[a] (12)	65 ± 11[a] (10)
p-value	<0.0001	0.002

[1] Values with different superscript letters in the same column are significantly different ($p<0.05$).

Previous research has applied Pavlovian flavor-flavor associative learning or flavor-flavor theory to explain changes in liking for specific foods (Rozin & Zellner, 1985). Flavor-flavor learning occurs when a nonpreferred flavor is paired with a naturally preferred flavor to enhance liking for the nonpreferred flavor. The effectiveness of this strategy has been observed in several studies based on serving a preferred food with a nonpreferred food (Piazza et al., 2002); blending a preferred food with a nonpreferred food in various ratios (Mueller, Piazza, Patel, Kelley, & Pruett, 2004); or fading which is a varaition of blending with more than one food (Patel, Piazza, Kelly, Ochsner, & Santana, 2001). Although these studies were limited to one to two children with extreme eating disorders, extrapolating from these cases would indicate that blending of nonpreferred flavor (whole grain flour) with preferred flavor (refined flour) may be a potential approach to increase consumption of whole grain foods in the general population.

The manner in which preferences for foods are developed in children and modulated is thought to be based on long-term repeated exposure (Liem & de Graaf, 2004). In the current study, repeated exposure to bread products at each level of red whole wheat flour was minimal (ranging from 3-4

exposures) but the long-term exposure to products containing whole wheat flour was extensive (9 months). This long term repeated exposure through school meals may have been helpful in facilitating increased whole grain intake.

With repeated exposure, the modified bread products may have become more familiar to children. A recent study by Cooke, Carnell, and Wardle (2006) showed no association between intake of bread rolls by 4-5 year old children and scores on a food neophobia scale indicating that bread rolls are considered familiar foods that children are not reluctant to taste. According to U.S. CSFII data (1994-1996), one of the major food sources of whole grains for children and adolescents were yeast breads accounting for about 20% of intake (Harnack et al., 2003). These promising aspects related to bread intake by children provide support for a better understanding of factors that might affect intake of whole grain bread within a school meal. In the current study, rolls served with breaded meats were consumed at lower levels compared to buns and rolls served with other menu items. This raises the possibility that the moisture content of the accompanying food may affect intake of bread products consumed as part of a school meal. However, research focusing on the moisture content of one food and its effect on consumption of other school meal components has not been reported in the literature.

The limitations of this study include a small convenience sample from two elementary schools in a Midwestern suburban area thus limiting the potential to generalize to other students in a broader geographic area. Data from this study indicated that a gradual incorporation approach was feasible to increase whole grain intake by children and therefore additional replication studies are needed with a more rigorous controlled experimental design. Although having adults establish the difference threshold levels could be considered a limitation, adults can more accurately detect difference in products based on color, texture and taste.

CONCLUSIONS AND APPLICATIONS

A gradual increase in the red and white whole wheat flour content of bun and roll products served in a school lunch program increased whole grain consumption by school-aged children over the course of a school year. However, based on the results of this study, whole grain bread products for school meals may be more acceptable with a total whole grain flour content approaching 75%. This may be a more feasible approach than serving bread products made with whole wheat flour as 100% of the flour content.

The incremental levels of whole wheat flour used in the current study were based on difference threshold testing by trained adult panelists regarding the color, texture and flavor of sample rolls (Delk & Vickers, 2007). It was thought that making the transition between levels as transparent as possible would enhance acceptability at each incremental level. The ability to discriminate between levels based on color, texture and flavor differences was greater for the red whole wheat products compared to the white whole wheat products in part because of the larger bran particle size and darker color resulting in a greater number of incremental levels. Sensory panelists in a previous study rated bread crust as smoother and texture as less gritty when the bread was made with bran of a finer particle size (Zhang & Moore, 1999). Bread made with white wheat bran was also rated as having better flavor and mouthfeel compared to bread made with red wheat bran. These findings are important as they indicate that replication studies in school feeding programs should be designed to optimize liking of bread products for children based on color, texture and flavor.

School food service professionals are encouraged to implement guidance from the Dietary Guidelines for Americans, 2005 regarding whole grain intake in school meal programs. To address this guidance, the amount and variety of whole grain products offered to students should be increased within the limitations of cost and group feeding situations. The gradual introduction of either red or white whole wheat flour into familiar grain products represents a novel, feasible approach to increase the amount and variety of whole grain containing products in school meals.

Additional research is needed to assess the influence of taste masking by accompanying food items, flavor-flavor learning based on the ratio of refined and whole wheat flour, effects of repeated

exposure and transparency of the transition between levels according to type and particle size of whole wheat. Because intake by children is largely driven by food preferences, it will be important that the quality and acceptability of whole wheat products meet the expectations of students so whole grain consumption is increased in schools. From a management and economic perspective, it may not be feasible to allow for a transparent transition between levels in many schools. A more practical approach may need to be implemented with fewer levels (25%, 50% and 75% whole wheat flour) over the course of a school year. This may allow school foodservice directors to gradually introduce acceptable whole grain products into school menus and more closely meet student taste profiles. During menu planning, it may be important to consider how the overall meal taste/texture/moistness and quality is affected by the combination of whole grain and other accompanying foods.

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