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Effects of Oats and Distiller's Dried Grains Fibers on Fortification of Asian Noodles – Evaluation of Glycemic Response, Noodle Quality and Nutritional Composition

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EFFECTS OF OATS AND DISTILLER'S DRIED GRAINS FIBERS ON FORTIFICATION OF ASIAN NOODLES – EVALUATION OF GLYCEMIC RESPONSE, NOODLE QUALITY AND NUTRITIONAL COMPOSITION

BY KARA KONST

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements of this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

ABSTRACT

EFFECTS OF OATS AND DISTILLER DRIED GRAINS FIBERS ON FORTIFICATION OF ASIAN NOODLES – EVALUATION OF GLYCEMIC RESPONSE, NOODLE QUALITY AND NUTRITIONAL COMPOSITION

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The objective of this study was to develop Asian wheat noodle formulations enriched with oat flour and corn DDG at 10, 20 and 30 % wheat flour replacement levels and to evaluate the effects of this fiber and protein enrichment on the glycemic response of human subjects. We hypothesized that the addition of high-fiber oats and high-fiber, high-protein DDG will have synergistic effects in lowering the glycemic response in human subjects. In this study, steamed instant Asian noodles were prepared with DDG(D) and oats(OF) in combination with all-purpose wheat flour(W) in the following flour blends: (W:D) 90:10, (W:OF) 90:10, (W:D) 80:20, (W:OF) 80:20, (W:D:OF) 70:10:20 and (W:D:OF) 70:20:10 and control (100% W). The nutrient composition of each flour and type of noodle was determined. A series of 10 different glycemic test were conducted on each of the 7 different kinds of noodles and on a 50g glucose beverage. The control noodles were tested 3 times. Twelve, generally healthy, participants determined by a health screening, were recruited for glycemic testing. Noodles were served to participants in 50g of available carbohydrate sized portions after a 12 hour fast. Capillary blood glucose readings were measured at 0, 15, 30, 45, 60, 90 and 120 minutes using OneTouch Verio glucometers. Sensory testing using 4 different pair test and 4 different triangle tests on control noodle and (W:D) and (W:OF) in ratios of 90:10 and 80:20

noodles were examined using 20 untrained panelist. Sensory tests showed that participants preferred noodles containing oat fortified noodle over the control noodle. The sensory score indicated that oat noodles hold potential for further development and commercialization. Noodles fortified with DDG significantly increased the protein, fiber and total phenolics content and correspondingly lowered the calories and carbohydrate content. To a lesser degree, oat flour also increased the protein, fiber and total phenolics and lowered the calories and carbohydrates content of noodles. Noodles containing 70W:10D:20OF had the lowest glycemic index followed by the control. Noodles containing 20% DDG yielded the highest glycemic index. Overall, the fortified noodles, while reducing glycemic index relative to pure glucose significantly in subjects, did not reveal significant differences between noodle treatments and the all wheat control noodle.

CHAPTER 1. INTRODUCTION

Cereal grains make up a major contribution to the food supply in the world as they provide two thirds of the energy and protein intake in the world. In the U.S., cereal grains make up about 1/4th the energy intake (Slavin, 2000). Cereal grains come from the grass family called Monocots (Truswell, 2002). Many commonly consumed cereal foods include wheat, oats, rice, corn, barley, sorghum, rye and millet as key ingredients. The term "whole-grain" is used to refer to equivalent proportions of endosperm, germ and bran in the intact grain are present after processing (Flight & Clifton, 2006). Whole-grain cereal grains are a reliable source of carbohydrates, fiber, protein and micronutrients. Micronutrients in cereal grains include B-vitamins, folate, vitamin A, vitamin E, iron, magnesium, zinc, phosphorus and a substantial quantity of phytochemicals such as phenolic compounds, antioxidants and phytoestrogens (Flight & Clifton, 2006). It has been suggested that the nutrient content of whole-grains work in a synergistic fashion in the diet to help protect against diseases such as cardiovascular disease, cancer, diabetes, atherosclerosis and many other health problems (Flight & Clifton, 2006; Slavin, 2000). Cereal grains such as oats and grain fractions like corn DDG are potentially key ingredients in the human diet and play an important and affordable role in preventing and treating obesity and diabetes.

In 2016, approximately 40% of the U.S. population was classified as obese or over weight and more than 30% of the world's population was overweight or obese (Center for Disease Control and Prevention, 2017; Tremmel, Gerdtham, Nilsson, & Saha, 2017). If this incidence continues at this rate, by the year 2,030, almost half the world's population will be overweight or obese (Tremmel et al., 2017). Obesity is a complex multifaceted health issue that involves the environment, genetic predisposition and

human behavior (You & Henneberg, 2016). Past activities that needed high energy expenditure have become effortlessness due to industrialization, urbanization and technological progress. Consequently, decreasing energy expenditure during commuting during work, commuting, household and recreational activities. Additional factors in this reduced energy expenditure involve globalization of eating habits that encourage obesity due to extensive distribution of refined and processed foods, abundant in sugars and fat and distributed in oversized portions (Hassan et al., 2015). Obesity is associated with increased risk of health problems including diabetes, strokes, cardiovascular disease, high cholesterol, cancer, arthritis, sleep apnea, asthma, hypertension, hyperlipidemia and musculoskeletal disorders (Center for Disease Control and Prevention, 2017; Levine, 2011; Levine & Koepp, 2011; Tremmel et al., 2017; You & Henneberg, 2016). Preventable illnesses account for most of health-care expenditure and obesity influences most preventable illness (Levine & Koepp, 2011). Obesity is directly associated with three of the five most costly diseases in the United States; heart disease, hypertension, and diabetes (Levine & Koepp, 2011). In 2016 the United States the annual health expenditure exceeded $3.3 trillion and about 70% of this cost is due to obesity-associated health problems (Center for Medicare and Medicaid Services, 2019; Levine, 2011).

Obesity is the most common risk factor in the development of type II diabetes as it contributes to about 55% of all diabetic cases (Olokoba, Obateru, & Olokoba, 2012). The most recent estimate (2014), places the estimate at 422 million people in the world with diabetes (Abid, Ahmad, & Waheed, 2016). Diabetes impacts about 9.2% people in the united states. Diabetes is a disease that allows sugar/glucose to collect in the blood steam due insulin resistance. Diabetes results in more blindness, renal disease and

amputation than any preventable disease. In 2012, about 245 billion dollars were spent on diabetic health care (Abid et al., 2016).

Diet and lifestyle changes constitutes a crucial aspect of the overall management and prevention of type II diabetes, which may involve diet and exercise alone, diet and exercise with oral hypoglycemic drugs, or diet and exercise with insulin. Diets typically involve a well-balanced diet that is appropriate for the individual's height, weight, age and activity level (Asif, 2014). The goal in managing diabetes is to maintain a blood glucose level within a healthy level with a pre-meal glucose target of <140 and random blood glucose of <180mg/dl (7.8-10mmol/L) (Asif, 2014). The glycemic index classifies foods based on their blood glucose-raising potential, as not all foods with equal carbohydrate contents will have the same impact on blood glucose (Eleazu, 2016). The glycemic index is an effective way to determine the best food choices for foods that contain a significant portion of carbohydrates such as grain products. A low GI diet has been shown to help reduce body fat, improve lipid profiles and improve glycemic control. Low GI diets tend to be higher in fiber and tend to increase satiety. In many cases, lower GI foods tend to be more expensive (Cleary et al., 2012). Few packed ready to eat foods are low GI and tend to be expensive. There is a need more affordable ready to eat grain-based products that are low in GI.

Consumption of cereal grains forms a basis of a healthy diet. All current dietary guidelines have cereal foods as the largest component of the recommended daily intake (Flight & Clifton, 2006). The current recommendation for grain consumption in the United States is about 3-5 servings for adults and it is recommended that at least half of all grains eaten should be whole-grains. Whole-grains that undergo processing must

contain the same proportions of endosperm, germ and bran as the original intact grain to be considered a whole-grain. Nearly all the U.S. population overconsumes refined grains and does not meet the recommendations for whole-grains (McGuire, 2016; USDA, 2015). Dietary guidelines advocate the consumption of mixed cereal grains to prevent chronic disease and their risk factors. A diet rich in whole mixed grains versus an individual cereal grain, has been increasingly encouraged as a major food group for healthy body weight. Certain factors restrict the increase consumption of whole-grain foods such as, higher prices for some whole-grain foods, complications in recognizing whole-grain foods in the stores, insufficient consumer mindfulness of the health benefits of whole-grains, consumer complaints and palatability, and lack of experience with preparation methods (Kantor, Variyam, Allshouse, Putnam, & Lin, 2001). Insufficient consumption of whole-grains contributes to inadequate intake of numerous nutrients of public concern and deficient nutrients. However, refined grains are still part of the daily intake recommendation because they are typically enriched with micronutrients such as iron, thiamin, niacin and riboflavin (McGuire, 2016; USDA, 2015). Fortifying refined grain products with other grain products like DDG and oats may help create more nutrient dense products without significantly effecting the cost or taste of the product.

Most grains, whole or refined, are subjected to some type of processing in order to make a desirable product by optimizing texture, appearance, flavor, color and shelf stable products (Slavin, 2000). Whole-grains are commonly milled into a flour. Milled whole-grains can be nutritionally superior to intact whole-grains for human consumption because poorly digested compounds are removed during milling process and nutrient availability is enhanced. Refining grains is another commonly practiced processing

technique where the bran and germ of the grain are removed leaving the starchy endosperm (Flight & Clifton, 2006). Refined grains have a high GI. In addition, they lack fiber, micronutrients and phytochemical due to the removal of the bran and germ (Mazur et al., 2007). Refined grains are used in many food products for a variety of reasons such as cost, taste, shelf-life stability, acceptance and technical practicability (Jonnalagadda et al., 2011). Fortifying refined grain products with other grain products create more nutrient dense products without significantly affecting the cost or taste of the product.

One way to enhance refined grains maybe to use adjuncts such as distillers dried grains (DDG). DDG is a co-product that results from milling of corn to manufacture ethanol (Amezcua & Parsons, 2007). DDG is the remnant, namely, the non-fermentable components of the corn kernel that includes the germ, fiber and protein (Martinez-Amezcua, Parsons, Singh, Srinivasan, & Murthy, 2007; Roth, Döring, Jekle, & Becker, 2015). Due to the high global demand for energy, there has been an increase in ethanol production resulting in an increase DDG supply (Rosentrater & Krishnan, 2006). It is estimated that 60 million tons of DDG is produced per annum. DDG is an affordable high protein and high fiber food source with a cost of $0.02- $0.12/ per pound (Mary Kennedy, 2018). Currently, most of the distiller's dried grain supply is used as animal feed (Rosentrater & Krishnan, 2006). However, human food applications have been explored especially in grain-based foods (Rosentrater & Krishnan, 2006; Roth, Döring, Jekle, & Becker, 2016). DDG contains all the same nutrient components of the whole-grain corn in a concentrated form, excluding, the starch and fermentable carbohydrates (Roth et al., 2016). It is well documented that DDG is high in protein, fiber, vitamins and mineral content. Several studies found distillers dried grains with solubles (DDGS) used

for animal feed contains vitamin and minerals such as Vitamin E, thiamine, riboflavin, pyridoxine, pantothenic acid, phosphorus, calcium, sodium, potassium, chlorine, sulfur, magnesium, Copper, zinc, iron, Manganese, biotin, carotene and xanthophyll (Jung, Batal, Ward, & Dale, 2013; Lumpkins, 2004; Salim, Kruk, & Lee, 2010). The fortification of grain-based foods using DDG has the potential to improve the nutrient density, lower the energy density of products also reduce glycemic response in consumers.

Another possible fortification option for refined grain products includes oats. Oat is an important cereal crop that is primarily used as animal feed and to some extent as food (Rasane, Jha, Sabikhi, Kumar, & Unnikrishnan, 2015). In the United States, the annual oat supply consists of about 66% of oats for animal feed and about 33% for industrial and food uses (Paudel, Caffe-Treml, & Krishnan, 2018). Oats are primarily grown in European and North American countries especially in Canada, U.S. and Russia. The U.S. oat production in 2016 was 939,121 tons and South Dakota, the top oat producing state, contributed 193,050 tons of oats (Rasane et al., 2015). Recently, there has been a steady increase in consumption of oats which may be related to the increase in awareness of health benefits in oats (Ahmad, Anjum, Zahoor, Nawaz, & Ahmed, 2010; Paudel et al., 2018; Rasane et al., 2015). The fat, fiber, protein, starch and phytochemical content of oats has appealing health benefits. Many studies suggest that oats may be beneficial for prevention and treatment of diabetes, high cholesterol, CVD and several types of cancers (Clemens & van Klinken, 2014). As a result, there has been an interest in incorporation of oats into food products. Oats and oat components have been incorporated in products such as granola bars, cookies, flakes, Oatrim, biscuits, probiotic

beverages, pasta, infant food and breakfast cereal and oat bread. The integration of oats in food products has been shown to improve the overall quality of food (Rasane et al., 2015).

There is a preponderance of highly refined grain food products available in the marketplace. Regular overconsumption of refined grains is one of many factors that may contribute to obesity and diabetes. Fortifying refined grain products with other grains and grain products may offer more diverse nutrient-dense, lower energy-dense and low-glycemic index products. Fortification of refined grain products with other grains may enhance the consumption of a verity of whole-grains, satiety, aid in weight loss and control of blood glucose levels. To our knowledge, there are no studies that have investigated the glycemic response of whole oat flour and FDDG fortification in food products. In this study, low-GI noodle products were developed using DDG and oats in select combinations with up to 30% wheat flour replacement. The nutrient content, acceptability, effects on satiety and glycemic response were evaluated in the noodle products.

CHAPTER 2. LITERATURE REVIEW

Asian Noodles

Noodles have been a staple food in many Asian countries for centuries. There is record of Asian noodles that dates back to 5000BC in China. Since then, noodles have been introduced to countries around the world. Overtime, noodles processing, technology and ingredients have evolved. The first instant noodles, called *chicken ramen*, were invented in 1958 by Momofuku Ando at Nissin Foods in Japan (Fu, 2008; Gulia, Dhaka, & Khatkar, 2014). Today, noodles are commonly eaten in more than 80 countries all over the world. About 270 million servings of instant noodles are eaten around the world each

day (Farrand et al., 2017). The total noodle consumption in 2017 was about 100.1 billion servings, with 80% of total intake in Asian countries. China consumes the highest quantity of instant noodles followed by Indonesia, Japan, India and Vietnam. The United States is 6th largest consumer of instant noodles consuming 4.13 billion servings of instant noodles in 2017. Inexpensive cost, extended shelf life, taste and convenience make noodles highly popular (Farrand et al., 2017).

Noodles are primarily made from wheat flour, salt and water, and, combined and mixed to make a dough that is fashioned by sheeting (Fu, 2008; Oh, Seib, Deyoe, & Ward, 1983). Noodles and pasta are closely related but differ in that pasta is processed from a mixture of water and course semolina (from durum wheat) extruded through a metal die. Noodles vary from country to country and may be modified for geographical taste preference, available technology and eating habits (Fu, 2008). According to the International Food Standard for Instant Noodles, instant noodles are made from starch, salt or Kansui (a combination of potassium carbonate, sodium phosphate and sodium carbonate) water, wheat flour and additional ingredients maybe included to enhance flavor and texture of the noodles. However, noodles can be made by a variety of raw materials such as wheat flour, rice flour, sweet potato starches, buck wheat flour, corn, tapioca, wheat, mung bean, rice or sago. Noodles consisting of wheat flour remain the most common followed by rice and starch-based noodles (Food and Agriculture Organization of the United Nations, 2018; Fu, 2008; Gulia et al., 2014; World Instant Noodles Association, 2018). While there is currently no specific standard for non-instant noodles, it is specified in the, International Food Standard for Instant Noodles, that standard applies to various kinds of noodles (Food and Agriculture Organization of the

United Nations, 2018). Noodles vary from country to country and may be modified for geographical taste preference, available technology and eating habits (Fu, 2008; G. Hou, Kruk, & Center, 1998). Many countries have their own standards for noodles. For example, in the United States, the standard of identity of noodles requires noodles to be made by drying fashioned units of dough made from egg and wheat flour such as semolina, durum flour, farina and flour (FDA, 2018). There are wide differences in noodle nomenclature in each country. Thus, there is a need to standardize noodle classification and/or nomenclature using a universal classification system based on ingredients, salt configuration, size/ shape and processing method (Fu, 2008; G. Hou et al., 1998).

Noodles tend to be high in carbohydrates and low in fiber, protein, vitamins and minerals (Park, Lee, Jang, Chung, & Kim, 2011). This may be due to the high use of refined flour in noodles (Q. Hou et al., 2015). Thus, noodles represent a class of food that shows potential for nutritional improvement. Developing countries encourage instant noodles as a nutrient vehicle by fortifying noodles or the seasoning powders consumed with the noodles (Park et al., 2011). Commercial noodle products are commonly fortified with micronutrients such as vitamin A, B1, B2, iron niacin, iodine and folic acid. There has been recent interest in improving the fiber and protein content of noodles. One solution maybe through fortification of flour by incorporating other flours such as soy, barley, legumes, buckwheat, oats and FDDG (Gulia et al., 2014). Few studies have investigated the incorporation of whole oat flour in noodles and no studies have investigated the incorporation of DDG into noodles. One study found that the optimum consumer acceptance fortification level of oat flour was 10% (Aydin & Gocmen, 2011).

Another study found that optimum consumer acceptance fortification level of oat flour was 20% (Majzoobi, Layegh, & Farahnaky, 2014). Three studies have been done on the impact of oat bran, oat beta-glucan fortification on the chemical, physical and sensory attributes of the noodles (Choo & Aziz, 2010; Inglett, Peterson, Carriere, & Maneepun, 2005; Reungmaneepaitoon, Sikkhamondhol, & Tiangpook, 2006). Another, study determined that the enzyme, transglutaminase, improves the rheology of noodles containing only oat flour, egg albumin and vital wheat gluten (Wang, Huang, Kim, Liu, & Tilley, 2011).

Glycemic response

The glycemic index (GI) was developed as a guide to food selection in the early1980's by Dr. David Jenkins for people with diabetes. The concept was generated to offer a ranking system for carbohydrates contingent on their instant effect on blood glucose levels (Arvidsson-Lenner et al., 2016; Jenkins et al., 2002; Venn & Green, 2007). Hence, the faster the food can raise the blood glucose levels, the greater the GI of the food. A GI classification system, ranging from 0-100, foods are characterized as having low (<55), medium (55–69) or high GI (>70) (Venn & Green, 2007). Jenkins provides a hypothetical drawing of the glucose absorption of a high and low GI food in the gastrointestinal tract and corresponding blood glucose response graph is shown in figure 1 (Jenkins et al., 2002). GI value of table sugar (glucose) is 100, while that of a slice white bread and whole grain bread are 72-76 and 73-77, respectively. Table one provides adopted information on GI for common foods (Atkinson et al., 2008).

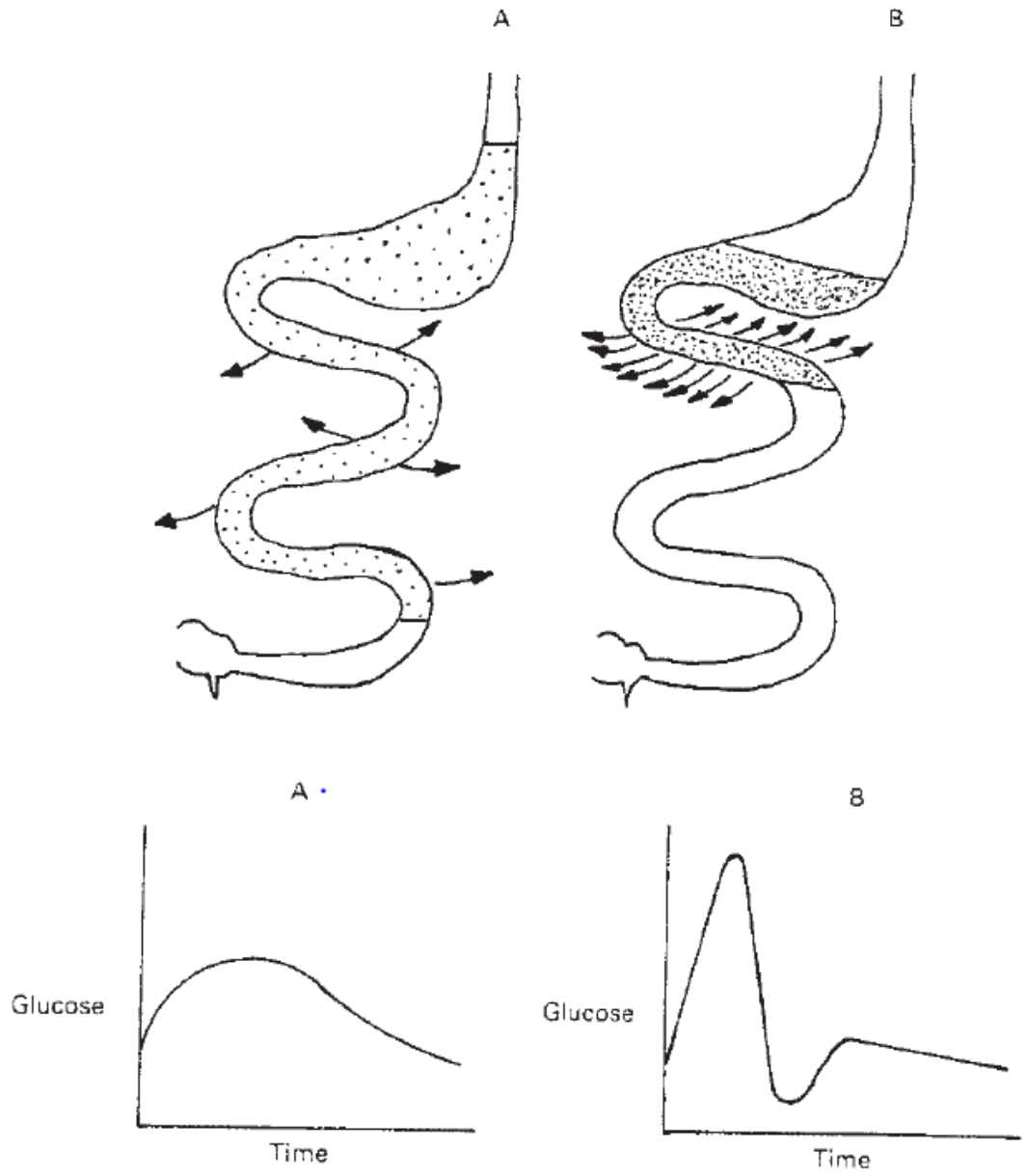


Figure 1. Hypothetical effect of feeding diets with a low (A) or high (B) glycemic index on gastrointestinal glucose absorption and postprandial blood glucose (Jenkins et al., 2002).

Table 1. Glycemic Index Values of common foods (Atkinson, Foster-Powell, & Brand-Miller, 2008).

High-carbohydrate foods		Breakfast cereals		Fruit and fruit products		Vegetables	
White wheat bread*	75 ± 2	Cornflakes	81 ± 6	Apple, raw†	36 ± 2	Potato, boiled	78 ± 4
Whole wheat/whole meal bread	74 ± 2	Wheat flake biscuits	69 ± 2	Orange, raw†	43 ± 3	Potato, instant mash	87 ± 3
Specialty grain bread	53 ± 2	Porridge, rolled oats	55 ± 2	Banana, raw†	51 ± 3	Potato, french fries	63 ± 5
Unleavened wheat bread	70 ± 5	Instant oat porridge	79 ± 3	Pineapple, raw	59 ± 8	Carrots, boiled	39 ± 4
Wheat roti	62 ± 3	Rice porridge/congee	78 ± 9	Mango, raw†	51 ± 5	Sweet potato, boiled	63 ± 6
Chapatti	52 ± 4	Millet porridge	67 ± 5	Watermelon, raw	76 ± 4	Pumpkin, boiled	64 ± 7
Corn tortilla	46 ± 4	Muesli	57 ± 2	Dates, raw	42 ± 4	Plantain/green banana	55 ± 6
White rice, boiled*	73 ± 4			Peaches, canned†	43 ± 5	Taro, boiled	53 ± 2
Brown rice, boiled	68 ± 4			Strawberry jam/jelly	49 ± 3	Vegetable soup	48 ± 5
Barley	28 ± 2			Apple juice	41 ± 2		
Sweet corn	52 ± 5			Orange juice	50 ± 2		
Spaghetti, white	49 ± 2						
Spaghetti, whole meal	48 ± 5						
Rice noodles†	53 ± 7						
Udon noodles	55 ± 7						
Couscous†	65 ± 4						
Dairy products and alternatives		**Legumes**		**Snack products**		**Sugars**	
Milk, full fat	39 ± 3	Chickpeas	28 ± 9	Chocolate	40 ± 3	Fructose	15 ± 4
Milk, skim	37 ± 4	Kidney beans	24 ± 4	Popcorn	65 ± 5	Sucrose	65 ± 4
Ice cream	51 ± 3	Lentils	32 ± 5	Potato crisps	56 ± 3	Glucose	103 ± 3
Yogurt, fruit	41 ± 2	Soya beans	16 ± 1	Soft drink/soda	59 ± 3	Honey	61 ± 3
Soy milk	34 ± 4			Rice crackers/crisps	87 ± 2		
Rice milk	86 ± 7						

Data are means ± SEM. *Low-GI varieties were also identified. †Average of all available data.

It is imperative to standardize GI testing process, and the international standardized procedure for the quantification of GI is defined in the 1998 FAO/WHO (Venn & Green, 2007). According to FAO and WHO, the GI is defined as the incremental area under the blood glucose response curve (IAUC) of a 50g of available carbohydrate serving of a test food expressed as a percent of the response to the same amount of carbohydrate from a standard food taken by the same subject (FAO/WHO, 1998). The GI is calculated using the following equation (Bechen, 2008):

$$GI = \frac{IAUC_{Test\ Food}}{IAUC_{Glucose}}\ x\ 100.$$

Available carbohydrates are calculated from the food's total carbohydrate content using the Association of Official Analytical Chemist (AOAC) method. The standard GI protocol requires 6 or more healthy subjects, a 10-12 hour overnight fast before the morning of consumptions of each standard/test food (FAO/WHO, 1998). Glucose or bread can be used as a reference food. For international standardization, it is advised that GI values should be calculated in relation to glucose (Wolever, 2001). A new standard food can be used in place of white bread or glucose. The GI of the standard food must be determined in relation to glucose or white bread. The standard food test must be repeated 3 times while the test food only needs to be tested once. Each food test must be tested on separate days in a random order (FAO/WHO, 1998). Blood glucose response can be determined using capillary blood or plasma glucose. Although, capillary blood is most popular and favored method because it is simpler to attain and the difference in responses among foods are greater and easier to distinguish statistically. The blood glucose response must be measured at intervals of 0, 15, 30, 45, 60, 90 and 120 minutes after consumption of test food (FAO/WHO, 1998).

In recent months, there has been some controversy relating to the application of GI. This primarily stems from the failure to acknowledge the insulin response, the high intra- and inter-subject deviations in glucose response to a food (biological variation, varying physical and chemical configuration of seemingly analogous foods and procedures of food preparation and consumption) and confusion when foods are mixed together in a mixed meal (Venn & Green, 2007). It can also be potentially misguiding as the GI does not take the energy density into consideration (Arvidsson-Lenner et al., 2016; Venn & Green, 2007; Wolever, 2001). For example, the GI for watermelon is higher than ice cream. Thus, inappropriately suggesting that ice cream is the better choice because energy density and total food quantity is not included in the parameters of this measurement (Venn & Green, 2007).

GI has many limitations. However, it may be appropriate to use for certain categories of carbohydrate-rich foods, containing at least 15g of carbohydrate per serving. Appropriate foods include grain-based foods such as pasta, rice, bread, breakfast cereals and potatoes. Thus, noodles fit well into this class of foods for GI tests. Comparison of GI should be restricted to foods within the same food group (Arvidsson-Lenner et al., 2016). An example of a useful application could be consumers with diabetes using the GI to determine which loaf of bread, containing similar nutrient composition, to buy at the grocery store. There is much evidence that shows that low GI foods improve blood glucose control in diabetes (Wolever, 2001). Additionally, low GI diets have been commonly advised for the prevention of chronic diseases such as cancer, obesity, heart disease, diabetes, and in the regimen of cardiovascular risk factors, particularly dyslipidemia (Venn & Green, 2007). High GI foods can elevate insulin levels

and result in intensified hunger, which consequently, encourages higher caloric consumption and storage as body fat (Bechen, 2008).

Glucose is a monosaccharide. It generates a large glycemic response and is frequently used as the reference food and designated a GI of 100. Some polysaccharides may generate a large glycemic response when ingested in a serving size consisting of 50g available carbohydrate because of accelerated and almost complete digestion and absorption in the small intestine. For example, such polysaccharides exist in instant potato. Adding protein, fat, resistant starch, dietary fiber and antioxidants in carbohydrate encompassing foods can decrease the overall GI (Venn & Green, 2007). Whole-grains, when largely intact, have been found to lower GI. Fortifying refined grain-based foods with other grain flours such as oats and DDG may improve the GI.

To the best of our knowledge, there are only two studies that have looked at the glycemic response to DDG. One study measured the glycemic response of DDGS in solution at different concentrations and the other used DDG in pita bread in various concentrations. Both studies found that the higher the DDG fortification resulted in the lower glycemic responses in test subjects (Alrayyes, 2018; Bechen, 2008). Several studies have shown that whole oats and components of whole oat result in low glycemic response. One study incorporated beta glucan-oat bran in noodles and estimated the glycemic index. These workers found that noodles with oat beta glucan had a lower glycemic index (Q. Hou et al., 2015). Powell and coworkers have provided a valuable list of over 1,300 GI values of various foods. An excerpt from these tables of various kinds of noodles and pastas with ingredient variations are provided in Appendix A (Foster-Powell,

Holt, & Brand-Miller, 2002). A detailed list of journals specific to GI is provided in the Appendix B. Based on the review of the literature the following objectives were outlined.

OBJECTIVES

To fortify wheat-based products particularly those that use refined wheat flour with other grains and grain products such as DDG and oats.

To determine the effects of nutrient enhancement in wheat-based products using DDG and oats.

To develop a high-protein and high-fiber wheat-based noodles employing oat-wheat flour blends, DDG-wheat flour blends and oat-DDG-wheat flour blends.

To measure the consumer sensory acceptability of the wheat-based noodles containing DDG and oats.

To determine the glycemic response and compare the glycemic response human subjects to consumption of oat flour enriched and DDG enriched noodles.

HYPOTHESIS

1. H0: There is no nutritional differences between the wheat-based noodles and the oat and DDG-fortified wheat-based noodles.

   H1: There is a nutritional differences between the wheat-based noodles and the oat and DDG-fortified wheat-based noodles.

2. H0: High-protein and high-fiber fortified wheat-based noodles are acceptable to a sensory panel.

   H1: High-protein and high-fiber fortified wheat-based noodles are not acceptable to a sensory panel.

3. H0: There is no textural and food functional differences between oat-wheat noodles, DDG-wheat noodles and the all-wheat control noodle.

H1: There is a textural and food functional differences between oat-wheat noodles, DDG-wheat noodles and the all-wheat control noodle.

4. H0: There is no differences in consumer acceptability of wheat noodles and oat and DDG-fortified wheat-based noodles.

   H1: There is a differences in consumer acceptability of wheat noodles and oat and DDG-fortified wheat-based noodles.

5. H0: There is no differences between the glycemic response to wheat noodles compared to the wheat-based noodles fortified with DDG and oats.

   H1: There is a differences between the glycemic response to wheat noodles compared to the wheat-based noodles fortified with DDG and oats.

6. HO: There is no differences between glycemic response of oat fortified and DDG fortified noodles.

   H1: There is a differences between glycemic response of oat-fortified and DDG-fortified noodles.

CHAPTER 3. MATERIALS AND METHODS

Oats and DDG were incorporated in a wheat-based Asian noodle product. The noodles were subjected to sensory analysis through triangle and pair test. The chemical analysis was performed on the noodles and the flours. The results from the chemical analysis of the noodles were used to determine how much noodles were need for glycemic testing by calculating the available carbohydrates. Glycemic response of the participants was tested using a glucometer. This overview of this experimental design is shown in figure 2 and 3.

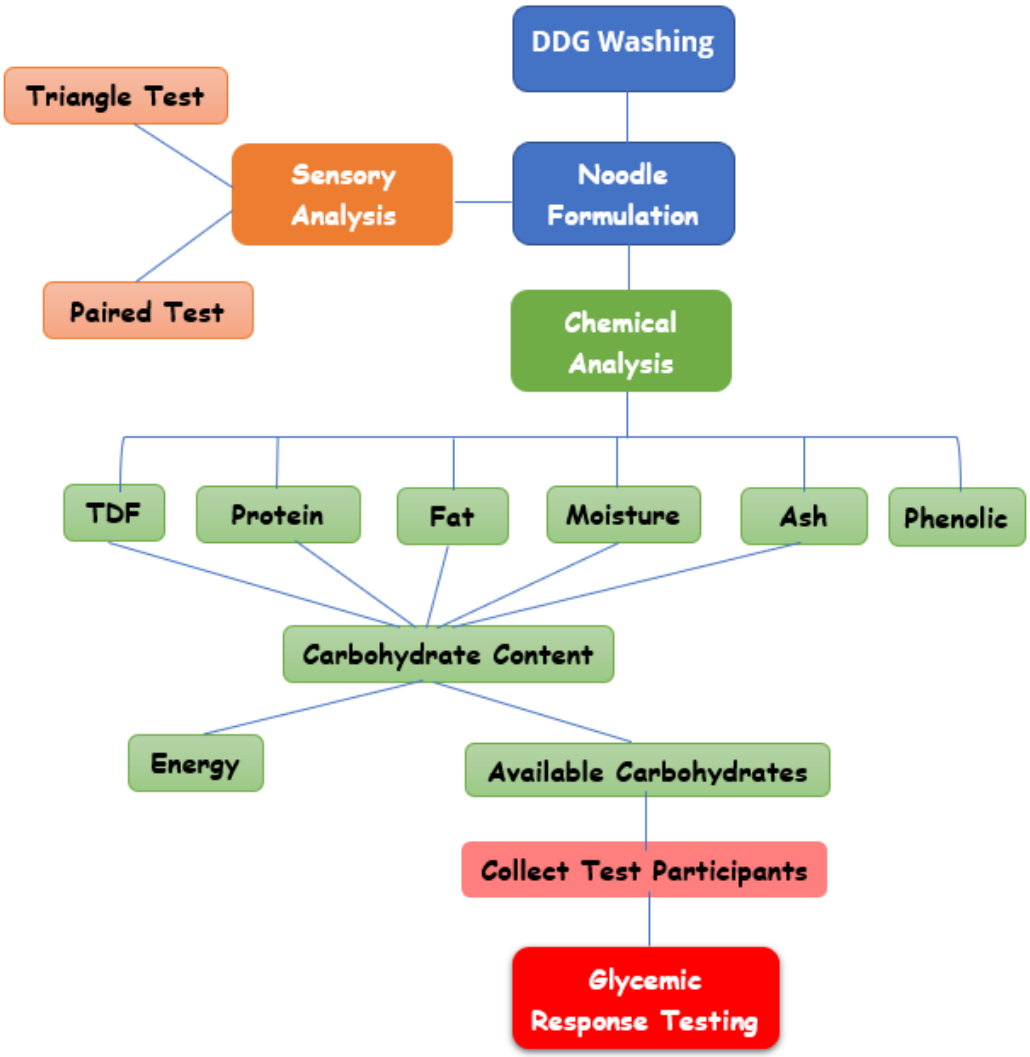


Figure 2. Experimental Design for food product development, nutritional analysis and glycemic response testing

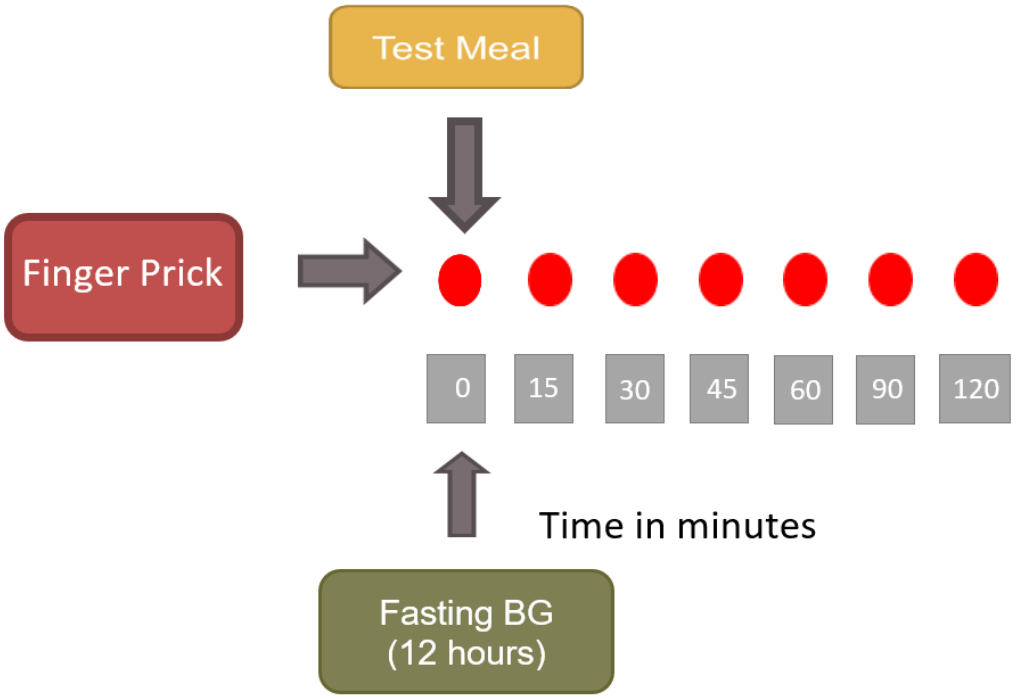


Figure 3. Graphic representation of Glycemic Response study for determination of effects of oat, DDG and wheat flour in noodles on blood sugar (Alrayyes, 2018).

Collections of Materials

Great Value All-purpose wheat flour (APF) was purchased from Walmart. Kauffman's Fruit Farm and Market bulk whole oat flour was purchased online from Amazon. The all-purpose flour was stored at room temperature in an air-tight plastic container. The oat flour was stored in a sealed plastic bag in the freezer. The distillers dried grains without solubles were collected from the commercial ethanol plant in Wentworth, South Dakota. The DDG was stored in plastic freezer bags in the freezer until further processing into FDDG.

Preparation of FDDG

The DDG collected from the ethanol plants was thawed to room temperature. Two kilograms of raw DDG was washed and de-fatted in a large bowl with 4L of ethanol solvent. After soaking for 2 hours with occasional stirring, the DDG was strained from the ethanol solvent using a #170 sieve. The DDG was then rinsed with 250ml of Ethanol in the #170 sieve. In a large bowl, an additional 1L of ethanol was added to the DDG and allowed to soak for 1 hour with occasional stirring. The ethanol was again strained from the DDG using #170 sieve and then rinsed with an additional 250ml of Ethanol. The washing of DDG was repeated by soaking DDG in 1L of ethanol for 1 hour, strained using a #170 sieve and rinsed with 250ml of ethanol 5 additional times shown in figure 4. A total of 2.5 gallons or 9 liters of ethanol was used to wash 2kg of DDG. After washing and defatting, the FDDG was spread out on baking sheets lined with aluminum foil and dried overnight. The dried FDDG was ground into a fine flour using a Retsch mill using a 0.25mm sieve at 20,000 rpm. The FDDG flour was placed in Mason jars and sterilized in an autoclave at 121°C for 15 minutes at 15 psi. The sterilized FDDG was transferred into freezer bags and placed in the freezer until further use.

(a)

(b)

(C)

Figure 4. FDDG washing process. (a) DDG soaking in ethanol during the first washing phase. (b) Straining ethanol from the DDG after soaking, done after each soaking. (c) DDG soaking in ethanol after several washing phases.

Flour Blend Preparation

Three different levels of flour replacements using enrichment ingredient oat and corn DDG were prepared (10%, 20% and (10%+20%)). The following flour blends were prepared in bulk: 10% oat 90% all-purpose wheat flour (APF), a 20% oat 90% APF, a 10% DDG 90% APF, a 20% DDG 80% APF, a 70% APF, 10% oat 20% DDG and a 70% APF 20% oat 10% DDG. The different flours were weighed, combined in a bowl and stirred together using a wire whisk and then blended together in a V-shaped lab scale blender (Patterson-Kelley, Harsco, East Stroudsburg, PA) for 45 minutes displayed in figure 5. Flours were stored in an air-tight container in the freezer until ready to use.

Figure 5. V-shaped lab scale blender (Patterson-Kelley, Harsco, East Stroudsburg, PA) for uniform and homogenous distribution of enrichment ingredients within flour.

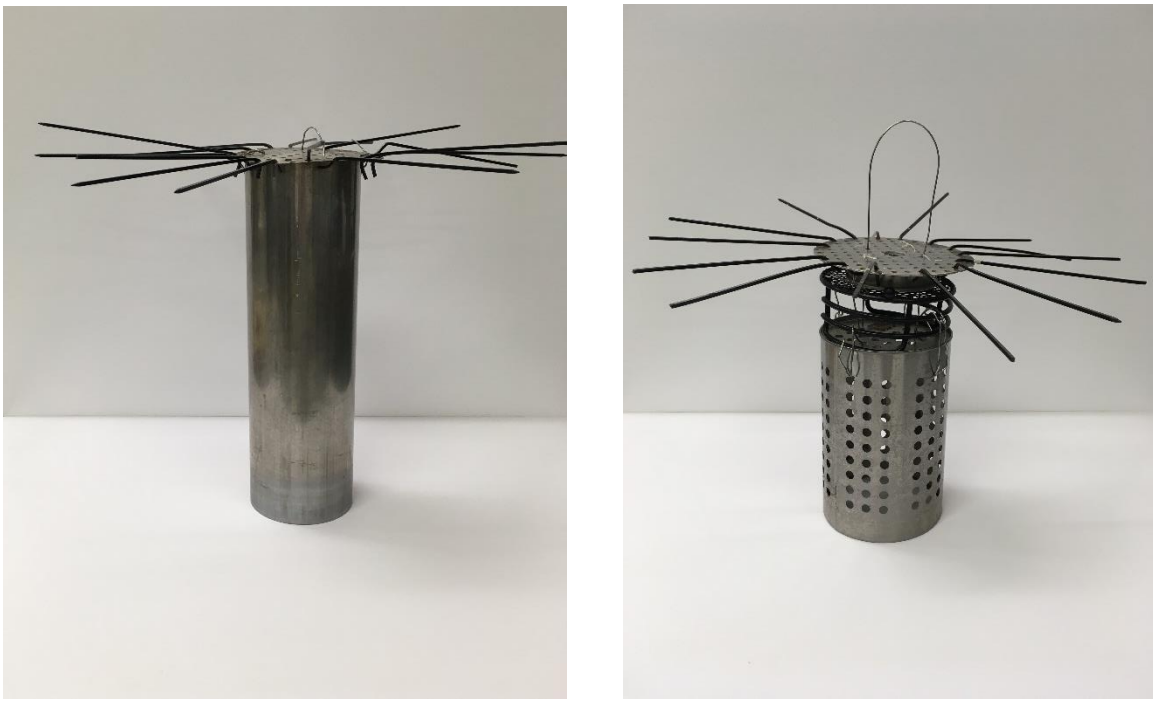
Noodle formulation

Noodles were prepared using all-purpose wheat flour(APF), FDDG, oat flour, salt and water. The quantities used are shown in table 2. Additional water may be needed to attain proper dough consistency. The methods described by K.D.P.P Gunathilake and Y.M.R.K. Abeyrathne (2008) were used in the noodle formulation and preparation (32). The salt was first dissolved in the warm water. The warm water was slowly added to the flour mixing at a medium/slow speed. The dough was mixed using a Kitchen NSF Certified Commercial Series 8 quart bowl lift stand mixer (model number KSM8990WH) with a flat beater attachment. The mixing process was completed by mixing/kneading the dough by hand. The dough was broken into 3 sections and was wrapped tightly with saran wrap and allowed to rest for a few minutes. Each dough section was taken out one at a time for sheeting to prevent the dough from drying out. The dough was first rolled out into a rectangular shape using a rolling pin. To sheet the dough an Imperia Pasta Presto Electric Pasta Maker was used. The dough sheets were obtained by feeding the rectangular dough through the rollers of a pasta machine starting on the thickest setting number 6 and working up each setting to the 2mm thickness, setting number 2. The 2mm thick dough sheets were cutting to 9-inch-long rectangles. The cut sheets were lightly coated with flour, stacked on top of each other and rapped in saran wrap to prevent drying. The dough sheets and allowed to rest for 30 minutes. After resting the dough was sheets were ran through the pasta maker on the number 3 setting once and then the number 2 setting three additional times. The dough sheets were cut into 5mm wide strips respectively using the fettuccini cutter on the pasta machine. The noodles were draped on the rods of a drying rack and placed in steamer at a low setting for 12 minutes.

Table 2. Formulation of noodles on a 100g basis

Ingredient	0% Control	10% FDDG	20% FDDG	10% Oat	20% Oat	70%W,20% D, 10%OF	70%W, 20%OF, 10%D
APF	100	87.6	78.1	87.6	78.1	68.3	68.3
FDDG	0	9.8	19.5	0	0	19.5	9.8
Oat flour	0	0	0	9.8	19.5	9.8	19.5
Salt	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Water	63ml	62ml	68ml	57ml	61ml	68ml	62ml

Steaming and drying tools were developed for this project and shown in figure 6. The steamed noodles were dried in the oven at 150°C for about 1 hour. Noodles were cooled for at least 30 minutes at room temperature. Noodles were placed in zip lock freezer bags and stored in the freezer until ready to cook. Figure 7 outlines the noodle processing steps.



(a) (b)

Figure 6. Both a and b were noodle hanging racks used in the steaming and drying stages of noodle preparation.

Figure 7. Graphic flowchart of the noodle making process.

Cooking of Noodles

Noodles were cooked for approximately 1 minute in boiling water.

Study Protocol

All tests were implemented in two separate occasions and samples were analyzed in duplicates for each test.

Chemical Analysis

Sample Preparation

Frozen noodles were thawed and then boiled for about 1min. Noodles were removed from boiling water and laid out on aluminum mesh sheets (Expert Grill Disposable Grill Topper purchased at Walmart). The aluminum mesh sheets were placed in a Fisherbrand Isotemp Forced Convection Oven at 60°C for about an hour until noodles were completely dry. The noodles were cooled for about 10 minutes. The dried noodles were ground into a fine powder using a Retsch mill using a 0.25mm sieve and operated at 20,000 rpm.

Moisture Content

The APF, FDDG flour, oat flour, and noodles before and after cooking were placed in a forced air convection oven for 3 hour at 103°C. The loss of water was used to calculate the moisture content according American Association of Cereal Chemistry (AACCI) oven drying method 44-15.02.

$$Moisture\ (\%) = \frac{100\ x\ (W2 - W3)}{W1}$$

where:

W1= original weight of the sample

W2= Initial weight of the aluminum dish + sample

W3= Final weight of the aluminum dish + sample

Fat Content

The fat content was determined using American Oil Chemists' Society(AOCS), Am 5-04 method using a machine called Ankom^{XT15}Crude Fat extractor (ANKOM Technology, Macedon, New York, USA). The machine extracted the crude fat using petroleum ether at 90°C for 60 minutes. Samples are sealed in special filter bags made of a polymetric material with a controlled porosity. The seal bags were pre-dried and placed in a sample holder and submerged and spun in petroleum ether in a sealed chamber for 60 minutes. The solvents high temperature (twice its boiling point) and elevated pressure in the sealed chamber accelerated the kinetic extraction. The fat content was determined by measuring the loss of mass after the extraction from the sample contained in the filter bag. The substances extracted were predominantly triacylglycerols and a small portion of lipids.

Fat extraction was achieved by the following methods. First, filter bags were labeled with pencil. Then, the weight of the empty filter bag and 1.5g to 2g of sample were measured and recorded. The initial weight of the sample with the filter bag was recorded as (W1). The mouth of the filter bags with sample were sealed shut with a heat sealer. Samples were pre-dried before extraction in a forced air convection oven at 103°C for 3 hours. The samples were removed from oven and directly placed in desiccant pouch to cool for 10 minutes at room temperature. The cooled filter bags were weighed and recorded as (W2). The moisture content was determined from the sample and bag weight after drying:

$$\text{Percentage Moisture (\%)} = \frac{(\text{Filter bag weight} + \text{sample weight}) - \text{weight after drying}}{\text{Sample Weight}}$$

Up to 15 bags were placed in the bag holder in the PTFE insert in the extraction vessel. The machine was set for 60 minutes at 90°C using petroleum either. Then, the machine automatically filled the extraction vessel with solvent, extracted the fat from the samples and recycled the solvent. The bags were removed from the bag holder and placed in oven for 30 minutes at 102°C to dry. The fat/oil remaining on the bottom of the extraction vessel was removed with a paper towel and discarded. Samples were then placed in desiccant pouch for 10 minutes to cool. The sample bags were weighed and recorded as (W3). The fat content was calculated using the using the following formula:

$$\text{Crude Fat (\%)} = \frac{W2 - W3}{W1} x\ 100$$

Where, W1= Original Weigh of sample

W2= Weight of pre-extraction dried sample and filter bag

W3 = Weight of dried sample and filter bag after extraction.

Protein Content

The nitrogen content of the flours and noodles was used to estimate the protein content according to the AACCI method 46-30.01 determined by a N/protein analyzer using a CE Elantech Flash EA 1112 (Lakewood, NJ). Samples were prepared for analysis by weighing 230-260mg in a tin capsule. Samples were placed in autosampler. The sample name, method, conversion factor and weights were selected and entered in the computer program. A conversion factor of 6.25 was used. Once the machine was started the auto sampler released each sample individually into reactor one within furnace one where the sample was combusted at 900°C in the presence of oxygen. In this process the samples CO_2, H_2O and N_2 gases were released. Helium carries the products through the

series of reactors, filters and columns to remove the unwanted gases. The gas mixture was reduced by passing through the second reactor filled with copper within furnace 2 at 600°C removing the oxygen. The remaining CO_2, H_2O and N_2 were carried by helium and passed through a series of 2 filters. First CO_2 was removed in the first filter filled with soda lime. Next, H_2O was removed in the second filter filled with molecular sieves and silica gel. Then, N_2 and helium passed through a gas chromatography column. The N_2 was quantified by the gas chromatography column and a thermal conductivity detector (TDC). The signal from TDC was converted to N_2 content. The following equation with a 6.25 conversion factor was used to calculate the percent protein.

$$\text{Protein}(\%) = \%\text{N X } 6.25$$

Ash

The ash content of the flours and noodles was determined by incinerating at 525°C for 12 hours in a muffle furnace using Box Furnace, 51800. The dry oxidation method according to the AACC 08-03 method was used to estimate the total inorganic mineral content.

$$\text{Ash } (\%) = \ ((\text{weight after ashing} - \text{weight of empty crucible})/(\text{orginal sample weight}) \ \text{x } 100$$

Total Dietary Fiber (TDF)

The non-digestible fibers in the flours and noodles will be estimated by enzymatic gravimetric method via a simplified modification of the AOAC 30-05.01 method. The Megazyme assay test kit was used. Where, 1g of sample was subjected to sequential enzymatic digestion using three different enzymes including thermostable α-amylase, purified protease and purified amyloglucosidase. A diagram of this procedure is depicted in figure 8.

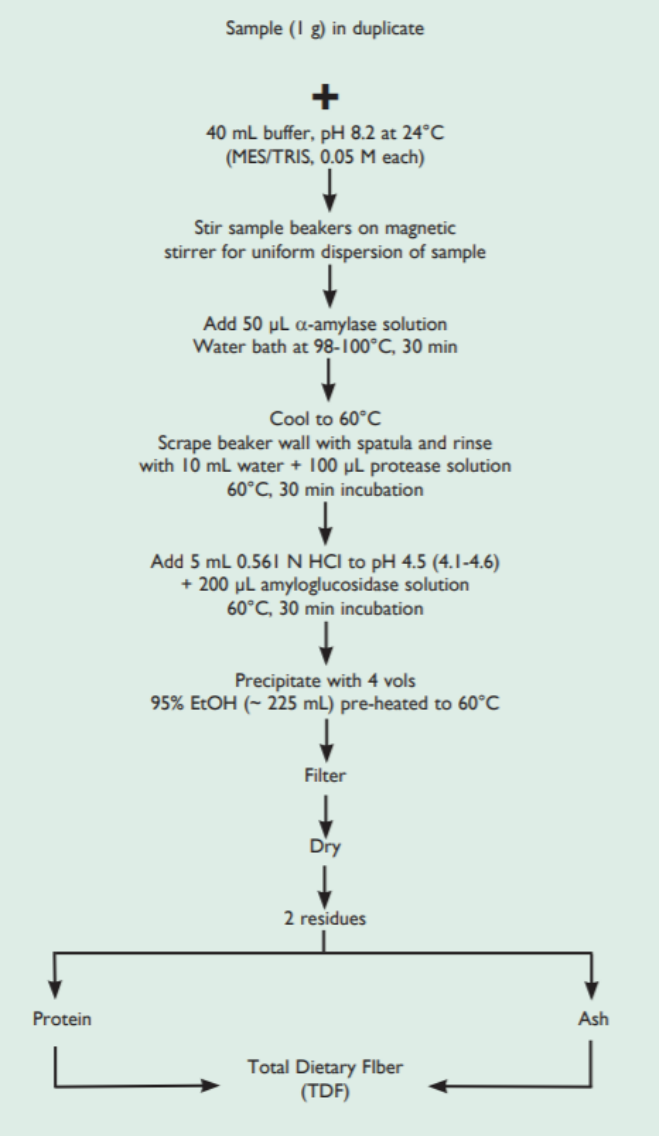


Figure 8. Analytical scheme for the total dietary fiber determination procedure.

Carbohydrate Content

The carbohydrates content of the flours and noodles were calculated utilizing the difference method according to the FAO.

$$Carbohydrate\ Content(\%) = \{100\% - (\%Protein + \%Fat + \%Ash + \%Moisture)$$

Energy

The caloric content per 100grams of flour and noodles will be calculated using the Atwater conversion factor (FAO) method.

$$\text{Energy (kcal/100g EP)} = \text{protein (g/100g EP)} \times 4 + \text{fat (g/100g EP)} \times 9 + \text{available carbohydrates (g/100g EP)} \times 4 + \text{dietary fiber (g/100g EP)} \times 2 + \text{alcohol (g/100g EP)} \times 7$$

Total Phenolic Content

The total phenolic content was determined using Folin-Ciocalteu and Gallic acid reagents following a modified spectroscopic method described by Singleton (Singleton, 1965). The modified method used was described by (Yu, Nanguet & Beta, 2013).

Determination of Glycemic or Available Carbohydrates

The available carbohydrates of the flours and noodles were calculated using the difference method according to FAO/WHO (33).

$$\text{Available Carbohydrate} = \{100 - (\text{Weight(g)} \times [\text{Protein} + \text{Fat} + \text{Water} + \text{Ash} + \text{Alcohol} + \text{Fiber}] \text{ in 100g of food})\}$$

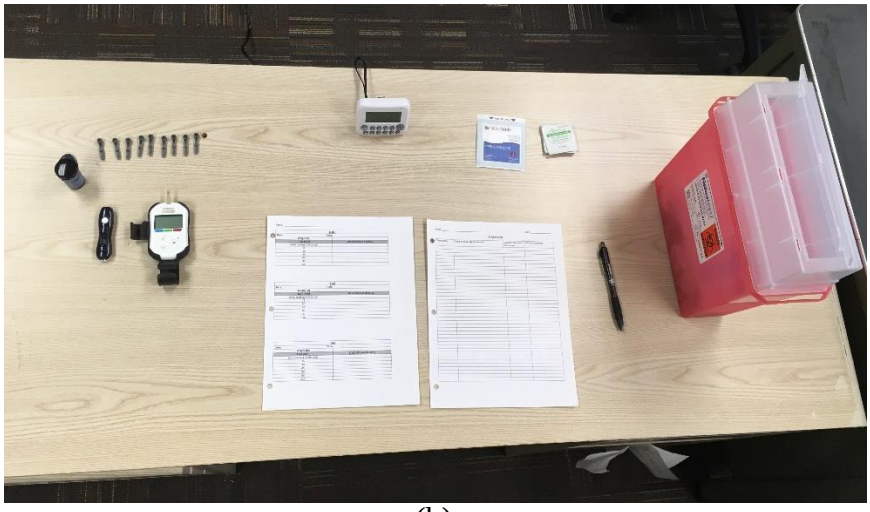
Measuring of Glycemic Response of Noodles

The international standard GI test protocol (ISO/FDIS 26642:2010 Food products—Determination of the glycemic index (GI) and recommendation for food classification conforms with procedures recommended by the Food and Agricultural Organization of the United Nations/World Health Organization fix (FAO, 1997). The glycemic responses of noodles was measured in healthy volunteers who signed a consent form and a pre-screening form shown in appendix C. Twelve test subjects with a BMI within normal range (calculated using height and weight), fasting blood glucose of 70-100mg/dL between the ages of 18-70 years were selected for the test. Tobacco users and those with chronic diseases were excluded from the study.

Participants were required to limit physical activity for 48 hours, avoid consuming alcohol 24 hours before testing, avoid consuming an abnormally large meal

the night before the testing, avoid abnormal/ new food the day before the test, fast for 12 hours prior to testing and must not consume any liquids 1 hours prior to testing. A 24-hour recall shown in appendix D was given prior to each test as a precautionary measure to determine participants last meal time Participants were asked to come in for testing first thing in the morning. The participants were given a portion of noodles containing 50g of available carbohydrates and 250ml of water to drink. Participants were required to consume both the water and all of the noodles within 8 minutes or less. Participants were fed 6 different test meals, over 6 separate days with at least 1-2 days in between each test. Participants were also fed the same control noodles on 3 separate days and a 250ml glucose tolerance beverage containing 50g of glucose on one other separate day. After ingestion of noodles or glucose beverage, capillary blood samples were collected from participants with a finger-prick test using a OneTouch Verio Flex lancet device and glucometer. Blood glucose levels were measured at 0, 15, 30, 45, 60, 90 and 120 minutes. The participants recorded their blood glucose readings in logs provided in Appendix E. Assessment of the postprandial glucose response will be established by calculating the incremental area under the curve (IAUC) as described by FAO (33).

(a)



(b)

Figure 9. Glucometer, consumables and glycemic test set up.

Calculating the Incremental Area Under the Curve

The IAUC was calculated individually for each test participant for each test. All blood glucose values taken during each test were used to help calculate the IAUC. The incremental area under the blood glucose response curves were calculated geometrically using the trapezoid rule, ignoring the area that falls below the fasting blood glucose value. The IAUC was calculated using excel.

Calculating the Glycemic Index

The GI for each test food was calculated using the mean IAUC for each test food. The glucose beverage was used as a reference food and the GI values were adjusted so that the GI of glucose equals 100. The following equation was used to calculate the GI:

$$GI = \frac{IAUC_{Test\ Food}}{IAUC_{Glucose}}\ x\ 100.$$

Sensory Analysis

A series of triangle tests and pair tests were used to evaluate the noodles by untrained panelists. The untrained panelists included 20 students and staff members at South Dakota State University and were recruited via word of mouth. Each panelist participated in two separate days of testing. Each day panelist were given two triangle test where they were asked to determine which one of the three samples was different. The panelist were also given two pair-test on each test day where panelist were given two different kind of noodles and asked to determine which sample they prefer. On the first test day the test 1-4 were given and on the second day test 5-8 were given. The test sheets are provided in Appendix F. Deferent code number were assigned to each sample in each test. A permanent marker was used to draw lines dividing sections on plates and label each section with is assigned code number. Three cooked noodles were placed in each section on the plate for sampling. Noodles were cooked for about 1 minute in boiling water. A few drops of olive oil was added to the noodles to prevent sticking. Noodles were cooked right before serving to panelist. Panelist were placed in paneling rooms with red lighting. Panelist were provided with a fork, a cup of ice water, saltine crackers, a pen and a test sheet. The test sheets included instructions and a place to write their response for each test. Panelist were also given verbal instructions before starting the test. Panelist were instructed to start by rinsing their mouths with ice water and a bite of a saltine

cracker before tasting each test sample. Panelist responded to the question after tasting each test sample. Test one was a triangle test where the panelist were given two different samples of 10% oat noodles and one sample of control noodle. Test two was another triangle test where panelist were given two separate samples of 20% oat noodles and one 10% oat noodle sample. Test three was a pair test where panelist were given a sample of control and 20% oat noodles. Test four was a pair test where panelist where given a sample of 10% oat noodles and 20% oat noodles. Test five was a triangle test where the panelist were given two different samples of 10% DDG noodles and one sample of control noodle. Test six was another triangle test where panelist were given two separate samples of 20% DDG noodles and one 10% oat noodle sample. Test seven was a pair test where panelist were given a sample of control and 20% DDG noodles. Test eight was a pair test where panelist where given a sample of 10% DDG noodles and 20% DDG noodles.

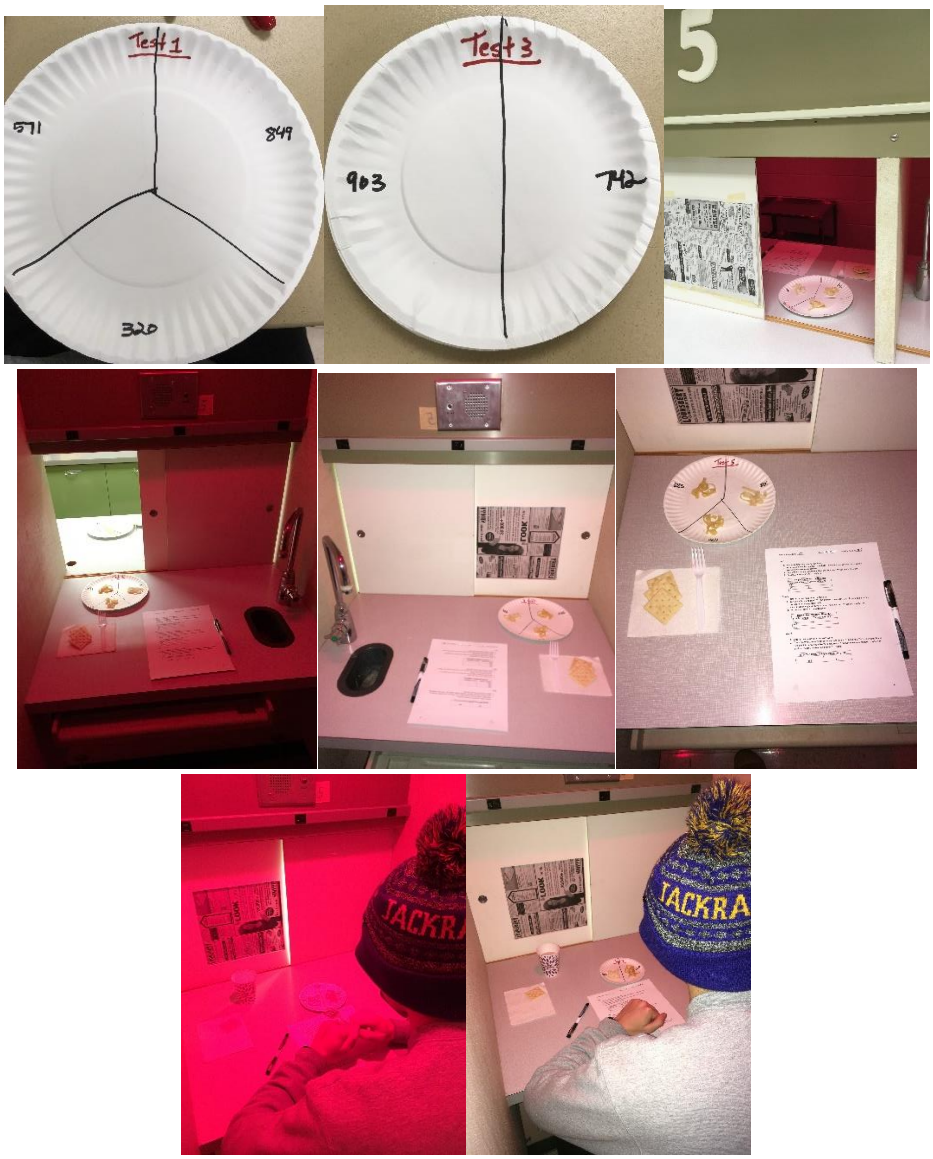


Figure 10. Sensory analysis set up.

Texture Analyzer

A TA.XT*Plus* Texture Analyzer was employed to test noodle texture through Texture Profile Analysis (TPA) according to the AOAC method P/0.5.

Raw noodles were randomly selected and broken into five 8.5cm in length. Noodles were cooked in boiling tap water for about 1 minute. Noodles were extracted from boiling water using a King Kooker Mesh Skimmer Utensil. With noodles still in the skimmer utensil noodles were then placed in ice water of about 4°C for 5 seconds. Noodles were then laid out on a paper towel for about 15 seconds. Noodles were transferred and placed side by side in the base plate. Noodles were compressed with a TA-47 W Pasta Blade (5-mm thickness flat blade) with a 5kg load cell. The pre-test speed was 1.00mm/sec, the test speed was 1.00mm/sec, the post-test speed was 1.00mm/sec, the target mode was set to strain, the compression strain was set to 70%, the time was 1.00sec, the trigger type was auto(force), and the trigger force was 5.0g. The average of four analysis per set of five noodles were calculated for each duplicate. The hardness, springiness, cohesiveness and resilience was determined with TPA.

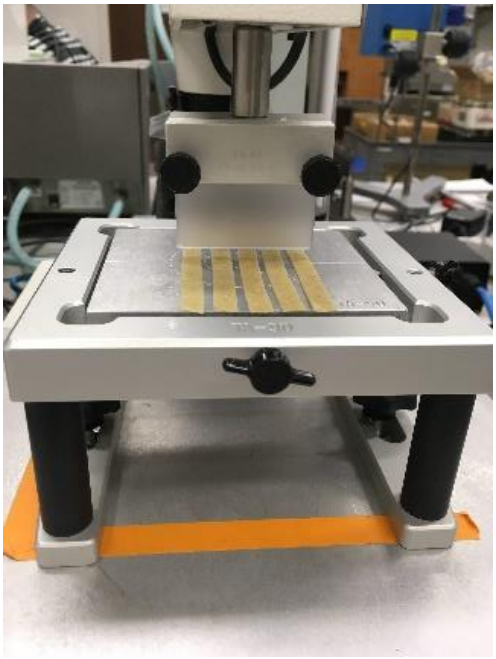


Figure 11. Texture analysis setup.

Color

The color of the raw noodles and the flours were measured using a Chroma meter (Konica Minolta CR-410, Japan). The granular materials attachment CR-A50 attachment was used. The raw noodles were taken out the freezer and broken into several small pieces and allowed to thaw for two hours before taking readings of the raw noodles. The *L, *a, *b values were recorded.

Figure 12. Chroma meter (Konica Minolta CR-410, Japan) and granular materials attachment CR-A50 attachment.

Water Activity

The water activity (aw) of the raw dried noodles and flours was measured using an AquaLab CX-2 (Decagon devices, Inc, Pullman, WA). The LiCL 8.57M check standard was used to check the devices before measuring samples. The raw noodles were thawed and broken into small pieces before placing in disposable cups.

Figure 13. Disposable cups with samples and Aqua lab CX-2 (Decagon devices, Inc, Pullman, WA).

Statistical Analysis

Data on physical properties, proximate composition and glycemic response were analyzed by Microsoft Excel (version 2016) and RStudio software (RStudio, 2015). Least Significant Difference (LSD) test was done to determine the means, standard deviation using ANOVA. To evaluate the significance level a p-value $< \sigma=0.05$ was as a rule of thumb. To examine the relationship between the nutrient composition and glycemic response the linear regression model also examined correlations between nutrients and for each nutrient, to determine R^2. Finally, a Person's Product moment correlation was also used to determine r for each nutrient composition and the glycemic response. All data analyzed and generated in RStudio were placed into tables and graphs using excel.

CHAPTER 4. RESULTS AND DISCUSSION

Proximate Analysis of Raw Ingredients

All-purpose wheat flour (APF), food grade DDG, and oat flour were all used as the main ingredients in developing the various treatment of noodles. The fat, protein, ash, moisture, Total Dietary Fiber (TDF), available carbohydrates, calories and Total Phenolic Content (TPC) were analyzed to help further understand how each flour contributed to the noodle nutrient composition and potential influence on blood glucose, noodle color, noodle sensory characteristics and noodle texture. The moisture content was analyzed using a forced air oven method. Crude Fat content was measured by petroleum ether extraction using an ANKOM fat extractor (ANKOM Technology, Macedon, New York). Protein content was measured by Nitrogen determination employing the Dumas combustion method and N% conversion factor of 6.25. Ash content was measured by incinerating samples at 500°C using a muffle furnace. TDF was measured using an enzymatic method (Megazyme TDF kit) using AOAC 30-05.01 method. Total phenolic content was measured using a spectroscopic method described by Singleton (Singleton, 1965). Available carbohydrates content was calculated by difference (100%-% protein -% moisture- % ash-%fat) and Total Calories was calculated using the Atwater conversion factor method.

Table 3 provides the physico-chemical properties of the three flours, namely wheat flour (APF) Food grade DDG (FDDG) and Oat Flour (OF), used in making the noodle treatments. Analysis of Variance (ANOVA) and LSD test results showed significant differences between each of the flours in relation to nutrient composition. Food Grade DDG was substantially higher in phenolic content, (TPC), protein content and TDF content in comparison to APF and oat flour. Due to the high fiber content and

previous fermentation pretreatment, FDDG had a low available carbohydrates content resulting in a lower caloric ingredient in comparison to APF and oat flour. FDDG had protein content and TDF content of 36.8% and 44.3%, respectively. Thus, protein and Fiber, together made up major proportion (81.1%) of the FDDG. In contrast, the oat Flour had a protein and TDF content of 14.4% and 11.6%, respectively. Wheat flour replacement with up to 10 to 20%, of either ingredient will therefore bring about significant changes in the intrinsic nutritional content of the new flour blends. Removal of 10 to 20% wheat flour removes corresponding and significant levels of wheat gluten proteins that could negatively influence the functionality of the resulting wheat-oat and wheat DDG flour blends.

FDDG, with 204 micrograms/gram of phenolic compounds, represented a significant and potent source TPC enrichment that could influence taste and acceptability of fortified products. The major phenolic compounds found in TPC of DDG primarily consist of ferulic, p-coumaric, sinapic and caffeic acids (Luthria, Liu, & Memon, 2012).

Table 3. Physico-chemical properties of Flours (dry basis) used as ingredients in noodle production.

Nutrients	**APF**			**FDDG**			**Oat Flour (OF)**		
	Mean %	**SD**		**Mean %**	**SD**		**Mean %**	**SD**	
Calories (kcal/100g)	343.82			202.72			348.15		
Total Phenolic µg/g	37.00	(±7.07)	c	204.00	(±1.41)	a	78.50	(±2.12)	b
Fat(%)	1.21	(±0.04)	c	4.23	(±0.09)	b	6.35	(±0.15)	a
Protein(%)	12.45	(±0.01)	c	36.77	(±0.10)	a	14.39	(±0.07)	b
Ash(%)	0.68	(±0.01)	c	1.62	(±0.01)	b	2.27	(±0.00)	a
Moisture(%)	11.41	(±0.08)	a	8.67	(±0.01)	b	7.01	(±0.27)	c
TDF(%)	3.47	(±0.12)	c	44.31	(±0.36)	b	11.62	(±0.24)	a
Available CHO(%)	70.78	(±0.08)	a	4.39	(±0.37)	c	58.35	(±0.28)	b
Total	100%			100%			100%		

TDF: Total Dietary Fibers, Kcal: Kilocalories, g: grams, CHO: Carbohydrates APF=All Purpose flour, FDDG=Food grade Distillers grains, and OF= Oat Flour. Means across rows with the same letter are not significantly different ($p \leq 0.05$)

Proximate Analysis of Noodles

Asian noodles were formulated employing varying proportions of the ingredients, namely the base wheat flour (APF) and oat flour (OF) and corn flours (FDDG)) that were reported in table 1. Food Grade DDG (FDDG), oat flour (OF) and all-purpose flour (APF) were formulated to yield wheat flours enriched with up to 30% employing oat and FDDG fiber sources. The flour blends included a Control (100% APF wheat), wheat flour blends containing 10% and 20% oat, 10% and 20% FDDG, and wheat flour blends containing 10% oat & 20 FDDG, and 20% oats and 10% FDDG. These represent a total of 7 blends, including the all-wheat control.

To determine the effects of fortification with oat flour and DDG in wheat flour, seven different instant Asian noodles were developed employing the blends described above. The fat, protein, ash, moisture, TDF, available carbohydrates, total phenolic content and calories of cooked noodles were analyzed chemically after drying the cooked noodles.

Table 4 provides the effects of fiber enrichment on the composition each of the 7 types of noodles (control, 10% oat, 20% oat, 10% DDG, 20% DDG, 70W:10D:20OF and 70W:20D:10OF noodles). ANOVA and LSD tests showed that there were significant differences between the types of noodle in relation to nutrient composition owing to the various fortification levels as well as the fiber source ($p \leq 0.05$). The nutrient composition of the control noodle reflected almost identical nutrient composition to APF. Losses in noodle production and cooking process were small since both fat and phenolic content were low to begin with.

Table 4. Effects of FDDG and Oat flour fortification on nutritional composition of cooked noodles. Comparisons are made on a dry weight basis.

Constituent	Control 100W	90W: 10OF	80W: 20OF	90W: 10D	80W: 20D	70W:10 D:20OF	70W:20 D:10OF
Fat(%)	0.55e	0.76d	0.89c	0.59e	0.83c	1.12b	1.47a
	(±0.01)	(±0.03)	(±0.00)	(± 0.03)	(± 0.03)	(± 0.05)	(±0.01)
Protein(%)	12.72g	13.2f	14.09e	15.04d	17.46b	16.18c	17.94a
	(±0.05)	(±0.05)	(±0.07)	(±0.00)	(±0.02)	(±0.03)	(±0.01)
Ash(%)	0.95c	0.88d	0.86de	0.98c	1.04b	1.09a	0.82e
	(±0.02)	(±0.02)	(±0.01)	(±0.01)	(±0.03)	(±0.03)	(±0.01)
Moisture(%)	6.95c	8.16c	7.13c	6.27d	6.17d	8.85a	8.82a
	(±0.07)	(±0.13)	(±0.13)	(±0.13)	(±0.01)	(±0.09)	(±0.01)
TDF(%)	3.38g	5.12f	6.95d	5.92e	12.77b	8.02c	14.39a
	(±0.01)	(±0.2)	(±0.20)	(±0.49)	(±0.26)	(±0.24)	(±0.23)
Available CHO(%)	75.46a	71.88b	72.00	71.20c	61.72e	64.73d	56.56f
	(±0.09)	(±0.04)	(±0.15)	(±0.56)	(±0.25)	(±0.29)	(±0.25)
Total Phenolic (µg/g)	30.50d	35.00d	46.00c	54.00c	90.50a	71.50b	92.50a
	(±3.53)	(±2.83)	(±2.83)	(±0.00)	(±2.12)	(±3.54)	(±6.36)
Calories (kcal/100g)	357.66	347.20	354.44	350.23	324.23	333.76	311.19
Amt. ser. TA/50g Av CHO	66.26	69.56	68.94	70.22	81.01	77.24	88.40

TDF: Total Dietary Fibers, Kcal: Kilocalories, g: grams, Amt.: Amount, ser.: served, TA: to achieve, Av: available CHO= Carbohydrates, [*Available CHO = 100 – (weight(g) of {Protein + Fat + Moisture + Ash + Fiber}x in 100g of noodles)*]; W= All-purpose wheat flour, D= DDG, DDG= distiller dried grains, OF=oat flour; Values represent mean blood glucose (mg/dl) with standard deviation in parentheses below in N=2 subjects. (Letter denotes significant difference between groups within the same row using LSD post hoc analysis ($p \leq 0.05$).)

All 7 types reported noodles in this study can be categorized as low fat according to the FDA requirements, as they are all contain less than 3% fat. All of the nutrients (fat,

protein, ash, TDF and total phenolic content) increased significantly relative to the control with increased concentrations of oat flour and DDG in the noodles. These increases were expected as DDG and oat flour are concentrated sources of these nutrients. The available carbohydrates and calories decreased correspondingly, which was also expected.

The 10% and 20% oat flour fortification rendered a protein content of 13.2% and 14.1%, respectively, in cooked noodle products. The control noodle with made of only all-purpose wheat flour contained a protein content of 12.7%. These increases in protein contents were statistically significant. Fortification of 10% and 20% DDG, delivered significant protein content increases that consisted of, 15.0% and 17.5%, respectively. The 30% wheat flour replacement with combinations of 10% and 20% oat and DDG brought about noodles having protein contents of 16.2% and 17.9%, respectively. In essence, fortification with oats and DDG significantly improved protein content in the noodles.

As DDG was richly endowed with phenolic compounds (TPC=202ug/g), 10% and 20% DDG noodles offered a TPC content of 54ug/g and 90.5ug/g. Oat flour contained a TPC of 78.50 ug/g.

Similarly, a total dietary fiber content of 44.3% in FDDG, when used as an enrichment medium, brought about correspondingly high TDF content in noodles (up to 14.4% TDF). Combining Oat flour and FDDG together in 30% APF replacement also resulted in noodles with high TDF content (8.02% and 14.4%). The Control All wheat noodles had the lowest TDF content (3.38% TDF).

There were higher observed cooking losses in DDG noodles and oat noodles compared to the control. Losses were observed during the processing, specifically during the steaming step, and when cooking the noodles. However, it appears that these losses did not significantly impact the nutrient composition of oat and DDG noodles when considering the estimated nutrient composition based on the flour content. One study reported cooking losses with an increase in oat flour levels in noodles. They suggested that this may be due to the disruption and weakening of the protein-starch matrix due to a decrease in gluten (Aydin & Gocmen, 2011). Similarly, another study that reported on the incorporation of chickpea flour in pasta, found a positive correlation in decline in production and cooking characteristics with an increase in protein content and fortification level (Sabanis, Makri, & Doxastakis, 2006).

Table 4 also shows the quantity of noodles needed to achieve 50g of available carbohydrate calculated based on their available carbohydrate content. These values were used in determining the weight of cooked noodles fed to test participants in the glycemic study.

Glycemic Response Study Demographics

Twelve individuals participated in the chemical study. A screening form was issued to each participant to collect information about participants and to determine if they met the inclusion and exclusion requirements. Table 5 displays the demographic information for each participant gleaned from the screening forms. Table 6 summarizes the gender-based demographics. Test subjects included a total of 9 females and 3 males between the ages of 18-27, and the mean age was 22. The mean Basal Metabolic Rate (BMI) was 21.61 and ranged from 19.1 to 24.4. Participants were required to have a BMI

within the normal healthy range of 18.5-24.9. All participants met the inclusion and did not meet any of the exclusion requirements. Participants were required to fast for 12 hours prior to testing. A 24-hour diet recall was conducted immediately before each test to determine when participants last ate a meal. Screening forms are provided in Appendix C and the 24-hour diet recall log is provided in Appendix D.

Table 5. Demographics for each participant in the glycemic response study.

Participant	Gender	Race	Age	Height (cm)	Weight (kg)	BMI (kg/m^2)
1	Female	white	18	175.26	75.00	24.40
2	Female	white	20	172.72	59.09	19.80
3	Male	white	20	180.34	72.73	22.30
4	Male	Asian	21	180.34	77.27	23.70
5	Female	Black	27	154.94	50.00	20.80
6	Male	white	23	185.42	82.27	23.90
7	Female	white	20	172.72	63.64	21.30
8	Female	white	20	177.8	60.45	19.10
9	Female	white	26	160.02	52.27	20.40
10	Female	Asian	27	154.94	49.55	20.60
11	Female	white	20	162.56	57.27	21.60
12	Female	white	20	157.48	53.18	21.40
Average			21.83			21.61
Std. Dev.			±3.13			±1.67

Std. Dev.: Standard Deviation, BMI= Basal metabolic rate, BMI was required to be between 18.5-24.9.

Table 6. Gender- Based Demographic data of participants.

Gender	Num.	Age		Height (cm)		Weight (kg)		BMI (kg/m^2)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Male	3.00	21.33	(±1.25)	182.03	(±2.39)	77.42	(±3.90)	23.30	(±0.71)
Female	9.00	22.00	(±3.57)	165.38	(±9.20)	57.83	(±8.06)	21.04	(±1.49)

Num.: number of participants; SD: Standard deviation, BMI= Basal metabolic rate, BMI was required to be between 18.5-24.9.

Glycemic Response

The glycemic response is the measure of blood glucose in humans after ingestion of a food product typically measured at several different time intervals over a 2-hour time period. The blood glucose measurements taken for each food product represents the glycemic response. The incremental area under the curve (IAUC) is calculated geometrically using the trapezoid rule from information provided by the glycemic response curve. The IAUC measures the fasting blood glucose area under the curve excluding the area that falls below the fasting blood glucose value. The glycemic index is calculated using the IAUC of the test food and by dividing it by the IAUC for glucose and then by multiplying it by 100. The glycemic index value is used to understand how the response of 50g of available carbohydrates worth of glucose (the highest possible response) compares to 50g of available carbohydrates found in the food item. Thus, the lower the IAUC, the lower the glycemic index. The lower the IAUC and/or glycemic index the lower the overall blood glucose response was to the food item (FAO/WHO, 1998). The percent reduction is another way to show the difference between the how the test food glycemic index and glucose glycemic index compare.

To determine the effects of a control noodle and 6 different fortified noodles on the glycemic response and glycemic index, a total of 10 separate glycemic trials were conducted. All 12 subjects participated in each trial. One trial was conducted for each type and level of noodle fortification. Three separate trials were held for testing the Glycemic Response using the Control (100% APF). A 250ml beverage containing 50g of glucose was used to determine the glycemic response to this glucose dose. Portion sizes of uncooked noodles containing 50g of available carbohydrates were weighed out separately for each participant prior to cooking. These portion sizes are shown at the

bottom of table 2. Participants' fasting blood glucose was determined right before serving the noodles or glucose beverage. Noodles were served immediately after cooking. Participants were required to consume all of the noodles and 250ml of water within a time-period of 8 minutes. Blood Glucose readings were determined at 15, 30, 45, 60, 90 and 120min after the participants began to eat.

Table 7 provides the treatment effects resulting from the feeding trial involving 7 noodle treatments and glucose on the blood glucose readings at each time interval. There was no significant difference between fasting blood glucose values, 0 minutes, in all trails ($p=0.961 > 0.5$). There was a significant difference between noodle treatments at 15, 30 and 45 minutes ($p < 0.5$). However, in examining this data further, it is evident that there was a significant difference only between the glucose response and all the other treatments. At 60 minutes there was a no significant difference between glucose and 20% DDG but there was a significant difference between glucose and all other noodle treatments ($p= 0.1161 > 0.05$). There were no significant differences between noodle treatments at 90 minutes ($p= 0.3312 > 0.5$) and 120 minutes ($p=0.7991>0.5$).

To help further characterize the effect of each treatment on the glycemic response, the incremental glucose values were calculated. Table 8 provides the incremental blood glucose values and the original (absolute) blood glucose values from table 7. Figures 14 and 15 reflect the data shown in table 8. The IAUC was calculated and used to calculate the glycemic index. Table 9 summarizes the IAUC, the GI and the percent reduction for each trial.

Table 7. Table Glucose response (mg/dL) of subjects monitored at 15minute intervals for the first hour and 30-minute intervals for the second hour after consuming noodles from different treatments.

Treatment (T)	Time (minutes)													
	0		15		30		45		60		90		120	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Control	90.72a	(±7.73)	106.32b	(±12.19)	129.31b	(±13.81)	129.04b	(±21.04)	121.47b	(±20.91)	116.95ab	(±19.36)	105.02a	(±16.00)
90W:10OF	87.67a	(±6.29)	107.67b	(±12.55)	128.92b	(±16.11)	138.58b	(±26.96)	126.33b	(±29.28)	113.17b	(±17.52)	101.50a	(±13.49)
80W:20OF	89.47a	(±6.42)	113.82b	(±12.90)	135.31b	(±14.43)	134.90b	(±19.88)	124.92b	(±18.45)	111.81b	(±16.26)	105.04a	(±17.89)
90W:10DF	89.22a	(±6.30)	107.79b	(±13.98)	136.31b	(±19.55)	133.60b	(±25.44)	125.58b	(±25.20)	114.40ab	(±25.08)	108.14a	(±21.16)
80W:20DF	88.08a	(±8.16)	107.33b	(±13.28)	132.83b	(±26.87)	141.33b	(±27.64)	134.25ab	(±29.94)	119.75ab	(±27.10)	111.83a	(±17.07)
70W:10D:20O	87.11a	(±6.42)	103.92b	(±12.54)	135.56b	(±16.62)	128.31b	(±17.40)	117.61b	(±22.36)	108.72b	(±11.57)	100.58a	(±11.70)
70W:20D:10O	89.30a	(±8.32)	113.72b	(±15.52)	137.86b	(±18.32)	133.60b	(±22.14)	125.08b	(±22.31)	116.84ab	(±16.17)	104.06a	(±14.80)
Glucose	88.91a	(±9.87)	135.21a	(±20.26)	163.79a	(±27.93)	162.22a	(±31.36)	148.91a	(±32.67)	130.53a	(±29.95)	100.59a	(±29.23)

W= All-purpose wheat flour, D= DDG, O=oat flour; SD = Standard deviation; Values represent mean blood glucose (mg/dl) in *n*= 12 subjects; Letter denotes significant difference between groups within the same row using LSD post hoc analysis ($p \leq 0.05$).

Table 8. Absolute and incremental glucose response (mg/dL) of subjects monitored at 15 minute intervals for the first hour and 30 minute intervals for the second hour after consuming noodles from different treatments.

Treatment (T)	Time (minutes)													
	0		15		30		45		60		90		120	
	Abs	Inc	Abs	Inc	Abs	Inc	Abs	Inc	Abs	Inc	Abs	Inc	Abs	Inc
Control	90.72	0.00	106.32	15.60	129.31	38.59	129.04	38.32	121.47	30.75	116.95	26.23	105.02	14.31
90W:10OF	88.91	0.00	135.21	20.00	163.79	41.25	162.22	50.92	148.91	38.67	130.53	25.50	100.59	13.83
80W:20OF	87.67	0.00	107.67	24.35	128.92	45.84	138.58	45.43	126.33	35.44	113.17	22.33	101.50	15.57
90W:10D	89.47	0.00	113.82	18.57	135.31	47.08	134.90	44.38	124.92	36.36	111.81	25.18	105.04	18.92
80W:20D	89.22	0.00	107.79	21.00	136.31	47.92	133.60	51.83	125.58	40.75	114.40	28.67	108.14	21.00
70W:10D:20OF	88.08	0.00	107.33	17.72	132.83	46.19	141.33	43.61	134.25	33.50	119.75	23.61	111.83	16.81
70W:20D:10OF	87.11	0.00	103.92	24.42	135.56	48.56	128.31	44.30	117.61	35.78	108.72	27.54	100.58	14.76
Glucose	89.30	0.00	113.72	46.30	137.86	74.88	133.60	73.32	125.08	60.00	116.84	41.63	104.06	11.68

W= All-purpose wheat flour, DDG= distillers dried grains; D= DDG, O= oat flour; Abs= absolute Glucose (mg/dL) where absolute glucose are the mean glucose readings in *n*= 12 subjects; Inc = Incremental glucose (Abs_{0min} - Abs_{xmin} = *Incremental glucose)*; Where Inc represents the mean in *n*= 12 subjects.

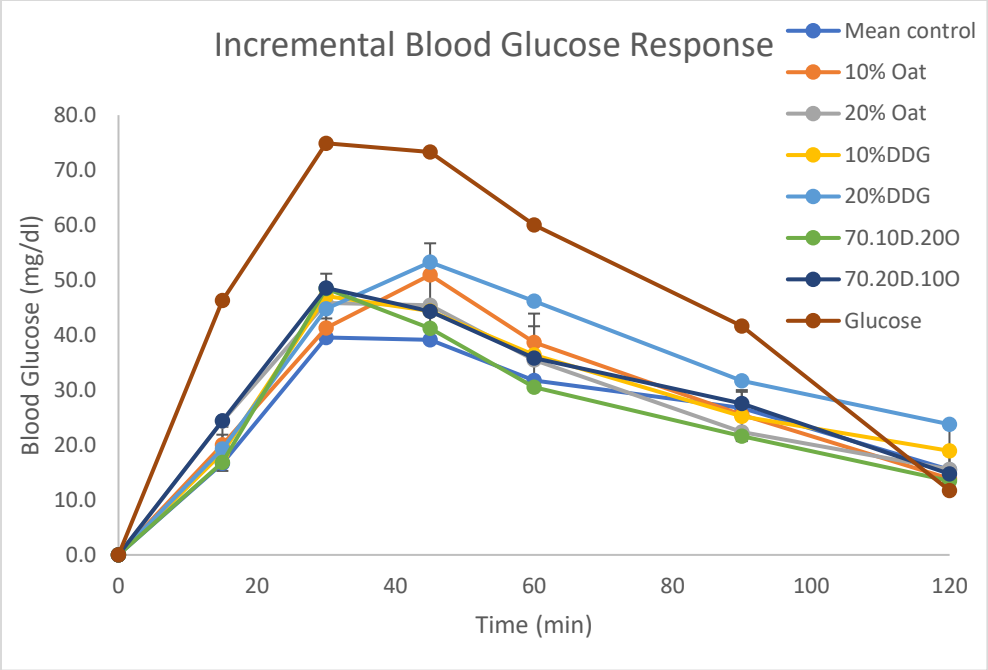


Figure 14. Incremental blood glucose responses in 7 different noodles and in 50g glucose beverage. W= All-purpose wheat flour, DDG= distillers dried grains; D= DDG, O= oat flour; Inc = Incremental glucose (Abs0min – AbsXmin = Incremental glucose).

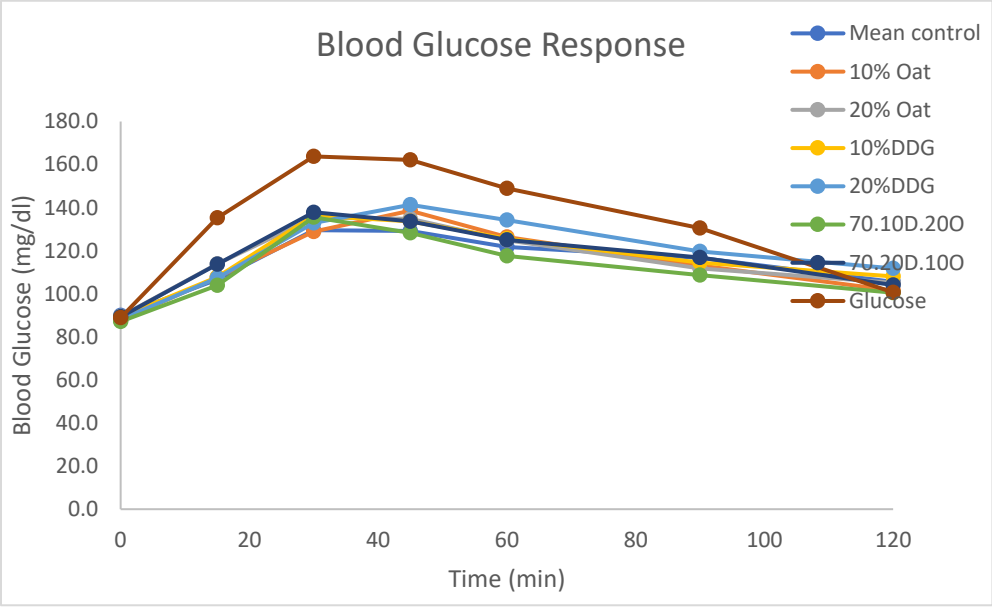


Figure 15. Blood glucose responses after consumption 7 different noodles and 50g glucose beverage. W= All-Purpose wheat flour, DDG= distillers dried grains; D= DDG, OF= oat flour (Each curve reflects the mean responses of twelve test subjects)

Table 9. Incremental Area under the Curve (IAUC) and Glycemic Index (GI,) each test noodle and 50g of glucose containing varied ratios of all-purpose wheat flour, distillers dried grains and oat flour.

Noodles	IAUC mg.min/dl	IAUC mmol.min/L	GI	Reduction%
Control	3188.35b	176.95	56	44.35
90W:10OF	3528.69b	195.83	62	38.41
80W:20OF	3440.48b	190.94	60	39.95
90W:10D	3546.84b	196.84	62	38.09
80W:20D	4110.79b	228.14	72	28.25
70W:10D:20OF	3156.97b	175.20	55	44.89
70W:20D:10OF	3614.76b	200.61	63	36.90
Glucose	5728.56a	317.92	100	0.01

W= All-purpose wheat flour, DDG= distillers dried grain, D= DDG, O=oat flour; IAUC: incremental area under the curve (measured by FAO method calculating area under the curve for triangles and trapezoid) represents means in *n*= 12; GI: glycemic index, [$GI = (IAUC_{tested\ food} / IAUC_{glucose}) \times 100$]; Reduction %= *(100-GI*); Letter denotes significant difference between groups within the same column using LSD post hoc analysis ($p<0.05$).

Table 9 provides the incremental area under the curve (IAUC) all of the treatments. As, shown in table 9, there was a significant difference between glucose IAUC and the treatment groups. This was expected as 50g of glucose should give the highest response possible for a serving of 50g of available carbohydrates. The IAUC of glucose and each test food were used to calculate the glycemic index (GI) of each noodle. Thus, the higher the IAUC, the higher was the GI. Noodles made with Control flour and the 70W:20D:10OF blend had the lowest GI values of 55 and 56, respectively. Surprisingly, noodles made with 20% DDG and those made with 70W:20D:10OF, had the highest GI values of 72 and 63, respectively, even though these two noodles had the highest fiber and protein content. It is not clear why these high fibers yielded the highest GI values.

To examine the relationship between the nutrient compositions and IAUC, linear regression test was run for each nutrient shown in table 10. There was an positive correlation between TDF and IAUC, where, r= 0.64 and R^2= 0.41. Likewise, there was a positive correlation between protein content and IAUC, where, r=0.55 and R^2= 0.30 and total phenolic content and IAUC, where, r=0.57 and R^2= 0.32. There was a negative correlation between carbohydrate content and IAUC, where, r= -0.49 and R^2= 0.24 and calories and IAUC, where, r= -0.50 and R^2= 0.25. There was no correlation between fat content and IAUC, where, r=0.07 and R^2= 0.004.

Table 10. Liner regression of IAUC and nutrient content.

Dependent Variables	Regression Equation	r	R^2	p-value
Calories	y = -0.5499x + 381.02	-0.5066	0.2566	0.06453
Carbohydrates	y = -1.2971x + 282.32	-0.487	0.2372	0.07738
Phenolic	y = 0.396x + 171.17	0.56505	0.3193	0.03525
TDF	y = 2.7882x + 172.41	0.64008	0.4097	0.01368
Fat	y = 3.625x + 191.72	0.06555	0.004297	0.8238
Protein	y = 4.7331x + 122.83	0.54754	0.2998	0.04269
Ash	y = -2.7057x + 197.49	-0.0151	0.00023	0.9591

Several studies have shown that whole oats and components of whole oat result in low glycemic response. One study incorporated beta glucan-oat bran in noodles and estimated the glycemic index of the noodles. The authors found that noodles with oat beta glucan had a lower glycemic index (Q. Hou et al., 2015). The results from this study reflected similar results when noodles were fortified with a combination of both 20% oats and 10% DDG the glycemic index was 55 in comparison the control noodle (GI=56). However, these results were not reflected in the glycemic index of noodles containing 20% oat (GI=60) and 10% oat (GI=62). In our current study, no statistically significant difference was determined between the glycemic index of the control and all other noodle treatments ($p \leq 0.5$).

Few studies have been done on the glycemic response and Distillers grains. As mentioned in the introduction and literature review, currently there are only two studies that have tested the glycemic response of DDG. In one study, the researchers fed 20g of DDG, whole flour and APF mixed with 20g water to 8 participants. The blood glucose of subjects was measured venously. The results showed that DDG had lower glycemic response then whole wheat flour and APF (Bechen, 2008). Another study measured the glycemic response of pita bread made with APF and APF fortified with both 10% and 20% chickpea flour and DDG as well as combinations of both 10% and 20% chickpea and DDG flour. The findings in this study also showed that fortified pitas had lower glycemic responses then the control. It was also shown that the higher the fortification of DDG and chickpea in pita bread the lower the glycemic response (Alrayyes, 2018).

The results in this study did not confirm the results of previous findings. This may be due to the small number of test subjects and replications in testing food products. It is

worth noting that all test implimented with glycemic response and DDG, were done on a small scale, with only a few subjects and test foods were only tested once. It should be noted that all glycemic test performed on DDG measured blood glucose using different methods and/or glucometers. Accuracy of handheld glucometers tend vary from glucometer to glucometer. The FDA requires glucometers to measure within ± 20mg/dL blood glucose in comparison to the standard laboratory method at least 95% of the time. A review found that studies testing accuracy of various brands of glucometers revealed a range of ±10mg/dL to ±30mg/dL of blood (Tonyushkina & Nichols, 2009).

It is common practices by most medical professions, consumers and scientist to assess the health quality of food products by their nutrient composition alone. However, composition does not fully characterize a food product because other properties such as the food structure are highly relevant when interpreting data on food behavior in the gut and its subsequent effects on postprandial metabolism. There is little knowledge of food properties in the digestive tract and nutrient bioavailability. This may result in a misunderstanding about gut function, metabolism and long-term health of food items. For example, the dietary fiber content of a food does not provide any information on the integrity of the food matrix, the physico-chemical characteristics of the dietary fiber or the subsequent physiological effects (e.g. transit time and glycemic response for starch-rich foods). Current methods of chemical analysis of dietary fiber, however, are not able to characterize the physical state of cell walls or provide any useful information on properties relevant to their impact on gut function and postprandial metabolism, other than providing data on fiber content (Grundy et al., 2016).

While there are limited number of studies on human testing with DDG there has been numerous studies on the digestibility of DDG in animals. There is a big interest in understanding the bioavailability of DDG fiber in farm animals (Council, 2018). Pigs and humans have been shown to have similar digestive tracts and pig metabolism and are often used for nutrition research (Lærke et al., 2014). About 96.5% of the total dietary fiber in DDG is insoluble. However, the apparent total tract digestibility ranges from 23 to 55%. Thus, a fraction of the fiber in DDG was digested and fermented to contribute to a significant quantity of calories when fed to pigs. It is not known if the residual starch content in DDG, which ranges from 3.8-11.4%, contributes to metabolizable energy as well. Readily degradable fiber may be partially degraded during the high temperature drying stages (>100°C) of DDG production (Council, 2018).

Food grade DDG goes through more extensive processing then DDG used as animal feed. After DDG is collected from the ethanol plant it must go through several of washing cycles using ethanol it then dried again, milled into a fine powder and autoclaved. These processes may have caused the fiber content in DDG to become even more bioavailable. All flours were exposed to physical abuse during mixing, kneading and rolling into fine sheets. They were also temperature abused during steaming of noodles (instantizing), drying with heat (150°F) and boiled during cooking. Perhaps the fiber in DDG has become more bioavailable after all the processing encountered from corn to noodle.

Color (L*, a*, b*) and Water Activity(a_w)

The color of dried uncooked noodles and that of flours blends used to produce the noodles was measure using the scale. Color measurements were taken using a Minolta

Chroma meter (Konica Minolta CR-410, Japan). Water Activity (a_w) was measured using the Aqual lab CX2 (Decagon devices, Inc, Pullman). The a_w instrument was calibrated with known standards and the temperature of the food products was recorded along with a_w measurements.

Table 11 shows the treatment effects, namely of different proportions of wheat (APF), corn FDDG) and oats (OF) ingredient flours, on the brightness (L*) , redness(a*) , yellowness (b*) values and a_w values of APF, DDG and oat flour as well as the control, 10% oat, 20% oat, 10% DDG, 20% DDG, 70W:10D:20OF and 70W:20D:10OF noodles. All flours had relatively high L* values (brightness), however, APF had the highest L* values and DDG had the lowest L* value. Control noodles (100% APF) yielded the highest L* values and 70W:20D:10OF had the lowest L* value. Oat flour had the highest a* value (redness) where as APF had the lowest a* value. Whereas, noodles containing 20% DDG produced the highest a* value and control had the lowest a* value. DDG tended to be more had the highest b* value (yellowness) and APF had the lowest yellow value. Similarly, 20% DDG had the highest b* value while control had the lowest b* value.

A_w of oat, wheat and corn DDG ingredients ranged from 0.29 to 0.37. Noodles that were processed and dried had a much lower range of A_w (A_w of 0.21-0.27) in comparison to the starting ingredients. All noodles had water activity levels of less than 0.3 which indicates the potential for extended shelf life.

Table 11. Treatment effects of the independent variables on the physical properties of All-Purpose flour, Distiller Dried Grain (DDG) and oat flour as well as dry uncooked noodles containing a variety of ratios of these flours (water activity and color)

	a_w		L*		a*		b*	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Flour								
APF	0.37a	(±0.00)	87.24a	(±0.01)	-0.63c	(±0.01)	7.84c	(±0.00)
DDG	0.34b	(±0.01)	70.78c	(±0.00)	-0.02b	(±0.00)	24.28a	(±0.00)
Oat Flour	0.29c	(±0.00)	75.01b	(±0.01)	0.96a	(±0.01)	11.90b	(±0.00)
Treatments (T)								
Control	0.23c	(±0.00)	69.79a	(±0.01)	0.70g	(±0.01)	16.51g	(±0.00)
90W: 10OF	0.24c	(±0.00)	64.40c	(±0.01)	1.93e	(±0.01)	19.10e	(±0.00)
80W: 20O	0.26b	(±0.00)	61.67e	(±0.00)	2.10d	(±0.01)	18.55f	(±0.00)
90W: 10D	0.26b	(±0.00)	66.06b	(±0.01)	1.22f	(±0.01)	21.56c	(±0.00)
80W: 20D	0.27ab	(±0.00)	62.13d	(±0.01)	2.98a	(±0.01)	25.38a	(±0.00)
70W: 10D: 20OF	0.27a	(±0.00)	61.23f	(±0.01)	2.17c	(±0.01)	21.25d	(±0.01)
70W: 20D: 10OF	0.21d	(±0.00)	61.19g	(±0.00)	2.84b	(±0.00)	24.54b	(±0.01)

Aw= Water activity; L*= Brightness; a* = Redness vs. greenness; b* yellowness vs blueness; W= All-purpose wheat flour, DDG= distillers dried grain, D= DDG, O=oat flour; Values represent mean values with SD=standard deviation of duplicates. Letter denotes significant difference between groups within the same column and section using LSD post hoc analysis ($p<0.05$).

Texture Analysis

The texture of each noodle cooked was measured using a TA.XT*Plus* Texture Analyzer with a TA-47W Pasta Blade attachment. A Texture Profile Analysis (TPA) protocol was used to determine various texture parameters such as hardness, springiness, cohesiveness and resilience of each cooked noodle. Hardness (or firmness) is the force needed to attain a particular deformation. Springiness is a measure of the elasticity of the noodle; where, the rate at which a substance that has been distorted resumes to its original shape. The cohesiveness measure of stickiness a product by the degree to which a product can be misshapen before it ruptures. The resilience is the capacity to bounce back after compressing by determining the absorb energy when it is compressed and to release this energy once the load is removed (Darly-Kindelspire, 2013).

Table 12 provides the treatment effects on hardness, springiness, cohesiveness and resilience values in each type of noodle. There was a significant difference between harness, cohesiveness and chewiness in noodles ($p<0.05$). The noodle hardness among all treatments ranged from 1,454.11g to 2,186.43g where the control noodle was the hardest and the noodle containing 70W:10D:20OF was the least hard. Cohesiveness ranged from 0.69 to 0.78% where control noodle had the lowest cohesiveness and 20% DDG noodle had the highest cohesiveness. Chewiness ranged from 983.59g to 1,171.94g where the 70W:10D:20OF had the lowest chewiness, the control noodle had the second highest chewiness of 1,360.43 and 70W:20D:10OF treatment had the highest chewiness. There was no significant difference between resilience with $p=0.0664> 0.05$ and springiness with $p=0.4165> 0.05$. While, there was no statistically significant difference between

treatments and resilience there mean values ranged from 50.01 to 58.74% where the control noodle had the lowest resilience and 20% DDG had the highest. Springiness ranged from 84.76 to 94.03% where the 20% oat noodle had the lowest resilience and 20% DDG had the highest. The springiness of 20% DDG, 10% DDG and 70W:20D:10OF was higher than the control noodle. The springiness of the 70W:10D:20OF, 10% oat and 20% oat were lower than the control noodle. The variability between treatments may have been significantly impacted by the inability to control the steam temperature. As, the steaming process was hard to regulate due to the steaming operation.

Table 12. Treatment combination effects of the independent variable on the textural properties of the cooked noodle treatments.

Treatment (T)	Hardness (g)		Resilience (%)		Cohesiveness (%)		Springiness (%)		Chewiness	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Control	2186.43a	(±148.61)	50.01c	(±0.90)	0.69c	(±0.01)	90.68ab	(±7.11)	1360.43ab	(±172.69)
90W:10OF	1563.21cd	(±127.85)	52.84bc	(±0.83)	0.75ab	(±0.01)	87.30ab	(±0.98)	1022.43c	(±63.10)
80W:20OF	1803.40bc	(±236.36)	51.72bc	(±1.79)	0.75ab	(±0.00)	84.76	(±5.91)	1140.99bc	(±62.02)
90W:10D	1510.18cd	(±110.08)	55.03ab	(±1.31)	0.75ab	(±0.02)	90.92ab	(±2.12)	1034.77c	(±79.96)
80W:20D	2027.83ab	(±131.85)	58.74a	(±3.71)	0.78a	(±0.03)	94.03a	(±2.24)	1491.94a	(±193.09)
70W:10D:20OF	1454.11d	(±122.84)	53.22bc	(±1.04)	0.76ab	(±0.01)	89.27ab	(±0.61)	983.59c	(±62.02)
70W:20D:10OF	1764.50bcd	(±106.02)	54.24abc	(±3.18)	0.74b	(±0.03)	90.71ab	(±2.95)	1171.94bc	(±13.96)

W= All-purpose wheat flour, D= DDG, DDG= distiller dried grian, O=oat flour; SD = Standard deviation; Values represent mean blood glucose (mg/dl) in *n*= 12 subjects; Letter denotes significant difference between groups within the same row using LSD post hoc analysis ($p<0.05$).

Sensory Analysis

To determine if consumer panelist could tell the difference between cooked fortified noodles and the control noodles containing only AFP, a series of 4 different triangle tests were carried out. In a triangle test, three randomly coded food products are provided to the panelist at the same time and the panelist is asked to identify the one dissimilar or odd product. Two of the products are the same even though they are labelled with different codes. In the four separate triangle tests, panelists were individually asked to differentiate between the following cooked noodle samples: control versus 10% oat, 10% oat versus 20% oat, control versus 10% DDG, and 10% DDG versus 20% DDG.

Figure 16 graphically illustrates the results of all 4 of the triangle tests. Thirteen out of 20 panelist could not tell the difference between control noodles and 10% oat noodles. Eleven out of 20 panelist could not tell the difference between 10% oat noodles and 20% oat noodles. Twelve out of 20 panelist could tell the difference between control and 10% DDG noodles. Eleven out of 20 pianist could tell the difference between 10% DDG and 20% DDG. In summary the panelist were not able to tell the difference between the control noodles and the 10% oat noodles or between the 10% and 20% oat fortified noodles. Whereas, the panelist could tell the difference between the control and the 10% DDG and between 10% and 20% DDG fortified noodles.

To gain insight on preference of noodle ingredients from a lay person perspective, a series of 4 different paired test were conducted. Figure 16 shows the results of each paired test. This test showed that more panelist preferred 20% oat over the control noodle. There was equal number of preference 10% and 20% oat noodles. Indicating that

both 10% and 20% oat fortification is accepted by panelist. More panelist preferred the control over 20% DDG. Most panelist preferred 10% DDG over 20% DDG noodles.

Overall, the results tell us that oat flour fortification was better received by the panelist. In general, panelists were not able to discriminate between the following: control and 10% oat noodles and 10% and 20% oat noodles. DDG on the other hand, was less well accepted by panelists. DDG fortification contributed to a noticeable difference in sensory perception and sensory scores.

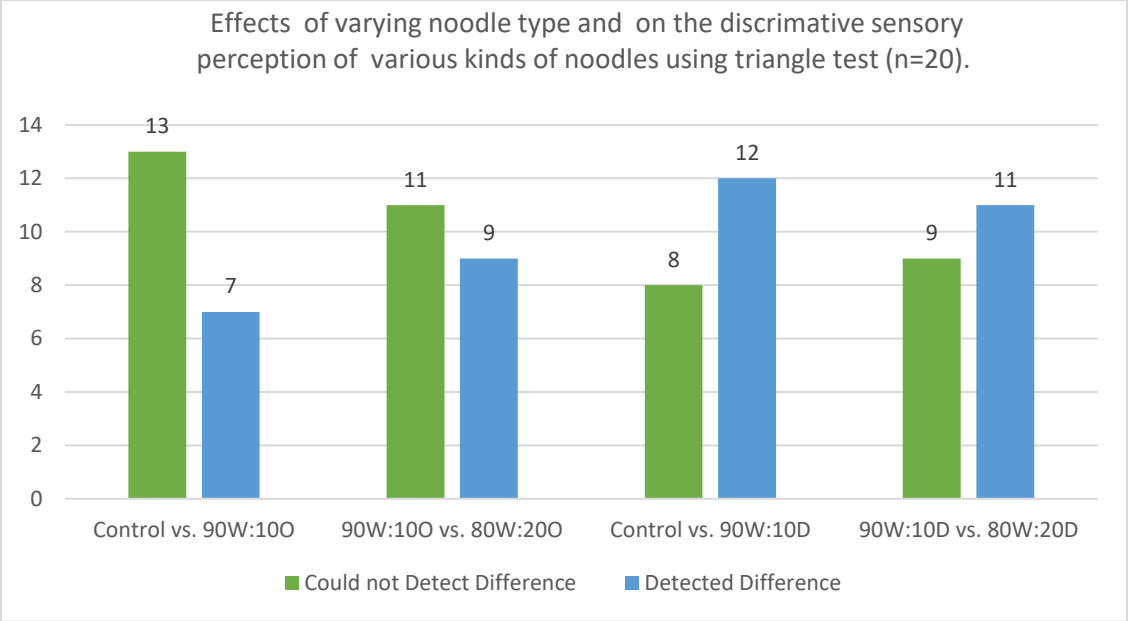


Figure 16. Results from 4 different triangle test with 20 lay panelists.

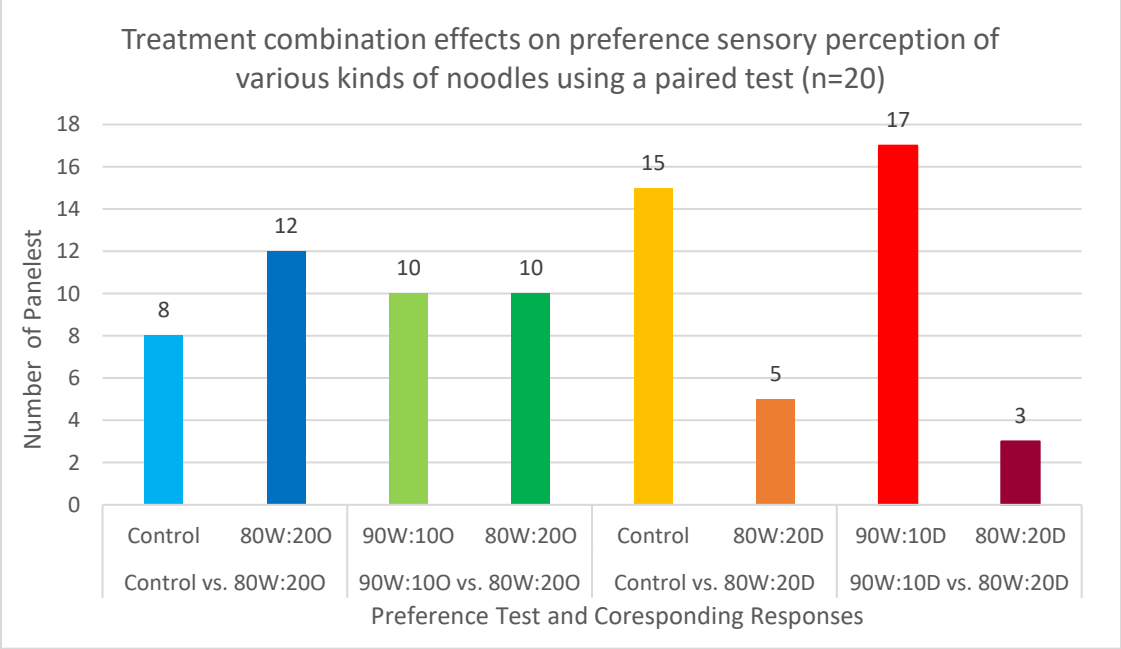


Figure 17. Results from 4 different paired test with 20 panelists.

CHAPTER 5. CONCLUSION

The global rise in preventable diseases and the increase in health-conscious consumers has resulted in a demand for low-calorie nutrient-dense food products. It is known that refined flours such as commonly used all-purpose wheat flours lack the majority of the desirable nutrients found in its original whole grain form. However, refined flours still dominate as an ingredient in the market due to its desirable processing properties, prolonged shelf life, desirable textural properties and its overall sensory acceptability by consumers. In efforts to address these issues oat flour and DDG were used to fortify of all-purpose wheat flour in the productions of instant Asian noodles. The nutrient composition, glycemic response, textural and sensory properties were then evaluated in an all wheat control noodle and 6 noodle types prepared with DDG and oat flour in various combinations.

DDG as a fortification agent in Asian noodle has proven to have a significant impact on the nutrient composition. DDG enrichment made significant improvement in fiber, protein, and total phenolic content, while also, lowering the calories and carbohydrate content in noodles. Similar results were seen with oat flour fortification as well. However, DDG's impact on nutrient composition was greater than oat flour.

Overall, fortification of noodle products did not statistically effect the glycemic response in contrast to the control. The 20% DDG fortification had the highest glycemic response with a GI of 72 and 70W:10D:20OF Noodles had the lowest GI of 55. The control surprisingly had the second lowest response with a GI of 56. 70W:20D:10OF had a GI of 63, 20% oat noodles yielded a GI of 60. Each of the noodles made with the 10% oat and 10% DDG had a GI of 62. There was an unexpected positive correlation between

TDF, protein, total phenolic compound and IAUC and negative correlation between calories, carbohydrates and IAUC. This meant that higher IAUC where achieved with higher TDF, protein and total phenolic compounds in the noodles. With the higher carbohydrate content and calories, however, the IAUC was lower.

The glycemic study suggests that perhaps the fortification of noodles with high fiber ingredients such as DDG and oat four are not appropriate for lowering the GI in instant Asian noodles food model. Further, using the nutrient composition as a way to predict the impact on instant Asian noodles may not be appropriate as they are subjected to considerable processing steps that may impact the structure of these nutrients, thus, impacting the bioavailability of some of these nutrients

The intensity of the brightness(L*), the redness (a*) and yellowness(b*) of raw noodles increased with increase in fortification level (of oat and DDG?) in comparison, to the control. The TPA texture analysis of cooked noodles showed that the fortified noodles were less hard, more resilient, more cohesive, less springy and less chewy then the control. The 20% DDG fortified noodles were chewier then the control. The overall sensory test showed that most lay consumers could not detect the differences in oat fortified noodles with higher fortification levels up to 20%. This suggests that oat fortified noodles may do well on the market. DDG in noodles was easily perceptible at all levels and panelist preferred the control over the DDG fortified noodles.

Overall, this study showed that DDG and oat flour are excellent ingredients for nutrient enchantment for products such as instant Asian noodle. This study also suggests DDG fortification is not an appropriate approach for lowering the glycemic response or improve the sensory attributes of instant Asian noodles. Similarly, oat fortification did

not have an impact on lowering the glycemic response. However, oat flour did improve the sensory acceptability of instant Asian noodles. Further, investigation on the impact of milling and processing as individual ingredients and in a complex food system on the bioavailability of DDG and oat phytonutrients may help our understanding of their behavior after ingestion and impact on metabolism.

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APPENDIX A: LIST OF GLYCEMIC INDEX VALUES OF NOODLES AND PASTAS

TABLE 1 *(Continued)*

Food number and item	GI[2] (Glucose = 100)	GI[2] (Bread = 100)	Subjects (Type and number)	Reference food and time period	Reference	Serving size	Available carbohydrate	GL[3] (per serving)
						g	*g/serving*	
498 White bread with skim milk cheese (Canada)	55	79 ± 10	Type 2, 6	Bread, 3 h	84	100	47	26
499 White bread with butter and skim milk cheese (Canada)	62	89 ± 9	Type 2, 5	Bread, 3 h	84	100	38	23
500 White and whole-meal wheat bread with peanut butter (Canada)	51	73 ± 6	Type 1, 6	Bread, 3 h	84	100	44	23
White and whole-meal wheat bread with peanut butter (Canada)	67	95 ± 9	Type 1, 6	Bread, 3 h	84	100	44	30
Mean of 2 studies	59 ± 8	84 ± 11	—	—	—	100	44	26
NUTRITIONAL-SUPPORT PRODUCTS								
501 Choice$_{dm}$, vanilla (Mead Johnson Nutritionals, Evansville, IN, US)	23 ± 4	33	Healthy, 7–10	Bread, 2 h	8	237 mL	24	6
502 Enercal Plus, made from powder (Wyeth-Ayerst International Inc, Madison, NJ, US)	61 ± 13	87	Healthy, 12	Glucose, 5 h[27]	90	237 mL	40	19
503 Ensure (Abbott Australasia, Kurnell, Australia)	50 ± 8	71	Healthy, 7–10	Bread, 2 h	8	237 mL	40	19
504 Ensure, vanilla (Abbott Australasia)	48 ± 3	69	Healthy, 10	Glucose, 2 h	UO[4]	250 mL	34	16
505 Ensure bar, chocolate fudge brownie (Abbott Australasia)	43 ± 3	61	Healthy, 10	Glucose, 2 h	UO[4]	38	20	8
506 Ensure Plus, vanilla (Abbott Australasia)	40 ± 4	57	Healthy, 10	Glucose, 2 h	UO[4]	237 mL	47	19
507 Ensure Pudding, old-fashioned vanilla (Abbott Laboratories Inc, Ashland, OH, USA)	36 ± 4	51	Healthy, 10	Glucose, 2 h	UO[4]	113	26	9
508 Glucerna, vanilla (Abbott Laboratories Inc, USA)[6]	31 ± 2	44	Healthy, 10	Glucose, 2 h	UO[4]	237 mL	23	7
509 Jevity (Abbott Australasia)	48 ± 3	69	Healthy, 10	Glucose, 2 h	UO[4]	237 mL	36	17
510 Resource Diabetic, French vanilla (Novartis Nutrition Corp, Young America, MN, USA)[6]	34 ± 3	49	Healthy, 10	Glucose, 2 h	UO[4]	237 mL	23	8
511 Resource Diabetic, Swiss chocolate (Novartis, Auckland, New Zealand)	16 ± 4	23	Healthy, 11	Glucose, 2 h	25	237 mL	41	19
512 Resource thickened orange juice, honey consistency (Novartis, New Zealand)	47 ± 9	67	Healthy, 11	Glucose, 2 h	25	237 mL	39	21
513 Resource thickened orange juice, nectar consistency (Novartis, New Zealand)	54 ± 7	77	Healthy, 11	Glucose, 2 h	25	237 mL	36	14
514 Resource fruit beverage, peach flavor (Novartis, New Zealand)	40 ± 8	57	Healthy, 11	Glucose, 2 h	25	237 mL	41	13
515 Sustagen, Dutch Chocolate (Mead Johnson, Bristol Myers Squibb, Rydalmere, Australia)	31 ± 4	44 ± 6	Healthy, 10	Bread, 2 h	UO[4]	250 mL	41	13
516 Sustagen Hospital with extra fiber, drink made from powdered mix (Mead Johnson, Australia)	33 ± 4	47 ± 6	Healthy, 10	Bread, 2 h	UO[4]	250 mL	44	15
517 Sustagen Instant Pudding, vanilla, made from powdered mix (Mead Johnson, Australia)	27 ± 3	38 ± 4	Healthy, 10	Bread, 2 h	UO[4]	250	47	13
518 Ultracal with fiber (Mead Johnson, USA)	40	55 ± 16	Healthy, 8	Bread, 2 h	UO[4]	237 mL	29	12
PASTA AND NOODLES								
519 Capellini (Primo Foods Ltd, Toronto, Canada)	45	64 ± 8	Type 1 and 2, 8	Bread, 3 h	1	180	45	20
520 Corn pasta, gluten-free (Orgran Natural Foods, Carrum Downs, Australia)	78 ± 10	111	Healthy, 10	Glucose, 2 h	UO[4]	180	42	32
521 Fettucine, egg								
Fettucine, egg	32 ± 4	46	Healthy, 7	Glucose, 2 h	91	180	46	15
Fettucine, egg (Mother Earth Fine Foods, Rowville, Australia)	47 ± 6	67	Healthy, 14	Glucose, 2 h	25	180	46	22
Mean of 2 studies	40 ± 8	57 ± 11	—	—	—	180	46	18
522 Gluten-free pasta, maize starch, boiled 8 min (UK)	54	77 ± 18	Healthy, 8	Bread, 2 h	18	180	42	22
523 Gnocchi, NS (Latina, Pillsbury Australia Ltd, Mt Waverley, Australia)	68 ± 9	97	Healthy, 8	Bread, 2 h	13	180	48	33

(Continued)

TABLE 1 *(Continued)*

Food number and item	GI[2] (Glucose = 100)	GI[2] (Bread = 100)	Subjects (Type and number)	Reference food and time period	Reference	Serving size	Available carbohydrate	GL[3] (per serving)
						g	*g/serving*	
524 Instant noodles								
Instant two-minute noodles, Maggi (Nestlé, Australia)	46 ± 5	66	Healthy, 8	Bread, 2 h	13	—	—	—
Instant two-minute noodles, Maggi (Nestlé, New Zealand)	48 ± 8	69	Healthy, 15	Glucose, 2 h	25	—	—	—
Instant noodles (Mr Noodle, Vancouver, Canada)	47	67 ± 8	Type 1 and 2, 10	Bread, 3 h	1	—	—	—
Mean of 3 studies	47 ± 1	67 ± 2	—	—	—	180	40	19
525 Linguine								
Thick, durum wheat, white, fresh (Sweden)	43	62 ± 11	Healthy, 10	Bread, 1.5 h	19	180	48	21
Thick, fresh, durum wheat flour, 0.6% (by wt) monoglycerides, boiled 8 min (Sweden)	48	68 ± 13	Healthy, 9	Bread, 2 h	92	180	48	23
Mean of 2 studies	46 ± 3	65 ± 3	—	—	—	180	48	22
Thin, durum wheat (Sweden)	49	70 ± 9	Healthy, 10	Bread, 1.5 h	19	180	48	23
Thin, fresh, durum wheat flour, 0.6% (by wt) monoglycerides, boiled 3 min (Sweden)	61	87 ± 13	Healthy, 9	Bread, 2 h	92	180	48	29
Thin, fresh, durum wheat with 39% (by wt) egg, (Sweden)	45	64 ± 11	Healthy, 10	Bread, 1.5 h	19	180	41	18
Thin, fresh, with 0.6% (by wt) monoglycerides and 30% (by wt) egg, boiled 3 min (Sweden)	53	76 ± 13	Healthy, 9	Bread, 2 h	92	180	41	22
Mean of 4 studies	52 ± 3	74 ± 5				180	45	23
526 Mung bean noodles								
Lungkow bean-thread noodles (National Cereals, Oils and Foodstuffs, Qingdao and Guangdong, China)	26	37 ± 6	Type 1 and 2, 9	Bread, 3 h	1	180	45	12
Mung bean noodles (Longkou bean thread), dried, boiled (Yantai cereals, China)	39 ± 9	56 ± 13	Healthy, 12	Glucose, 2 h	73	180	45	18
Mean of 2 studies	33 ± 7	47 ± 10	—	—	—	—	—	—
527 Macaroni								
Macaroni, plain, boiled 5 min (Lancia-Bravo Foods Ltd, Canada)	45	64 ± 8	Type 1 and 2, 13	Bread, 3 h	93	180	49	22
Macaroni, plain, boiled (Turkey)	48	69	Type 2, 52; type 1, 31	Glucose, 2 h	32	180	49	23
Mean of 2 studies	47 ± 2	67 ± 3	—	—	—	180	48	23
Macaroni and cheese, boxed (Kraft General Foods Canada Inc, Don Mills, Canada)	64	92 ± 5	Type 1 and 2, 9	Bread, 3 h	1	180	51	32
528 Ravioli, durum wheat flour, meat-filled, boiled (Australia)	39 ± 1	56	Healthy, 6	Glucose, 2 h	91	180	38	15
529 Rice noodles and pasta								
Rice noodles, dried, boiled (Thai World, Bangkok, Thailand)	61 ± 6	87 ± 9	Healthy, 12	Glucose, 2 h	73	180	39	23
Rice noodles, freshly made, boiled (Australia)	40 ± 4	57 ± 6	Healthy, 12	Glucose, 2 h	73	180	39	15
Rice pasta, brown, boiled 16 min (Rice Grower's Co-op, Australia)	92 ± 8	131	Healthy, 6	Bread, 2 h	48	180	38	35
Rice and maize pasta, gluten-free, Ris'O'Mais (Orgran Foods, Australia)	76 ± 6	109	Healthy, 9	Glucose, 2 h	UO[4]	180	49	37
Rice vermicelli, Kongmoon (National Cereals, Oils and Foodstuffs, China)	58	83 ± 5	Type 1 and 2, 9	Bread, 3 h	1	180	39	22
Spaghetti								
530 Spaghetti, gluten-free, rice and split pea, canned in tomato sauce (Orgran Foods, Australia)	68 ± 9	97	Healthy, 10	Glucose, 2 h	UO[4]	220	27	19
531 Spaghetti, protein enriched, boiled 7 min (Catelli Plus; Catelli Ltd, Montreal, Canada)	27	38 ± 4	Type 1 and 2, 13	Bread, 3 h	93	180	52	14
532 Spaghetti, white, boiled 5 min								
Boiled 5 min (Lancia-Bravo Foods Ltd, Canada)	32	45 ± 6	Type 1 and 2, 13	Bread, 3 h	93	180	48	15

(Continued)

TABLE 1 *(Continued)*

Food number and item	GI[2] (Glucose = 100)	GI[2] (Bread = 100)	Subjects (Type and number)	Reference food and time period	Reference	Serving size	Available carbohydrate	GL[3] (per serving)
						g	*g/serving*	
Boiled 5 min (Canada)	34	49 ± 7	Type 2, 11	Bread, 3 h	22	180	48	16
Boiled 5 min (Canada)	40	57 ± 8	Type 1, 6	Bread, 3 h	93	180	48	19
Boiled 5 min (Middle East)	44	63 ± 9	Type 1, 7	Bread, 3 h	22	180	48	21
Mean of 4 studies	38 ± 3	54 ± 4	—	—	—	180	48	18
533 Spaghetti, white or type NS, boiled 10–15 min								
White, durum wheat, boiled 10 min in salty water (Barilla, Parma, Italy)[12]	58	83 ± 16	Healthy, 8	Bread, 2.8 h	37	180	48	28
White, durum wheat flour, boiled 12 min (Starhushålls; Kungsörnen AB, Järna, Sweden)	47	67 ± 10	Healthy, 10	Bread, 2 h	19	180	48	23
White, durum wheat flour, 0.6% (by wt) monoglycerides, boiled 12 min (Sweden)	53	76 ± 12	Healthy, 9	Bread, 2 h	92	180	48	25
Boiled 15 min (Lancia-Bravo Foods Ltd, Canada)	32	46 ± 5	Type 1 and 2, 13	Bread, 3 h	93	180	48	15
Boiled 15 min (Lancia-Bravo Foods Ltd, Canada)	36	52 ± 7	Type 2, 7	Bread, 3 h	22	180	48	17
Boiled 15 min (Canada)	41	59 ± 11	Type 1, 4	Bread, 3 h	22	180	48	20
White, boiled 15 min in salted water (Unico, Concord, Canada)	44 ± 3	63	Healthy, 10	Glucose, 2 h	UO[4]	180	48	21
Mean of 7 studies	44 ± 3	64 ± 5	—	—	—	180	48	21
534 Spaghetti, white or type NS, boiled 20 min								
White, durum wheat, boiled 20 min (Australia)	58 ± 7	83	Healthy, 6	Bread, 2 h	48	180	44	26
Durum wheat, boiled 20 min (USA)	64 ± 15	91	Type 2, 3	Glucose, 3 h	9	180	43	27
Mean of 2 studies	61 ± 3	87 ± 4	—	—	—	180	44	27
535 Spaghetti, white, boiled								
White (Denmark)	33	47 ± 9	Type 2, 6	Bread, 3 h	94	180	48	16
White, durum wheat (Catelli Ltd, Montreal Canada)	34	48 ± 5	Type 2, 9	Bread, 3 h	38	180	48	16
White (Australia)	38	54 ± 13	Type 2, 10	Bread, 3 h	41	180	44	17
White (Canada)	42	60 ± 9	Type 2, 6	Bread, 3 h	30	180	48	20
White (Canada)	48	68	Diabetic, number NS	Glucose, time NS	20	180	48	23
White (Vetta, Greens Foods, Glendenning, Australia)	49 ± 7	70 ± 10	Healthy, 12	Bread, 2 h	UO[4]	180	44	22
White (Canada)	50 ± 8	71	Healthy, 6	Glucose, 2 h	3	180	48	24
Mean of 7 studies	42 ± 3	60 ± 4	—	—	—	180	47	20
536 Spaghetti, white, durum wheat semolina (Panzani, Marseilles, France)								
Boiled in 0.7% salted water for 11 min	59 ± 15	84	Healthy, 12	Glucose, 3 h	95	180	48	28
Boiled in 0.7% salted water for 16.5 min	65 ± 15	93	Healthy, 12	Glucose, 3 h	95	180	48	31
Boiled in 0.7% salted water for 22 min	46 ± 10	66	Healthy, 12	Glucose, 3 h	95	180	48	22
Mean of 3 cooking times	57 ± 6	81 ± 8	—	—	—	180	48	27
537 Spaghetti, whole meal, boiled								
Whole meal (USA)	32	46 ± 7	Type 2, 10	Bread, 3 h	41	180	44	14
Whole meal (Canada)	42 ± 4	60	Healthy, 6	Glucose, 2 h	3	180	40	17
Mean of 2 studies	37 ± 5	53 ± 7	—	—	—	180	42	16
538 Spirali, durum wheat, white, boiled to al denté texture (Australia)	43 ± 10	61	Healthy, 8	Glucose, 2 h	91	180	44	19
539 Split pea and soya pasta shells, gluten-free (Orgran Foods, Australia)	29 ± 6	41	Healthy, 9	Glucose, 2 h	UO[4]	180	31	9
540 Star Pastina, white, boiled 5 min (Lancia-Bravo Foods Ltd, Canada)	38	54 ± 6	Type 1 and 2, 13	Bread, 3 h	93	180	48	18
541 Tortellini, cheese (Stouffer; Nestlé, Don Mills, Canada)	50	71 ± 5	Type 1 and 2, 8	Bread, 3 h	1	180	21	10
542 Udon noodles, plain, reheated 5 min (Fantastic, Windsor Gardens, Australia)[6]	62 ± 8	43	Healthy, 10	Glucose, 2 h	UO[4]	180	48	30
543 Vermicelli, white, boiled (Australia)	35 ± 7	50	Healthy, 7	Glucose, 2 h	91	180	44	16

(Continued)

APPENDIX B: DETAILED LIST OF JOURNALS SPECIFIC TO GI

Glycemic Index and Response Sources Used in Literature Review

Category	Topic	Author	Title	Date
Glycemic	Overview	David Jenkins, Cyril Kendall, Livia Augustin, Silvia Franceschi	Glycemic index: overview of implications in health and disease	2002
Glycemic	Overview	BJ Venn and TJ Green	Glycemic index and glycemic load: measurement issues and their effect on diet–disease relationships	2007
Glycemic	Overview Carbs and health	Thomas Wolever	Carbohydrates and health—the FAO/WHO consultation	2001
Glycemic	General	Ragnhild Arvidsson-Lenner, Nils-Georg Asp, Mette Axelsen	Glycemic Index	2003
Oats	Glycemic Response	Hou, Qingtao, Li Yun, Li Ling	The Metabolic Effects of Oats Intake in Patients with Type 2 Diabetes: A Systematic Review and Meta-Analysis.	2015
Glycemic	Methods	Camille Adam Kouamé, Nestor Kouakou Kouassi, Jacko Rhedoor Abodo	Glycemic Responses, Glycemic Index, and Glycemic Load Values of Some Street Foods Prepared from Plantain (Musa spp., AAB Genome) in Côte d'Ivoire	2017
Glycemic	Methods	Adam C. Kouamé, Kouakou N. Kouassi, Yao D. N'dri and N'guessan G. Amani	Glycemic Index and Load Values Tested in Normoglycemic Adults for Five Staple Foodstuffs: Pounded Yam, Pounded Cassava-Plantain, Placali, Attieke and Maize Meal Stiff Porridge	2015
Glycemic	Methods FAO/WHO	FAO/WHO	Carbohydrates in human nutrition. (FAO Food and Nutrition Paper - 66)	1997
Glycemic	Methods	Franca Finocchiaro, Barbara Ferrari, Alberto Gianinetti	Effects of barley β-glucan-enriched flour fractions on the glycaemic index of bread	2011
Diabetes	Blood glucose	Leonor Corsino, MHS, FACE, Ketan Dhatariya, and Guillermo Umpierrez	Management of Diabetes and Hyperglycemia in Hospitalized Patients	2017
Statistics	Diabetes	Colin D. Mathers, Dejan Loncar	Projections of Global Mortality and Burden of Disease from 2002 to 2030	2006
Diabetes	Glycemic Response	Chinedum Ogbonnaya Eleazu	The concept of low glycemic index and glycemic load foods as panacea for type 2 diabetes mellitus; prospects, challenges and solutions	2016
Diabetes	Glycemic Response	Jane Cleary, Shelly Casey, Clare Hofsteede	Does a Low Glycemic Index (GI) Diet Cost More during Pregnancy?	2012
Glycemic Index	Method	F. Brouns, I. Bjorck, K.N. Frayn, A. L. Gibbs, V. Lang	Glycemic index methodology	2005

APPENDIX C: PRE-SCREENING FORM

HEALTH HISTORY QUESTIONNAIRE

Name Date / / Phone (H)

Date of Birth ___/___/___ Age____ Gender____ Ethnicity_____ (W)_____

Address (home)_____zip_____

_____.

email

♦♦

MEDICAL HISTORY

Self-reported: Height_____ Weight_____ Calculated BMI_____

What do you do for physical activity/exercise now?_____

How often do you exercise? _____ How long per week (hr)?_____

Are you currently on/following a diet?
Are you taking any vitamins or dietary supplements now? Y N
If yes, what are they?_____

Do you use Tabaco products?_____
Do you consume alcoholic beverages? _____
Do you have allergies? If yes, what are they? _____

Do you have any know food intolerances? If yes, what are they? _____

Do you have a family history of: Diabetes Obesity Cardiovascular disease None
Are you currently taking any medications: Y N

_____

Have you ever had any of the following? Please check all that apply.

HIV/AIDs		Cancer (specify type)	
Hepatitis	_____	High blood pressure	____
Diabetes (specify type)	_____	Biliary Disease	____
Cardiovascular condition		GI Disease	
Pulmonary Disorders	_____	Thyroid problems	____
Total cholesterol >200 mg/dl		HDL cholesterol <35 mg/dl	
LDL cholesterol >130 mg/dl	_____	Trigylcerides >150 mg/dl	____

Do you have the presence of disease or drug (s) which influence digestion and absorption of nutrients? (If uncertain please list)

_____

Do you currently take steroids, protease inhibitors or antipsychotics? Y N

Do you have any medical conditions which might make participation dangerous to you of affect the results? Y N ____

Indicate level of your overall health. Excellent ____ Good ____ Fair ____ Poor_____

Are you taking any medications, vitamins or dietary supplements now? Y N
If yes, what are they?____

Do you have allergies? If yes, what are they? _________________________

Do you have any know food intolerances? If yes, what are they? ___________________

Are you pregnant? Y N Are you currently think about getting pregnant? Y N

♦♦

Study Terms and Conditions

Any subject who cannot or will not comply with the experimental procedures or do not follow the guidelines cannot participate. Please check each of the following statements that you can comply with.

_____No exercise or vigorous activity within 24hr of each test date.
_____No alcohol, smoking or any tobacco use within 24 hours of each test date.
_____You must make sure that your last meal before each test day consists of foods that are not unusual in your diet or consume an abnormally larger quantity of food then you typically consume on a regular basis. For, example, eating curry or meat the night before when you typically do not or eating at a buffet or splurging and eating a whole large pizza.
_____You will have to have be capable of a 12 hour overnight fast before each test day (12 hours is the minimum).
_____You must be comfortable with having your finger pricked with a small needle.
_____You **must** be able to commit **2.5 hours** of your time in the morning **on 9 separate occasions** for testing

Pre-Glycemic Testing Values	
Date:	
Normal Blood Glucose	
Weight	
Height	

What kind of breakfast food do you like in the morning?
____

Schedule times:

If needed would you ever be willing to do a test on a weekend? Y N Maybe

2

APPENDIX D: 24 HOUR RECALL

Name:______________________________________ Date :___________________

24 Hour Recall

Time of Day	Food or Beverage Consumed	Quantity/Amount Consumed	Where Consumed

APPENDIX E: BLOOD GLUCOSE READING LOG

Name:_____

Trial 1-	
Date:	**Time:**
Weight (lb.)	
Time (min)	**Blood Glucose Reading**
Initial reading (0 Minutes)	
15	
30	
45	
60	
90	
120	

Trial 2-	
Date:	**Time:**
Weight (lb.)	
Time (min)	**Blood Glucose Reading**
Initial reading (0 Minutes)	
15	
30	
45	
60	
90	
120	

Trial 3-	
Date:	**Time:**
Weight (lb.)	
Time (min)	**Blood Glucose Reading**
Initial reading (0 Minutes)	
15	
30	
45	
60	
90	
120	

APPENDIX F: SENSORY TEST SHEETS

Test Participant ID #: _____ Date:_____ Paneling Room #:_____

Test 1

1. Before starting rinse mouth with water.
2. Taste samples numbered 320, 849 and 571. Have a few sips of water and a saltine cracker in-between each sample.
3. One of these samples is different than the other two. Which one is different?
4. Record your result in the data tables.

Triangle Test (Which is different?)	
Sample number	Same or different
320	
849	
571	

Test 2

1. Before starting rinse mouth with water.
2. Taste samples numbered 678, 950 and 421. Have a few sips of water and a saltine cracker in-between each sample.
3. One of these samples is different than the other two. Which one is different?
4. Record your result in the data tables.

Triangle Test (Which is different?)	
Sample number	Same or different
678	
950	
421	

Test 3

1. Before starting rinse mouth with water.
2. There are two cups with different samples labeled 903 and 742. Taste each sample and circle which sample you like the best below. (You may have a sip of water and bite of saltine cracker in-between samples if needed.)

Paired Test (circle/highlight sample you prefer)	
903	742

Test 4

1. Before starting rinse mouth with water.
2. There are two cups with different samples labeled 157 and 341. Taste each sample and circle which sample you like the best below. (You may have a sip of water and bite of saltine cracker in-between samples if needed.)

Paired Test (circle/highlight sample you prefer)	
157	341

Test Participant ID #: _____ Date:_____ Paneling Room #:_____

Test 5

1. Before starting rinse mouth with water.
2. Taste samples numbered 283, 801 and 411. Have a few sips of water and a saltine cracker in-between each sample.
3. One of these samples is different than the other two. Which one is different?
4. Record your result in the data tables.

Triangle Test (Which is different?)	
Sample number	Same or different
283	
801	
411	

Test 6

1. Before starting rinse mouth with water.
2. Taste samples numbered 702, 967 and 615. Have a few sips of water and a saltine cracker in-between each sample.
3. One of these samples is different than the other two. Which one is different?
4. Record your result in the data tables.

Triangle Test (Which is different?)	
Sample number	Same or different
702	
967	
615	

Test 7

1. Before starting rinse mouth with water.
2. There are two cups with different samples labeled 266and 459. Taste each sample and circle which sample you like the best below. (You may have a sip of water and bite of saltine cracker in-between samples if needed.)

Paired Test (circle/highlight sample you prefer)	
266	459

Test 8

1. Before starting rinse mouth with water.
2. There are two cups with different samples labeled 727 and 149. Taste each sample and circle which sample you like the best below. (You may have a sip of water and bite of saltine cracker in-between samples if needed.)

Paired Test (circle/highlight sample you prefer)	
727	149