Psyllium Husk Fortified Gluten-free Pasta

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Abstract

Psyllium husk had long been studied as a possible fiber source and a gluten replacer for those with celiac disease (CD). The use of psyllium in cooking might help to improve the life of CD patients by allowing them to consume fiber with regular meals instead of separately as a form of supplementation, which may not be as appealing in taste. In this experiment, the addition of two different ratios of psyllium powder was tested in a gluten-free pasta recipe. The products were served with marinara sauce to twenty-nine subjects. The ratings were generally somewhat acceptable. The potential of psyllium fortification in pasta might be useful in the future as an alternative fiber source for CD patients.

Introduction/Purpose

Celiac disease (CD) is a genetic and autoimmune disorder that is triggered by gluten, and it is a disease that increases in prevalence based on family history (Fasano, et al., 2003). Those with relatives that suffer from CD tend to have a higher risk for CD. It affects about 1% of people worldwide (Zandonai, Bothlho, & Araujo, 2009). Exposure to gluten causes inflammatory responses that usually result in damage to the intestinal mucosa (Nelms, Sucher, Lacey, & Roth, p. 402). Consequently, patients often suffer from maldigestion and malabsorption. Some of the symptoms of CD include bloating, gas, diarrhea, constipation, delayed growth, and poor weight gain (Celiac Disease Symptoms Can be Elusive, 2011). CD is especially detrimental to children, who need extra nutrients to grow. Failure to thrive is a common indicator of gluten intolerance among children. Anemia and weight loss are both symptoms associated with CD.

Gluten is a protein complex consists of gliadin and glutenin (McWilliams, p. 402). The formation of gluten occurs when flour containing these protein complexes is manipulated with water. Wheat, barley, rye, malt, and oats are the primary sources of gluten found in the western diet (Nelms, Sucher, Lacey, & Roth, 2007, p. 402). Nutrition therapy remains the primary treatment of CD. For

most patients, avoidance of gluten products allows time for the intestines to regenerate their epithelial cells, but this restriction must be maintained for an entire lifetime in order to prevent inflammation from reoccurring. Most of gluten-free recipes involved replacing gluten containing products for gluten-free ones. However, commercially prepared gluten-free products can be costly to buy on a regular basis (Zandonai, Bothlho, & Araujo, 2009). Having recipes that patients can make cheaply at home will be more convenient and cost effective. Advantages of incorporating psyllium husk into pasta are increase feeling of fullness and satiety. Instead of taking a fiber supplement with water, it can be incorporated into a dish where it will likely taste better. The whole family can enjoy the same food. In children especially, it can create a sense of inclusion.

According to the Journal of the American Dietetic Association, those who suffer from CD typically have a difficult time choosing and preparing their food. It becomes difficult for them to enjoy meals together with their family because the gluten-free diet is so restrictive. Developing appropriate recipes to accommodate everyone can be challenging because palatability becomes a big issue. (Zandonai, Bothlho, & Araujo, p. 1781). The purpose of this experiment was to test the acceptability of gluten-free pasta fortified with a whole serving of fiber from psyllium husk powder. Grounded psyllium husk powder is a mixture of white, gray and brown. The color, texture, and taste of pasta fortified with psyllium husk should be similar to the original gluten-free pasta and be accepted as a fiber rich alternative.

Review of Literature

Those who are affected by celiac disease often experience constipation. Increasing fiber intake into the diet can potentially combat this symptom. Psyllium husk is categorized as a gel forming soluble fiber and are found in products such as Metamucil (Psyllium, 2011). Psyllium husk comes from the seeds of a shrub known as *Plantago ovate*. When the husk comes in contact with water, it swells and forms a gelatin, which helps to move waste materials through the intestines (Psyllium,

2011). About 55-60% of the husk is responsible for this gel formation (Fischer, Yu, Gray, & Ralph, p. 2009). As with other soluble fiber, psyllium can help to decrease plasma cholesterol and bile acids by binding and trapping them (Summerbell, Manley, Barnest, & Leeds, 1994). Furthermore, psyllium husk can survive digestion and increase the volume of stool, unlike the β-glucans and pectins that are easily fermented and have no contribution to volume (Fischer, Yu, Gray, & Ralph, 2004). Analysis of the polysaccharide after various methods of extraction broke it down to revealed "a species of highly branched, acidic arabinoxylan" (Fischer, Yu, Gray, & Ralph, p. 2009). Arabinose and xylose were the two primary pentoses that were found.

A study done by the American Dietetic association explored psyllium as a gluten replacer in bread because it exhibits some of the same "sensorial and functional characteristics" as gluten (Zandonai, Bothlho, & Araujo, 2009). The study also explained that like gluten, the physical structure of psyllium can remain stable in a wide range of pH and temperature, making it ideal to use in various types of cooking. In addition to being pH and heat stable, it can also act as a fat substitute, emulsifier, and thickening agent due to its gel forming ability (Zandonai, Bothlho, & Araujo, 2009). When used as a gluten replacer in bread, the results showed a 93% acceptance rate, making it a good alternative for CD patients.

Some of the patents that currently exist for this line of product include psyllium containing ready to eat cereals, cookies, and microwaveable muffins (Bedard, Lai, Wullschlegar, & Kindaid, 1993). In U.S. Patent No. 5,384,144, pre-wetted psyllium was incorporated into various types of pasta products to yield psyllium enriched pasta that was acceptable to the palate. According to the research behind this invention, psyllium is mucilaginous material used in bulk laxatives. Psyllium seed gum, the active compound that forms this mucilaginous material, is primarily found in the husk. Due to the gel forming nature of psyllium husk, it can acquire "a slimy or adhesive texture and mouth feel upon hydration" (Bedard, Lai, Wullschlegar, & Kindaid, 1993). In addition to this adhesive nature, psyllium

also tends to develop undesirable flavor when added to hot water. All of these factors interfered with the normal preparation of the pasta mentioned in this patent. In this patent, it mentioned the controls that were tested with semolina flour were difficult to knead and broke apart easily. The dough also became increasingly harder to process as it was left out for a longer period of time. It also appeared that the control that used egg yolk, instead of egg white only, had better texture. The controls that didn't use any eggs had the worst texture and were falling apart. This suggests that psyllium binds better to flour if an emulsifier, such as egg yolk, is present. In the samples that were fortified, the psyllium was pre-wetted. Then flour, sugar and Myvaplex ™ (mono and diglycerides) were added to form pellets using cold press technique. These pellets were then grounded up and later used in the different variations. To briefly summarize the results for the different variations made, pre-wet psyllium (key ingredient) produced better pasta in conjunction with semolina flour. The end product had better flavor and texture. Pre-wet psyllium was more malleable, which suggested that manipulation of the amount of water would be a key point.

Method/Design

Independent Variable: Psyllium Husk Powder, amount of water, and cooking duration
Dependent Variables: Hygroscopicity and color of pasta
Extraneous Variable: Humidity and drying temperature

In this experiment, an existing gluten-free recipe was modified with the purpose of adding one full serving of fiber (5 grams of fiber per serving of pasta, 20% daily intake). The nutrition label showed that every 5 grams of psyllium provide 4.5 grams of fiber, so every 5.6 grams of psyllium would provide 5 grams fiber. The recipe made 4 servings of pasta, so a total of 22.4 grams of psyllium husk would be substituted into the recipe to achieve 5 grams of fiber per serving. Equal amounts of millet flour were taken out. Millet flour was substituted because its color is most similar to the color of psyllium powder. In order to establish how much fiber can be substituted into the recipe, a preliminary trial was done for the control and for one variation. Using household measurements (see Appendix IV

for measurements), 2 tablespoons of psyllium powder (about 30 grams) was added and two tablespoons millet flour was taken out. This amount was high for the purpose of determining the maximum limit of fiber that could be replaced. Comparing the two variations showed that added the 30 grams of psyllium changed the color of the pasta from a light yellow to a light brownish yellow, with specks of psyllium visible on the noodle. This fortified pasta looked a bit like wholegrain pasta, but was still visually acceptable. Its texture was slightly less tender but still good. Furthermore, this still far exceeded the amount of fiber needed based on calculated value.

Procedures for the product

See Appendix III for a list of materials.

1. Each ingredient was weighted and pour into the food processor one by one according to the order on the standardized recipe (See Appendix II)
2. Then they were blended together until all the ingredients were mixed. Water was added during blending to add moisture.
3. One team member timed the process and record the final time.
4. The ingredients were removed from the blender and manipulate to form a ball.
5. ¼ cup of dough was removed from the batch. The rest was covered with a moist towel to prevent drying
6. The dough was rolled out until it was thin enough to pass through the pasta maker
7. Thin out the dough in the pasta maker by putting it through these settings in this order (4-3-2) the final product was pressed through the 1 millimeter slot.
8. The dough was then cut into 12-15 centimeter long strips.
9. The dough was passed through the pasta maker to make pasta that were 5 mm in width.
10. The noodles were then dried on a cloth that was covered with white rice flour to prevent sticking.
11. The drying process was 1 day, in 63°F degree, and a low humidity room.
12. On the day of evaluation. The pasta was cooked until tender. They were all mixed with 1 cup of marinara sauce to ensure consistency in color and flavor.

Procedures for Line-Spread Test

1. ¼ cup of raw dough was measured and the dough was weighted. The same weight was used for the other two variations.
2. The same measuring cup was used for all three variations of pasta to keep the shape of the dough uniform for all trials.
3. The dough was placed in the center of the circular graphing paper.
4. A line was drawn around the dough to mark the initial starting point.
5. A weight of 1406.1 grams was placed on the dough for 15 seconds. (The weight was a flat bottom deep dish with a can of tomato inside)
6. The weight was then taken off and a new line was drawn around the dough to mark the distance it spread. The difference were recorded.
7. This process was repeated for the other two variations.

Procedures for Wettability Test

See Appendix III for a list of materials.

1. Three noodles were prepared for weighing. The weight of each sample of noodle was within 0.01 grams of each other.
2. Trial 1 was cooked for two minutes; Trial 2 was cooked for three and a half minutes, and Trial 3 was cooked for five minutes.
3. Water was prepared using a shallow pan with 3 cups of cold water. A thermometer was placed into the water and the boiling temperature was recorded.
4. The thermometer was left in the pan for the entire cooking duration so the final temperature could be recorded quickly.
5. When the water was boiling, one noodle from each of pasta variations (a control, 10% fiber serving, and 20% fiber serving) were weigh once more for accuracy.
6. All three variations of weighed pasta were placed into the boiling water at the same time to ensure that they were cooked at the same temperature and for the same duration. At the moment the noodle was added, the timer was set for two minutes (first trial). The cover of the pan was left open to prevent spilling.
7. After two minutes, the final cooking temperature was noted.
8. The pasta was removed from the stove and drained in a colander for twenty seconds.
9. The final weight of each of the three noodles was recorded immediately.
10. The number of grams of water retained for each noodle was calculated by subtracting initial weight from the final weight.
11. The noodles from trial 1 were evaluated for tenderness. A number grade was given between 1-10; 1 being the least tender and 10 being the tenderest.
12. Steps 3-11 were repeated for trial 2 and three. The time for step 6 was adjusted: three and a half minutes for Trial 2, and five minutes for Trial 3.

Procedures for the cooking time of each pasta variation

Due to the added fiber content of each variation of pasta, the cooking time was adjusted in order to achieve maximum acceptability for each product. Samples of the same weight were measured out. Each sample was cooked separately until the correct tenderness was achieved. The proper cooking time was recorded and later used as reference to cook the final product for taste test and evaluation by the average consumer.

See Appendix III for a list of materials.

1. With a piece of parchment paper, the tare weight for each of the pasta variation was recorded (control, 10% serving of fiber pasta, and 20% serving of fiber pasta).
2. 4 cups of cold water were boiled in a shallow pan. The boiling temperature was recorded.
3. The thermometer was left in the pan so the final temperature could be recorded efficiently.

4. First test was for the control pasta. After the water had boiled, gently add the sample into the liquid. Time timer was started at the same time.
5. The pot was left uncovered to prevent spilling over.
6. After 5 minutes, one strand of pasta was removed from the cooking liquid and evaluated for tenderness. If the tenderness was acceptable, the cooking time was recorded. If the tenderness was unacceptable, the rest of the pasta was cooked for a longer period of time, until it was tender. This step was repeated until the proper tenderness was achieved.
7. All pasta was cooked to a rating of 10 (most tender).
8. Steps 2-8 were repeated for the other two pasta variations.

Sensory Evaluation

White paper plates were divided into three equal sections, drawing lines from the center of the plate to the outter edge. A random number was assigned to each section and the number was written on the edge of the plate. The sample numbers were 392 (control), 746 (half serving of fiber), and 518 (full serving of fiber). The random numbers were assigned to minimize bias. Each sample of pasta was place in small black plastic cups onto the designated spot on the plate and served at room temperature. Each person received one bite of pasta. The characteristics evaluated on the scorecard were color, thickness, texture, tenderness, flavor, and overall acceptability. The first five characteristics were scored using a 7 point hedonic scale. A score of 1 to 3 was considered unacceptable, a score of 4 is neutral and a score of 5 to 7 was considered to be acceptable. A 9 point hedonic scale was used for overall acceptability. The evaluation panel consisted of students and faculty members on campus. The sample size for this evaluation was supposed to be 30 people. However, one person did not return the evaluation form, so only 29 evaluations were collected.

Results and Discussion

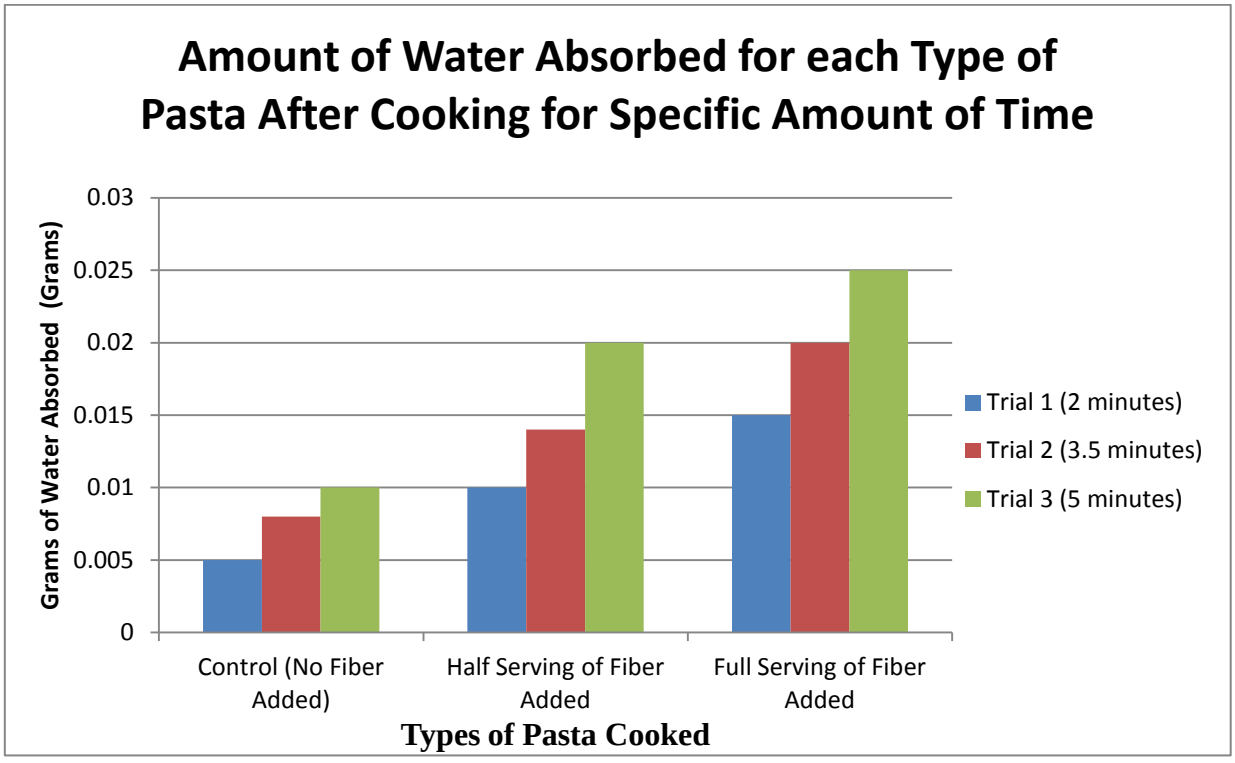
Objective tests results

Two objective tests were used to evaluate the three variations. The first test was the line-spread test to examine the spread of a measured amount of raw dough during 15 seconds. The second was a wettability test that examines each sample's ability to absorb moisture during a span of 2 minutes, 3.5

minutes, and 5 minutes. High water retention suggests that the pasta can hold sufficient moisture. The results are summarized below.

Type of Dough (1/4 cup)	Weight of Dough (g)	Duration of spread (sec)	Final Distance (diameter in cm)	Intial Distance (diameter in cm)	Distance of Spread
Full serving (5g added fiber)	66.2	15	6	6	0
Half serving (2.5g added fiber))	66.4	15	6	6	0
Control (No added fiber)	66.4	15	6.5	6	0.5

Table 1. The line spread test measured the pliability of the dough. The softer the dough, the further it would spread. The results showed that neither of the fortified pasta was very soft. The control spread for small amount.



Graph 1. The graph above show the amount of water absorbed by each type of pasta as they were cooked for an incrementally increasing amount of time.

Subjective test results

Six categories were evaluated during tasting. They were color, thickness, texture, tenderness, flavor, and overall acceptability (See Appendix IX – XI for raw data for results). The results were calculated to yield a mean (average) and a mode (most common score).

	Color	Thickness	Texture	Tenderness	Flavor	Overall Acceptability
Mean	5.90	4.48	4.52	5.45	5.03	5.59
Mode	7	5	4	5	5	5

Table 3. Control

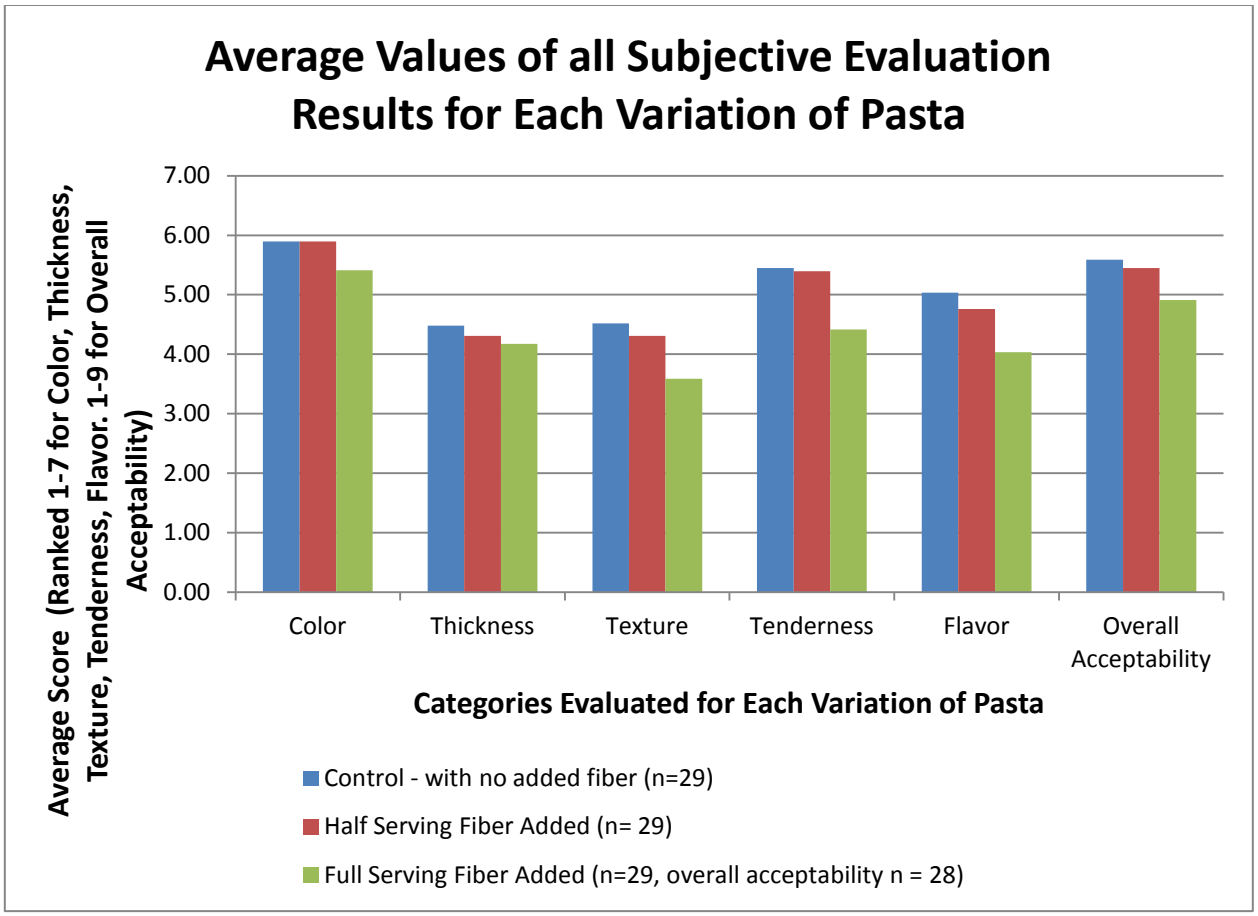
	Color	Thickness	Texture	Tenderness	Flavor	Overall Acceptability
Mean	5.90	4.31	4.31	5.40	4.76	5.45
Mode	7	4	7	5	5	5

Table 4. First variation – half a serving of fiber

	Color	Thickness	Texture	Tenderness	Flavor	Overall Acceptability
Mean	5.41	4.17	3.59	4.41	4.03	4.91
Mode	6	4	3	5	5	3

Table 5. Second Variation – full serving of fiber

The overall acceptability for this variation had only 28 scores because one person didn't give this sample a score. All other samples had 29 scores collected.



Graph 2. The above graph summarizes the average results of all categories evaluated in the subjective test. The trend shows the overall greater acceptability of the control and the pasta with half a serving of fiber. The pasta with a full serving of fiber had lower acceptability than the rest.

Discussion

Objective Test

The line spread test was performed on the raw dough and the results showed variations that were fortified with fiber were much firmer than the control (See Graph 2). This was probably due to the adhesive nature of psyllium, as explained in the review of literature. The fiber bound to the flour more tightly in the presence of water, making the dough firmer. This was also reflected in the cooking time (See Appendix VII) for the fortified pasta. Since psyllium is capable of absorbing a lot more water. It had to be cooked for a longer period of time in order to become tender.

The wettability test was performed on pasta that had been dried. They were dried in 63°F for one day and stored for five days in plastic containers. The results (See Graph 1) showed that as more fiber was added to the pasta, the more water it absorbed. It appears that psyllium increased the hygroscopicity of the pasta. As cooking time increased, water absorption also increased.

Subjective Test

To help alleviate constipation associated with celiac disease; this gluten-free pasta was developed as means to increase intake of dietary fiber in these patients. Modifications of a gluten-free pasta recipe were evaluated and the results were as follows (See graph 2). The control, on average was rated the highest, follow closely by the second variation of the pasta with half a serving of fiber. The pasta fortified with a whole serving of fiber was not as well accepted.

The highest rated attribute was color, which in part was due to the sauce covering the pasta. The mode for the control and the half serving of fiber were 7, which means more people considered it appealing. There is 86% acceptability for the control, 89% of the half serving and 72% for the full serving. The sample with the full serving of fiber had a mode of 6, one lower than the other two samples, because it had a darker color from the extra fiber. However, the score was still in an acceptable range. If it was not compared to two other different color pastas, the off color might be less noticeable and better accepted.

Thickness of the control had an average and mode rating that was higher than the fortified samples even though all the pastas were cut using the same setting. The mode for the control was 5, which means that more people thought the pasta was slightly thicker. It appears that the fortified samples did not expand as much as the control and there was a noticeable difference when eaten. As noted in the review of literature, psyllium has a mucilaginous quality. The fiber must have been binding more tightly to the flour making the pasta more compacted. In terms of percentages, the scores

were divided pretty evenly between people who think it was too thick or too thin. Thickness is a factor that comes down to preference. If this pasta were to be made at home, CD patients can cut the pasta into a thickness that they prefer.

The texture for the control and the half a serving of fiber had an average rating of 4.52 and 4.31 respectively. People found the control to be somewhat acceptable, and the half serving pasta to be similar in texture. The full serving sample had the average rating of only 3.59. People typically prefer the texture of the control and the half fiber pasta over the full serving of fiber. There seem to be a pattern where 41% of the people gave opposite rating between the control and the full fiber pasta. In this 41%, those who gave a high rating to the control tend to give a low rating to the sample with the full serving of fiber, and vice versa. Perhaps these people who normally enjoyed higher fiber products preferred the sample with the full serving of fiber, and those who didn't, preferred the control.

The average tenderness score in general was higher for the control and the half fiber pasta. About 79% found the control to be acceptable, and 82% found the half serving fiber pasta to be acceptable. The full fiber pasta only had a 58% acceptability rate. Again, fiber content affected tenderness due to its binding ability. The wettability test showed that fiber fortified pasta required longer cooking time to be tender.

For flavor, the control and half serving had higher average rating than the whole serving fiber pasta. While the first two samples had higher than average acceptability, the full fiber pasta only had average acceptability. According to the review of literature, psyllium fortified pasta did have the tendency to give an off flavor. However, about 48% of the people still find it the full serving fiber pasta acceptable. Perhaps extra sauce was needed to enhance its flavor. For the purpose of this experiment, the same amount of sauce was used for all three samples.

The average overall acceptance was still the highest for the control, which was 5.59 out of 9, with a mode of 5. However, coming closely to the second, with an overall acceptability of 5.45 was the

pasta fortified with half a serving of fiber. This sample also had a mode of 5. The two samples were very close in acceptability. They had the same score for color for both the mean (5.9) and the mode (7). With the pasta sauce covering the noodle, their appearances were almost identical. The lower score for the full fiber pasta was 4.9, which was considered less than acceptable.

Some of the possible errors that occurred during trials of this experiment were forgetting to measure in mL and not having a scale with decimal places. The olive oil was measured in tablespoon by mistake, but it was probably less of a factor since the ingredient that seem affect the outcome the most was the psyllium husk powder. Based on the calculations, 22.4 grams of psyllium was supposed to be used to substitute out 22.4 grams of millet flour for a full serving of pasta. However, since the scale that was available did not have decimal places, the amount had to be rounded up to 23 grams. For the half fiber pasta, instead of 11.2 grams, it was rounded up to 12 grams. Had the amount of fiber been lower, the acceptability might be higher. In retrospect, the ratings on the score cards should have all been kept consistent with the score of 1 to 7 or 1 to 9. One person gave a rating of 8 on the scale of 1 to 7. Perhaps they were confused by the instructions and thought the scale for all the categories were 1 to 9. This makes the data unreliable. If someone rated a 5 thinking the scale was 1 to 9, the rating would be considered a low rating, where as if that same score was out of a 7 point scale, it would have been considered a favorable rating.

Conclusion

Overall, the acceptability of the pasta was average according to the data, which was expected because of the nature of the gluten-free recipe. It did not have the same chewiness and body as regular pasta. For those who were used to eating pasta that contains gluten, they might find this recipe less appealing. In general, it appears that most people were only able to accept the pasta with a half a serving of added fiber. They would need to get 20% of their daily recommended value by consuming two servings. Psyllium fortification in pasta definitely has potential, but more experimentation and

research is needed in order to find the balance so there can be enough fiber added without compromising texture and appearance. Perhaps a pasta sample with 15% of added fiber could be a more acceptable alternative than 20%.

Appendices

Appendix I - Ingredients and procedures

Original Ingredients/Recipe (Kicinski, 2011)

1) 1 cup superfine white rice flour (Brand: Bob's red mill)
2) 1/3 cup millet flour (Brand: Bob's red mill)
3) 2/3 cup tapioca starch (Brand: Bob's red mill)
4) 3 tablespoon potato starch (not potato flour) (Brand: Bob's red mill)
5) 1 tablespoon xanthan gum (Brand: Bob's red mill)
6) 1 teaspoon sea salt (Brand: Whole Foods 362 Brand)
7) 2 tablespoons olive oil (Brand: Whole Foods Cold Pressed Virgin Olive Oil)
8) 3 large eggs (Brand: Large Eggs Costco)
9) 2 -4 tablespoons water (Tap water)

Sauce: Trader Joe's Marinara Sauce (Not part of original recipe)
Substitution Ingredient: Psyllium husk (Brand: Yerb Prima Husk Powder)

Appendix II - Standardized recipe

Recipe Title: Gluten-free Pasta

Total Yield: 4 cups

Serving Size 1 cup

Cooking Temp: Boiling (212 ° F)

Cooking Time: 13 minutes for control, 14 minutes and 20 seconds for the sample with a half serving of fiber, 15 minutes 36 seconds for the sample with a full serving of fiber

Ingredients	__4__ Servings		Preparation Instructions
	Volume	Weight	
1 cup superfine white rice flour		157 grams	Use a superfine mill of white rice flour. Weight out the correct amount of flour into a food processor.
1/3 cup millet flour		42 grams	Weight out millet flour and add to food processor with rice flour.
2/3 cup tapioca starch		82.5 grams	Weight out tapioca starch and add to food processor also.
3 tablespoon potato starch		42.5 grams	Add weighed out potato starch to food processor also.
1 tablespoon xanthan gum		14 grams	Weight out xanthan gum and also add to food processor.
1 teaspoon kosher or fine sea salt		4.6 grams	Add salt to food processor mixture also. Pulse these dry ingredients together until combined.
2 tablespoons olive oil	30 ml		In a separate bowl add olive oil
3 large eggs	3 eggs		Add 3 large eggs to the bowl with olive oil, and whisk until mixed evenly (can take anywhere from 30-45 seconds)
2-4 tablespoons water	30-60 ml		Add mixture of egg and olive oil to food processor slowly until dough starts to come together. Add water 30 ml at a time until dough forms into a ball. Split dough into 4 balls, and roll each ball out by putting through a pasta maker. Use the fettuccini side for pasta shape.
2 cups Tomato Sauce	16 oz		Mix pasta with sauce, you want a lighter sauce for this.

Appendix III - Materials

Taylor LED glass scale
Pasta maker with 6 thickness settings
1. 0.5mm
2. 1.00mm
3. 1.5 mm
4. 2.00 mm
5. 2.5 mm
6. 3.00 mm

Cuisinart food processor - 7 cups with 3100 strokes per minute

Materials

1. Shallow pot to boil pasta
2. Timer
3. Thermometer
4. Pasta fork
5. Colander
6. Plate
7. Food Scale

Appendix IV – Measurement of Ingredients during trials:

Preliminary Trial for the control - October 4, 2011

Ingredients	Measurements
Rice Flour	1 cup
Millet flour	1/3 cup
Tapioca Starch	2/3 cup
Potato Starch	3 tbsp
Xanthum gum	1 tbsp
Psyllium powder	N/A
Water	3 tbsp
Salt	1 tsp
Olive Oil	2 tbsp
Eggs	3 large eggs
Pulse duration	Not recorded, blended until evenly mixed

Ingredients	Measurements
Rice Flour	1 cup
Millet flour	3 1/3 tbsp
Tapioca Starch	2/3 cup
Potato Starch	3 tbsp
Xanthum gum	1 tbsp
Psyllium powder	2 tbsp
Water	3 tbsp
Salt	1 tsp
Olive Oil	2 tbsp
Eggs	3 large eggs
Pulse duration	Not recorded, blended until evenly mixed

Appendix V - Final Trials – November 16, 2011

Ingredients	**Types of Pasta**		
	0% replaced (Control)	Half a serving of fiber	Full serving of fiber
Rice Flour in (g)	157 g	157 g	157 g
Millet flour (g)	42 g	30 g	19 g
Tapioca Starch (g)	85 g	85 g	85 g
Potato Starch (g)	43 g	43 g	43 g
Xanthum gum (g)	14 g	14 g	14 g
Psyllium powder (g)	0 g	12 g	23 g
Water	3 tbsp	3 tbsp	3 tbsp
Salt	4 g	4 g	4 g
Olive Oil	2 tbsp	2 tbsp	2 tbsp
Eggs	3 large	3 large	3 large
Mixing of dry ingredients	3 seconds	4 seconds	2.6 seconds.
Pulse duration (Blended until evenly mixed)	46.6 seconds	54.4 seconds	52.3 seconds

Appendix VI – Wettability test (November 18, 2011)

	Samples		
	Control	Half Serving	Full Serving
Trial 1			
Initial Weight of noodles (grams)	0.236	0.236	0.236
Starting cooking temperature (F)	208° F		
Final cooking temperature (F)	206°F		
Total cooking time	2 minutes		
Total time drained	20 secs		
Final weight of each sample of noodle	0.241	0.246	0.251
Water retained (Final weight - initial weight)	0.005	0.010	0.015
Tenderness (10 most tender, 1 least tender)	4	2	1
Trial 2			
Initial Weight of noodles (grams)	0.236	0.236	0.236
Starting cooking temperature (F)	208° F		
Final cooking temperature (F)	206° F		
Total cooking time	3.5 mins		
Total time drained	20 secs		
Final weight of noodles	0.244	0.250	0.256
Water retained (Final weight - initial weight)	0.008	0.014	0.020
Tenderness (10 most tender, 1 least tender	7	6	4
Trial 3			
Initial Weight of noodles (grams)	0.236	0.236	0.236
Starting cooking temperature (F)	208° F		
Final cooking temperature (F)	206° F		
Total cooking time	5 mins		
Total time drained	20 secs		
Final weight of noodles	0.246	0.256	0.261
Water retained (Final weight - initial weight)	0.010	0.020	0.025
Tenderness (10 most tender, 1 least tender)	10	9	7

Appendix VII - Cooking time test for each type of pasta (November 30, 2011)

	Samples		
	Control	Half Serving	Full Serving
Cooking Time for Pasta			
Amount of Noodles (grams)	30 grams	30 grams	30 grams
Amount of water used (cups)	1.5 cups	1.5 cups	1.5 cups
Starting cooking temperature (F)	206° F	206° F	206° F
Final cooking temperature (F)	211° F	211° F	211° F
Total cooking time (min)	13 min	14 min 20 sec	15 min 36 sec
Tenderness (10 most tender, 1 least tender)	10	9	9

Appendix VIII - Score Card

Score Card			
Characteristic	**Samples**		
Please rate each item with a number.	392	746	518
Color 1= Unappealing, 7 = Most appealing			
Thickness 1= Too thin, 7 = Too thick			
Texture 1= Poor texture, 7 = Good texture			
Tenderness 1= Not tender, 7 = Most Tender			
Flavor 1= poor flavor, 7 = Good flavor			
Overall Acceptability 1 = least acceptable, 9 = Most acceptable			

Appendix IX – Final Evaluations for control (December 2, 2011)

	Evaluations					
Taster #	Color	Thickness	Texture	Tenderness	Flavor	Overall Acceptability
1	7	4	4	3	6	9
2	5	4	4	7	6	2
3	6	5	4	4	6	5
4	5	5	6	5	7	5
5	6	4	5	6	5	7
6	3	3	3	6	5	5
7	5	3	3	4	3	2
8	6	4	2	7	3	2
9	7	5	3	7	6	6
10	7	3	6	7	6	9
11	7	7	4	7	5	7
12	7	5	6	5	4	6
13	7	4	1	7	6	6
14	5	5	7	5	5	7
15	4	3	4	4	3	5
16	5	7	4	2	4	6
17	7	5	5	5	4	5
18	5	5	4	5	5	5
19	6	6	7	6	5	6
20	7	4	1	5	5	6
21	3	4	7	7	5	6
22	7	5	6	5	2	1
23	7	5	6	7	7	5
24	6	4	4	4	7	7
25	7	5	7	6	7	9
26	7	5	6	7	7	9
27	7	5	5	5	5	6
28	7	3	5	5	4	5
29	3	3	2	5	3	3

Appendix X - Evaluations for First variation - with an extra 10% fiber per serving

	Evaluations					
Taster #	Color	Thickness	Texture	Tenderness	Flavor	Overall Acceptability
1	7	4	7	5	7	9
2	7	4	5	6	6	4
3	6	5	1	7	2	3
4	5	1	1	3	2	3
5	6	4	6	5	6	8
6	3	3	3	6	6	6
7	6	6	6	6	7	8
8	6	4	4	6	4	4
9	7	5	2	6	6	5
10	5	4	4	5.5	4	6
11	7	7	2	7	2	2
12	5	2	1	1	4	5
13	7	4	3	5	1	5
14	5	3	3	3	1	3
15	4	4	3	3	4	5
16	6	5	7	7	7	9
17	7	5	7	7	7	7
18	5	5	3	5	4	4
19	5	6	6	6	5	5
20	5	4	3	5	6	5
21	6	4	2	7	6	5
22	7	5	7	5	5	7
23	6	4	5	5	5	5
24	7	5	7	5	5	8
25	7	5	5	7	5	5
26	7	5	7	6	5	7
27	7	5	3	5	5	5
28	6	3	7	7	7	6
29	4	4	5	5	4	4
Mean	5.90	4.31	4.31	5.40	4.76	5.45
Mode	7	4	7	5	5	5

Appendix XI – Evaluation for Second Variation – with an extra 20% of fiber per serving

	Evaluations					
Taster #	Color	Thickness	Texture	Tenderness	Flavor	Overall Acceptability
1	6	4	3	4	4	9
2	6	4	6	4	7	7
3	6	5	2	3	1	2
4	4	4	3	5	4	4
5	6	4	5	5	7	8.5
6	4	4	4	3	3	3
7	7	1	1	2	3	2
8	5	4	5	5	5	7
9	7	5	2	7	3	5
10	4	5	1	3	2	3
11	6	7	3	6	5	7
12	5	4	3	3	1	4
13	7	4	3	3	2	N/A
14	5	5	3	5	1	3
15	5	5	4	4	5	6
16	2	3	3	5	5	5
17	6	5	2	2	2	3
18	5	5	5	5	3	4
19	4	6	5	6	5	4
20	6	4	4	5	5	5
21	7	4	5	8	8	6
22	6	5	7	5	5	5
23	4	1	3	1	3	3
24	7	4	7	3	6	7
25	7	5	6	6	6	8
26	7	5	5	5	5	6
27	6	4	2	5	5	6
28	4	3	1	5	4	3
29	3	2	1	5	2	2
Mean	5.41	4.17	3.59	4.41	4.03	4.91
Mode	6	4	3	5	5	3

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