The Glycemic Response to High Amylose Rice Study

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Table of contents

Acknowledgements

Table of contents

Chapter 1

Literature Review

Introduction

Dietary fiber

Resistant starch

Glycemic response: Glycemic index and glycemic load

Glycemic response and T2DM

Appetite, obesity, and T2DM

Type 2 diabetes mellitus prevalence in Hawaii

Rice intake in Hawaii

Rice as a high source of carbohydrate

Resistant starch and glucose and insulin response in healthy adults

Resistant starch and glucose and insulin control in T2DM

Resistant starch and appetite

Conclusion

References

Chapter 2

The glycemic response to high amylose rice study

Abstract

Introduction

Methods

Results

Discussion

Conclusion

References

Figures

Tables

Appendix

A. Glucose beverage limitation

B. Study visit materials

C. Literature review summary tables
Chapter 1

Literature Review
Introduction

Millions of people worldwide have been diagnosed with the chronic disease type 2 diabetes mellitus (T2DM) (Wild 2004). Patients with T2DM are afflicted with abnormally high blood glucose concentrations. Diets with a low glycemic index (GI) may help to attenuate blood glucose concentrations and reduce risk of T2DM. High GI diets can have the opposite effect. Obesity, a risk factor for T2DM, can be reduced by appetite control.

Dietary fiber has numerous health benefits, including blood glucose attenuation. Resistant starch (RS) is a type of dietary fiber, and is present in high amylose rice varieties. Numerous studies have found that intake of RS in solid foods, including rice, can improve postprandial blood glucose and insulin response in healthy adults. There have been a few studies on the effects of intake of RS in solid foods intake in adults with T2DM, but these studies have inconclusive findings. Also, current research on RS in solid foods and appetite is not yet well established. These studies will be discussed in detail.

The prevalence of T2DM in the state of Hawaii (HI) matches the overall prevalence of T2DM in the United States. White rice, a staple in HI, is a high GI food, contributing to a high GI diet. Therefore, an alternative rice variety for glycemic control, e.g. rice with RS, needs to be determined. The following literature review discusses the current research on RS, glycemic control, and T2DM.
**Dietary Fiber**

Classified as a carbohydrate, *dietary fiber* is comprised of “non-digestible carbohydrates that are intrinsic and intact in plants” (Institute of Medicine 2005). *Functional fibers* are “isolated, non-digestible carbohydrates that have been shown to have beneficial physiological effects in humans.” *Total fiber* consists of “the sum of dietary and functional fiber.” The term non-digestible is defined as the inability of the human small intestine to digest and absorb a nutrient (Slavin 2009).

It is recommended to consume dietary fiber daily. The Adequate Intake (AI) for dietary fiber is 38 g and 25 g/day for young men and women, respectively (Institute of Medicine 2005). The AI for dietary fiber is based on the intake level that was evident in studies to protect against coronary heart disease (CHD).

There are many different dietary fiber types, depending on chemical structure, with many different physical properties. Dietary fiber can be found in many foods, such as whole grains, fruits, vegetables, and legumes (Institute of Medicine 2005). Dietary fiber types can be classified as either viscous or non-viscous. Viscous dietary fibers, such as beta-glucans and gums, thicken when they are mixed with fluid (Dikeman et al. 2006). Due to their viscosity, transit time of viscous dietary fibers through the small intestine is delayed, and diffusion of digestive enzymes and absorption of nutrients are slowed (Dikeman et al. 2006, Lattimer et al. 2010, Kumar et al. 2012). Therefore, attenuation of blood glucose and cholesterol absorption can occur (Lattimer et al. 2010, Dikeman et al. 2006). In addition, gastric emptying can be prolonged after consumption of viscous dietary fiber (Dikeman et al. 2006). Viscous dietary fibers also can delay the emptying of the stomach, expanding the effective unstirred layer (Institute of Medicine 2005). Some
non-viscous dietary fibers result in fecal bulking. Viscosity and bulking both create a feeling of fullness and satiation (Institute of Medicine 2005, Slavin 2009). Therefore, dietary fiber can decrease food intake due to satiation (Slavin 2009). Some studies have shown that high dietary fiber intake may contribute to weight loss at intakes of 20-27 g of fiber per day (Slavin 2009).

Some fibers can be fermented by microflora in the large intestine (Kumar et al. 2012). Fermentable fiber provides substrates for short chain fatty acid (SCFA) production by the microflora (Dikeman et al. 2006). Short chain fatty acids have numerous health promoting effects. For example, the SCFA butyrate stimulates growth of healthy colonocytes (colon cells) (Gropper et al. 2009). Slowly or poorly fermented fibers can also improve bowel health, by promoting laxation, reducing colonic transit time, and increasing stool weight (Institute of Medicine 2005). Inulin is a fermentable fiber, and the fiber cellulose is poorly fermentable.

Because the presence of dietary fiber causes delayed absorption of nutrients due to slower digestion rates, especially viscous dietary fiber, postprandial blood glucose concentration increases at a slower rate, and may even be reduced (Institute of Medicine 2005, Slavin 2009). Therefore, high dietary fiber intake may aid in glycemic control, including individuals with T2DM.

Cardiovascular health also benefits from dietary fiber intake (Slavin 2009). Dietary fiber intake may lower blood pressure, improve blood lipid levels, and reduce indicators of inflammation. As stated previously, the AI for dietary fiber is based on the amount shown in studies to protect against CHD.
Resistant Starch

Resistant starch (RS) is a type of dietary fiber. It is non-viscous and fermentable. Resistant starch is defined as all types of starch and starch degradation products that resist digestion and absorption in the small intestine when consumed, and enter the large intestine (Topping et al. 2001, Cummings et al. 2007). Starch is made up of many alpha-linked glucose units (Institute of Medicine 2005). The starch amylose is linear, with alpha-(1,4) linked glucose polymers, and amyllopectin is branched, with linear alpha-(1,4) linked glucose polymers and branched alpha-(1,6) glucose polymers. Amylopectin is digestedly more quickly than amylose. Due to amyllopectin’s branched structure, more reducing ends are accessible to digestive enzymes, thus increasing the rate of digestion of amyllopectin compared to linear amylose. Only starch that is incompletely digested is classified as RS (Topping et al. 2001). The rate and extent that starch is broken down changes according to a number of physical and chemical properties, leading to the classification of different types of RS (Cummings et al. 2007).

RS₁ is starch that is trapped within plant cell walls and food matrices (Topping et al. 2001). Therefore, RS₁ is physically inaccessible to alpha-amylase, a digestive enzyme in the small intestine (Institute of Medicine 2005). Sources of RS₁ include partly milled grains, seeds, and legumes (Topping et al. 2001). RS₁ can become more physically accessible and less resistant through more extensive milling and chewing.

RS₂ is classified as resistant granules that are poorly gelatinized and slowly hydrolyzed by alpha-amylase (Topping et al. 2001). Sources of RS₂ include raw potato, green banana, some legumes, and high-amylose starches, such as high amylose corn
starch. RS\textsubscript{2} can be made accessible to alpha-amylase by gelatinization (Institute of Medicine 2005).

RS\textsubscript{3} is formed during processing, making it a fiber that is isolated instead of intact and naturally occurring (Institute of Medicine 2005). It is a retrograded starch, formed from cooking and cooling, or extrusion from starch foods. Sources include cooked and cooled rice and potato (Topping et al. 2001). Extrusion sources include potato chips and cereals (Institute of Medicine 2005). RS\textsubscript{3} is not digested by enzymes in the small intestine, and is partly fermented in the large intestine (Institute of Medicine 2005).

RS\textsubscript{4} is also formed during processing, making it functional (Institute of Medicine 2005). It is chemically modified starch (such as esters, ethers, and cross-bonded starches) that is used in food manufacturing to improve the starch’s functional characteristics (Institute of Medicine 2005, Topping et al. 2001). It can be found in processed foods. Like the other RS types, RS\textsubscript{4} is not digested in the small intestine, and is partly fermented in the large intestine (Institute of Medicine 2005).

According to the Institute of Medicine (2005), RS is estimated to make up 10% of the total starch consumed in the Western diet. RS\textsubscript{1} and RS\textsubscript{2} are dietary fibers, and RS\textsubscript{3} and RS\textsubscript{4} are thought to be functional fibers.

The fermentation of RS in the large intestine may increase SCFA production such as butyrate, though more studies are needed. The fermentability of RS varies depending on RS type (Stewart et al. 2010). Stewart et al. (2010) found that 2 preparations of isolated RS from different sources significantly varied in fermentability. One RS was highly fermentable while the other RS was poorly fermented.
Because of the low digestibility of RS, RS has been shown to increase fecal bulk in studies (Institute of Medicine 2005), improving laxation. However, if the RS is fully fermented, fecal bulk does not increase. Animal studies show a decrease in blood lipid concentrations with RS intake (de Deckere et al. 1993, Ranhotra et al. 1997, Younes et al. 1995), but the few human studies in this area show no effects of RS on blood lipid concentrations (Heijnen et al. 1996, Jenkins et al. 1998). Finally, RS intake may reduce postprandial blood glucose and insulin concentrations (Goddard et al. 1984, Li et al. 2010, Behall et al. 2002, Behall et al. 2006, Behall et al. 1998, Granfeldt et al. 1995, Hallstrom et al. 2011, Al-Tamimi et al. 2010, Westrate et al. 1993).

Amylose is a source of RS. Starches with a high amount of amylose, such as high amylose cornstarch, are intrinsically more resistant than high amylopectin starches (Topping et al. 2001).

**Glycemic Response: Glycemic Index and Glycemic Load**

Carbohydrate containing foods have wide ranging effects on glycemic response (Institute of Medicine 2005). Some carbohydrate containing foods cause a rapid rise of blood glucose concentrations followed by a rapid fall, whereas others cause a slow rise and slow fall of blood glucose concentrations. To quantify the relative glycemic response to foods that contain carbohydrates, the GI is used. The glycemic index is calculated based on blood glucose area under the curve (AUC) over 2 hours, after the ingestion of a set amount of carbohydrate in a food (for example, 50 g), compared to the ingestion of an equal amount of a reference food (for example, white bread or glucose), both tested in the same individual (Wolever 1990, Institute of Medicine 2005). Blood glucose AUC is
calculated as the incremental area under the curve for blood glucose concentrations over time, after consumption of food. There are characteristic GI values for individual foods, but these values can vary between individuals. A limitation of GI is that it is generally based on feeding the amount of food that contains 50 g of carbohydrate. This may not be a realistic portion size for some foods.

Because GI is a measurement for ingestion of a single food, glycemic load (GL) was developed to address the quantity and quality of the carbohydrate in a meal, made up of a number of foods (Gropper et al. 2009). For example, the GI for carrots is based on a serving of 50 g carbohydrate, but carrots are rarely eaten in that quantity (Franz 2003). One medium carrot (61 g) has 6 g total carbohydrate, so 50 g carbohydrate from carrots would be a serving of about 8.3 medium-sized carrots (USDA Agricultural Research Service 2013). Glycemic load is calculated by multiplying the GI by the grams of carbohydrate in a serving of the food (Gropper et al. 2009). To provide an example of GI vs. GL, a serving of 80 g of raw carrots has a GI of 35, and a GL of 2 (Atkinson et al. 2008).

The usefulness of GI and GL is debated (Atkinson et al. 2008). Although organizations such as the World Health Organization and the American Diabetes Association support the concept of GI and GL, some health professionals believe that the variability and complexity of GI and GL make them unreliable for clinical use. Also, GI is calculated based on the measure of blood glucose from fasting until 2 hours after consumption, but blood glucose may continue to decrease over time. Thus, glucose AUC would be greater if measured past 2 hours (Franz 2003). In addition, the 2-hour standard in GI calculation may not relate to patients with T2DM, who may require longer than 2
hours for blood glucose concentrations to decrease, if at all. Finally, GI is based on
measurements done in the morning after an overnight fast; GI may be different at another
time of day, e.g. lunchtime. In addition, some foods may have a low GI but also little
nutritional value, so GI should not be used alone.

Glycemic Response and T2DM

Several studies have shown that a regular consumption of carbohydrates with high
GI values can result in high concentrations of circulating blood glucose and insulin,
compared to a regular consumption of low GI carbohydrate foods (Institute of Medicine
2005). Because high blood glucose concentrations are associated with T2DM, many
studies have been done on the relationship between GI and T2DM risk.

First, what is T2DM? Individuals with untreated diabetes have abnormally high
fasting blood glucose concentrations (National Institutes of Health 2013). A normal
fasting blood glucose concentration is equal to or less than 99 mg/dL. A pre-diabetic
individual, at increased risk for developing T2DM, has fasting blood glucose levels
between 100-125 mg/dL. An individual is diagnosed with diabetes if his or her fasting
blood glucose concentration is equal to or greater than 126 mg/dL. Other tests used to
diagnose T2DM include a hemoglobin A1c test (which measures the average blood
glucose level over 2 to 3 months), and an oral glucose tolerance test (National Institutes
of Health 2013). Those with T2DM are insulin resistant, and eventually do not produce
enough insulin in response to increased blood glucose. To compare, individuals with
type 1 diabetes mellitus (T1DM) do not make insulin at all, due to an immune system
attack on the insulin-producing beta cells of the pancreas.
After digestion of a meal, glucose is absorbed from the small intestine into the bloodstream, and blood glucose concentration increases as a result. The body’s response to increased blood glucose is to release the hormone insulin from the pancreas. Insulin signals adipose and muscle cells to absorb glucose from the blood, and signals the liver to stop synthesis of glucose (Gropper et al. 2009). Insulin receptors are located on adipose and muscle cell membranes, and when insulin binds to these receptors, the translocation of GLUT4 to the cell membrane is stimulated. GLUT4 is a glucose transporter. Once GLUT4 is translocated to an adipose or muscle cell membrane, glucose can then enter the cell from the bloodstream, decreasing the blood glucose concentration.

The adipose and muscle cells of non-diabetic individuals respond when insulin binds to its receptors, and GLUT4 translocates (Gropper et al. 2009). However, individuals with T2DM are insulin resistant. Muscle cells fail to translocate GLUT4 in response to insulin, while adipose cells have a depletion of the mRNA that encodes the GLUT4 transporter. This causes the depletion of GLUT4 stores in adipose cells. However, the pancreas continues to produce insulin due to high blood glucose concentrations (National Institutes of Health 2013), resulting in an excess of insulin circulating in the bloodstream, or hyperinsulinemia. Eventually, the pancreas no longer has the ability to secrete enough insulin as a response to increased blood glucose concentrations, called hypoinsulinemia.

Risk factors for T2DM include older age, obesity, family history of T2DM, prior history of gestational diabetes mellitus (onset of diabetes during pregnancy), impaired glucose tolerance, physical inactivity, and race and ethnicity (Centers for Disease Control
African Americans, Hispanic/Latinos, American Indians, Asian Americans, and Pacific Islanders are all at increased risk for developing T2DM.

A systematic review of 37 prospective cohort studies of GI and GL and chronic disease risk found that both low-GI and low-GL diets are independently associated with a reduced risk of T2DM (Barclay et al. 2008). Barclay et al. state that this reduced risk of T2DM from low-GI and low-GL diets is comparable to the reduced risk from whole grain and high fiber intakes. However, 90% of participants from the cohort studies were female; results may differ in males. Also, there could be many confounders in these studies. Other lifestyle effects may not have been completely adjusted for, such as body composition, total energy intake, etc.

One 4-year prospective study reviewed by Barclay et al. (2008) found that high GI food intake was associated with an increased risk of T2DM in women (Hodge et al. 2004). However, this association was weakened when adjusted for obesity. In addition, only one food frequency questionnaire (FFQ) was taken at baseline to measure dietary intake, and dietary intake may have changed over the course of the study. The FFQ also did not have enough detail regarding foods such as cereal; for example, it did not ask about type of cereal eaten.

A recent study by Shyam et al. (2013) investigated the impact of low GI diets on non-diabetic Asian women with previous gestational diabetes mellitus. In the randomized control trial, subjects received conventional healthy dietary recommendations along with advice on lowering GI; the control group did not receive low GI diet advice. The group of women that received the low GI advice had significantly improved glucose tolerance and body weight reduction compared to the
group that did not receive diet advice on lowering GI. Limitations of this study are that the GI and GL were calculated based on reported intakes by the participants, and at baseline, it was determined that 52% of the participants were under-reporters. Also, the low GI group received the conventional healthy dietary recommendations on energy restriction, consuming foods low in fat and refined sugars, and consuming high fiber foods, in addition to advice on lowering GI. All of these factors could have influenced results, or they could have worked together to improve glucose tolerance and body weight reduction.

**Appetite, Obesity, and T2DM**

An uncontrolled appetite leads to increased food and energy intake. Obesity results from an excess in calorie intake and is a risk factor for T2DM (Khavandi et al. 2013). As body fat increases, the risk of developing T2DM increases, and many obese individuals are also pre-diabetic. Therefore, appetite control can be a preventative measure for T2DM, because a controlled appetite is less likely to cause obesity. For example, a study found that middle-aged women had a lower BMI when they ate in response to hunger and satiety signals (Madden et al. 2012).

**Type 2 Diabetes Mellitus Prevalence in Hawaii**

The ethnic makeup in the state of HI is unique compared to the mainland of the United States. In addition to Native Hawaiians, migrants from the Pacific Islands, Asia, Philippines, and United States mainland live on HI. The HI Health Survey of 2010
determined that its population is made up of about 18% Caucasians, 20% Hawaiians, 
16% Filipinos, 26% Japanese, and 21% Other (State of HI DOH (A) 2010).

In 2008, the prevalence of type 2 diabetes mellitus (T2DM) in Hawaii was 8.2%, in a 
population of 1.3 million (Sinclair et al. 2013). This T2DM prevalence is akin to the 
overall national United States prevalence of 8.3%. The prevalence of T2DM in Hawaii is 
significantly higher among Native Hawaiians, Japanese, Pacific Islanders, and Filipinos 
than among Caucasians (Grandinetti et al. 2007; Finucane et al. 2008; Maskarinec et al. 
2009). Table 1.1 provides information from the 2010 Behavioral Risk Factor 
Surveillance Survey in Hawaii showing the percentage of the population group that 
answered “yes” to the question “Have you ever been told by a doctor that you have diabetes?” (State of HI DOH, BRFSS 2010). This survey does not distinguish between 
T1DM and T2DM.

<table>
<thead>
<tr>
<th>Population group in HI</th>
<th>Diabetes diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawaiian</td>
<td>11.4%</td>
</tr>
<tr>
<td>Japanese</td>
<td>9.8%</td>
</tr>
<tr>
<td>Filipino</td>
<td>10.1%</td>
</tr>
<tr>
<td>Caucasian</td>
<td>5.5%</td>
</tr>
<tr>
<td>Other</td>
<td>7.1%</td>
</tr>
</tbody>
</table>

Table 1.1 Percent of population diagnosed with diabetes in HI.

Native Hawaiians also have higher prevalence rates of obesity, a risk factor for 
T2DM (Maskarinec et al. 2009). In 2008, 19-22% of Native Hawaiians had T2DM, and
an additional 16-35% had impaired glucose tolerance (Sinclair et al. 2013). The range is taken from three different studies reviewed by Sinclair et al. (2013). Native Hawaiians also are an average of 7 years younger when diagnosed with T2DM compared to other ethnic groups, and have a higher death rate from T2DM (Sinclair et al. 2013). Forty-five percent of Filipinos in HI are overweight or obese, and consistently have two to three times the age-adjusted prevalence of T2DM compared to Caucasians (Finucane et al. 2008). In addition, Japanese Americans, though they have a lower prevalence of obesity than Native Hawaiians and Filipinos, have more visceral adipose tissue than Caucasians. Visceral adiposity precedes development of T2DM (Maskarinec et al. 2008, Boyko et al. 2000). In HI, body mass index (BMI) is positively correlated with T2DM risk in all ethnic groups, and education is inversely correlated with T2DM in Native Hawaiians and Japanese Americans (Maskarinec et al. 2009). In the Multi-Ethnic Cohort Study (MEC) data from 1993-1996, individuals with more than 12 years of education had a significantly lower risk of T2DM (Maskarinec et al. 2009). The incidence of T2DM for more than 15 years of education was 8, 10.3 for 13-15 years of education, and 12.9 for 12 or less years of education.

The prevalence of T2DM is a public health concern. In 2008, T2DM was the sixth leading cause of death in the United States (DHHS, CDC 2008). The risk of death in patients with T2DM is twice that of those without diabetes of similar age. Type 2 diabetes mellitus can lead to premature death, as well as many serious complications (State of HI DOH 2010). These complications include heart disease, stroke, eye disease and blindness, kidney disease, nervous system disease, and amputations (State of HI
DOH 2010, CDC 2012). Native Hawaiians and other Pacific Islanders in HI have an excess burden of T2DM and its health complications (Mau et al. 2010).

Economically, T2DM is expensive. The national cost in the United States of T2DM exceeded $174 billion in 2007 (State of HI DOH (B) 2010). The medical expenditures of those with T2DM are 2.3 times higher than those without diabetes. In HI, the state cost of T2DM was over $1 billion in 2006. This includes $764 million of excess medical costs, and lost productivity of $274 million.

Type 2 diabetes mellitus can be preventable, manageable, and controllable, and early intervention can minimize the burden of the disease (Pratley 2013). Also, progression to T2DM can be delayed by addressing pre-diabetes. The Diabetes Prevention Program (DPP) was a major clinical research study based at George Washington University, with 27 participating clinical centers from around the United States, not including HI, in its first interventions. This study investigated and compared the effects of lifestyle intervention to pharmacological intervention with the medication metformin, on the prevention or delay of T2DM (DPP Research Group 2002). Metformin is a drug that helps to control blood glucose by decreasing the amount of glucose absorbed into the bloodstream from food and decreasing the amount of glucose made by the liver (MedLine Plus 2013). Metformin also increases insulin response. The lifestyle intervention was found to decrease T2DM incidence by 58%, compared to 31% by metformin. The lifestyle intervention included daily exercise, weight loss, and a healthy diet.

In comparison to the DPP, another study looked at cost effectiveness of conventional blood glucose control (mainly through diet) compared to intensive blood
glucose control (with exogenous insulin therapy or sulfonylurea) in T2DM (Gray et al. 2000). Exogenous insulin therapy is the injection of insulin to help achieve glycemic control (Mayfield et al. 2004). Sulfonylurea is a drug that stimulates endogenous insulin release. This study found that intensive blood glucose control did significantly reduce costs of complications of T2DM, but treatment costs were significantly increased. Therefore, lifestyle interventions may be more cost effective than medical treatment. In many trials, lifestyle intervention has proven effective in preventing incident T2DM, but the widespread application of lifestyle interventions has been limited by local financial status of states and communities (Crandall et al. 2008).

In HI, there have been efforts to address the high T2DM prevalence. A study published in 2010 set out to culturally adapt the DPP lifestyle intervention for Native Hawaiians and other Pacific Islanders (Filipino, Samoan, Chuukese, or other Pacific Islander) (Mau et al. 2010). After completion of informant interviews and focus groups, cultural adaptions were created, including simplified language, incorporation of local examples, and reformatting of group learning and interaction. The intervention was entitled the Partnerships for Improving Lifestyle Interventions ‘Ohana Lifestyle Intervention (POLI). The POLI was done through small groups in a community setting, and the intervention goals had an emphasis on addressing family, social, and economic influence. After a 12-week pilot study, participants (who were overweight or obese Native Hawaiian, Filipino, or other Pacific Islanders) had a significantly reduced weight loss compared to those that did not complete more than 8 weeks of the lifestyle intervention. Diet and physical activity also improved in those that completed more than 8 weeks of the intervention compared to those that did not.
A pilot study published in 2013 continued the efforts of Mau et al. (2010) (Sinclair et al. 2013). It sought out to test the effectiveness of the Partners in Care intervention, part of POLI, which again was a culturally adapted diabetes self-management intervention. Participants were Native Hawaiian, Filipino, or other Pacific Islanders with T2DM. Participants received the intervention for 3 months, and the researchers determined that the intervention was effective in improving glycemic control of the participants. Average blood glucose concentration of the 3 months in the intervention group was significantly lower than the wait-list control group, and the intervention group understood and performed diabetes self-management significantly more than the wait-list control group.

Look et al. (2008) investigated the effects of training community health workers that serve Native Hawaiians and Pacific Islanders on diabetes prevention, control and management. A needs-assessment of the health agencies in HI determined that this topic was a priority. Community health workers received a 4-hour training curriculum, which included culturally relevant material on diabetes, physical activity, and nutrition. For example, the nutritional information on HI local foods was included. After the training, there was a significant increase in diabetes knowledge of the community health workers, including cultural aspects of diabetes in HI, compared to the community health workers’ knowledge before training.

In addition, the HI Diabetes Prevention and Control Program (DPCP) of the HI State Department of Health developed the HI Diabetes Plan (State of HI DOH, DPCP 2010). This plan has four content areas, with goals set for each: Diabetes Surveillance, Prevention and Public Awareness, Health Care Quality, and Focused Initiatives.
However, the HI DPCP has not published any documents on this plan, such as progress or achievements, since the HI Diabetes Plan was published in 2010.

Researchers in HI have addressed the burden of T2DM, and trainings and interventions have been piloted. However, governmental action against T2DM, such as the HI Diabetes Plan, needs to be set in gear and followed through. The government and community health organizations are key players in disease control and prevention.

**Rice Intake in Hawaii**

In HI, rice is served at almost every meal for many people, much like bread is a staple on the mainland of the United States (Braginsky et al. 2011, Shortridge et al. 1998). Not only is rice a side dish, but it is part of local mixed dishes such as “loco moco” (hamburger, gravy, rice, and fried egg) (Shortridge et al. 1998). Rice is a primary staple food across Asian and Pacific cultures in HI, including Chamorro (indigenous people from Guam), Filipino, Japanese American, and Native Hawaiian cultures (Leon Guerrero et al. 2009). It is a major source of energy across ethnic groups in HI (Sharma et al. 2012, Leon Guerrero et al. 2009). As much as 18% of daily energy intake in Filipino and Japanese American men is from rice (Leon Guerrero et al. 2009). Using a 2000 kcal diet as an example, 18% of total kcal from rice is 360 kcal, which is almost 2 cups of white rice. Two cups of white rice contains 90 g carbohydrate. To compare, three slices of whole wheat bread is about 384 kcal (with 42 g carbohydrate), and 1.5 cups of spaghetti noodles is about 330 kcal (64.5 g carbohydrate).

Japanese American women living in HI consume significantly more rice than Caucasians that live in HI (Takata et al. 2004). Rice intake for women in Japan,
however, has decreased over the past 50 years. For Native Hawaiians and Japanese Americans living in HI, white rice is the major contributor of refined grains in their diet, and it is the most commonly consumed and top choice for grain source (Sharma et al. 2013).

A study looking at T2DM self-management of Filipinos in Hawaii explored the role of rice in the Filipino diet (Finucane et al. 2008). Filipino Americans have two to three times the prevalence of T2DM compared to Caucasians in HI, and 45% are overweight or obese. Rice is a symbolic food in their culture. It is a symbol of strength, sustenance, sacrifice, wealth, and togetherness. According to one Filipino subject, “A meal is not a meal without rice.” This is evident in that rice is usually eaten at every meal. Finucane et al. noted that if a Filipino reduces or eliminates rice from his or her diet, he or she may be perceived as rejecting his or her Filipino culture (2008).

**Rice as a high source of carbohydrate**

White rice is classified as a high glycemic index (GI) food (GI of 70 or greater), with an average GI of 73 (Atkinson et al. 2008). To compare, white bread has an average GI of 75, and boiled potato an average GI of 78. Most varieties of pasta, legumes, fruits, and dairy are classified as low-GI foods (GI of 55 or less). One hundred g of cooked, short-grain white rice has about 29 g of carbohydrate, and one cup (186 g) has about 53 g carbohydrate (USDA Agricultural Research Service 2013). One hundred g of white bread contains about 49 g of carbohydrate, and one slice (28 g) contains about 14 g carbohydrate. For an example of legumes, kidney beans contain about 15 g carbohydrate
in 100 g, and 37 g carbohydrate in 1 cup. The GI of kidney beans is 24 (Atkinson et al. 2008).

Brand-Miller et al. (1992) determined the GI for 9 rice varieties using 8 healthy subjects. The rice varieties and their GI are listed in Table 1.2. Only the Doongara high amylose white and brown rice varieties are not considered a high GI food (GI of 70 or greater). All other rice varieties in this study are a high GI food. The Doongara high amylose varieties had a significantly lower GI than the normal amylose rice varieties, Calrose and Pelde.

<table>
<thead>
<tr>
<th>Rice variety</th>
<th>GI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calrose white</td>
<td>83</td>
</tr>
<tr>
<td>Calrose brown</td>
<td>87</td>
</tr>
<tr>
<td>Pelde white</td>
<td>93</td>
</tr>
<tr>
<td>Pelde brown</td>
<td>76</td>
</tr>
<tr>
<td>Pelde parboiled</td>
<td>87</td>
</tr>
<tr>
<td>Doongara white</td>
<td>64</td>
</tr>
<tr>
<td>(high amylose)</td>
<td></td>
</tr>
<tr>
<td>Doongara brown</td>
<td>66</td>
</tr>
<tr>
<td>(high amylose)</td>
<td></td>
</tr>
<tr>
<td>Sunbrown Quick</td>
<td>80</td>
</tr>
<tr>
<td>Waxy (0-2% amylose)</td>
<td>88</td>
</tr>
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A study investigating the association of a food’s GI with the shape of the curve of blood glucose response in healthy individuals found that high GI rice varieties had the highest 120-minute values of blood glucose, along with high GI whole grain breads,
compared to other foods such as pasta, breakfast cereals, and potatoes (Brand-Miller et al. 2009).

Therefore, white rice increases blood glucose concentrations at a faster rate compared to other carbohydrate foods such as legumes and fruits, and Brand-Miller et al. (2009) demonstrated that high GI rice varieties may cause a higher postprandial blood glucose concentration for a longer period of time. Again, low GI diets are associated with a reduced risk of T2DM (Barclay et al. 2008).

**Resistant Starch and Glucose and Insulin Response in Healthy Adults**

A number of studies have found that solid foods containing RS can improve postprandial plasma glucose and insulin response. Three studies have looked at the effects of high amylose rice (rice that contains RS) on postprandial plasma glucose and insulin response. Goddard et al. (1984) studied the effects of rice varieties with different amounts of RS on glucose and insulin in 33 healthy adults (16 males, 17 females aged 27-81 years, weight within 20% of desired weight as determined by body mass index (BMI), ethnicity not stated). The high amylose treatment rice was 23-25% high amylose per serving, but the gram amount of RS and serving size was not stated. The mid-amylose rice treatment contained 14-17% amylose, and the control rice contained 0% amylose. Subjects consumed a mixed diet of 200 g carbohydrate for at least 3 days prior to study visits. Postprandial plasma glucose concentrations were significantly decreased after high amylose rice intake at 30 minutes, compared to both the mid-amylose and control rice (0% amylose). Plasma insulin concentrations were significantly lower at 30 minutes and 60 minutes after high amylose rice consumption compared to the control.
Though this study has a fairly large sample size for a clinical trial, the age range is large. Age could be a confounding factor in this study as well as gender and ethnicity (which is not stated in the study). Additionally, the mixed diet consumed before treatments could be another confounding factor, and “mixed” is not defined. No nutrient or energy data was provided. Finally, the gram amount of RS in the rice treatments is unknown. This makes the study less comparable to other studies investigating RS in foods and glycemic response.

Li et al. (2010) compared genetically modified high RS rice to a control conventional rice and studied their effects on postprandial plasma glucose and insulin in 16 healthy Chinese adults (9 males, 7 females aged 23-26 years, BMI of 18-24 kg/m²). The high RS rice contained 8.05 g RS per serving, whereas the control rice contained 0.97 g RS. Though serving size was not stated, 40 g total carbohydrate was consumed in each treatment. For 24 hours before each study visit, the study subjects were advised to not consume fermentable products such as legumes, dairy products, and high-fiber foods. After the high RS rice was consumed, both plasma glucose and insulin concentrations and AUC significantly decreased in the subjects compared to the control rice. This study has a smaller sample size, but the age range is smaller, and ethnicity is known. No sample size calculation or power calculation were provided, but typically 17-18 subjects is enough to see differences in postprandial glucose and insulin concentrations. The amount of RS is stated, and shows that RS in rice may have an effect on glucose and insulin at a level of 8.05 g. The serving of rice in this study was 40 g total carbohydrate, and one cup of short-grain white rice contains about 53 g carbohydrate. Therefore, a serving of a little less than one cup of the high RS rice would possibly provide 8.05 g RS.
This is a reasonable amount of rice to eat at one meal.

Chiu et al. (2013) investigated the effects of a high RS rice and low RS rice on blood glucose AUC in 21 healthy adults (12 males, 9 females, mean age 29, mean BMI of 22.9, ethnicity not stated). The high RS rice contained 4.4 g RS (in a 50 g carbohydrate serving of rice), and the low RS rice contained 0.4 g RS. No significant differences were found between glucose AUC after high RS rice consumption and low RS rice consumption. The RS amount of 4.4 g in the high RS rice may not have been enough to cause a change in blood glucose concentrations; it is almost half the amount of the high RS amount in the Li et al. (2010) study.

The effects of RS in other solid foods on glycemic response have been studied. For example, bread with added RS is a common solid food used in studies. In one study, 25 healthy adults (13 males, 12 females, aged 23-58 years, mean BMI of 27.5 kg/m², ethnicity not stated) consumed bread containing high amylose cornstarch (Behall et al. 2002). For 2 days prior to their study visits, subjects consumed a standard equilibration diet containing 30% fat, 55% carbohydrate, and 15% fat. The high amylose treatment bread (70% amylose) contained 13.4 g RS per serving. The other treatment breads had 11.5 g RS (60% amylose), 8.2 g RS (50% amylose), 3.8 g RS (40% amylose), and 2 g RS (30% amylose). Serving sizes were 1 g carbohydrate per kg body weight of the subject. The mean body weight for the male subjects was 88 kg, so serving sizes were about 88 g carbohydrate. For females, the mean body weight was 72 kg, so serving sizes were about 72 g carbohydrate. Again, one cup of short-grain white rice is about 53 g carbohydrate, so serving sizes must have been around 1.5 cups of rice. Serving size was not mentioned in the actual study. Subjects had significantly lower postprandial peak plasma glucose
concentrations after the 50-70% amylose bread treatments. The 60 and 70% amylose bread treatments had significantly decreased glucose AUC compared to the other treatment breads. Behall et al. also found that postprandial plasma insulin concentrations were significantly lower after the 60 and 70% amylose bread treatments, and the insulin AUC was significantly decreased after 2 hours compared to the other bread treatments (2002). In this study, effects on blood glucose were found at 8.2 g RS or higher, similar to the 8.05 g RS amount in the Li et al. (2010) study that showed significant results. However, serving sizes of the rice samples must have been about 0.5 cups greater than Li et al. (2010), based on the 1 g carbohydrate/kg body weight method. One and a half cups of rice may be a less reasonable amount to eat in one meal. This study has a slightly larger sample size, and used a defined control diet prior to treatment. This is important to control for any influences of diet on outcomes. If not controlled, a subject who consumed a high amount of carbohydrates the day before a study visit may have different glucose and insulin values, compared to if he consumed a low carbohydrate diet the day before. Ethnicity is unknown, but ethnicity is an important factor regarding the differences in T2DM prevalence across ethnic groups.

Bread with 6 g RS from tapioca flour per serving significantly inhibited postprandial plasma glucose and insulin responses compared to control bread without RS in 20 Japanese adults with untreated borderline T2DM (9 males, 11 females, mean age 50.5 years, fasting blood glucose 100-140 mg/dL, BMI not stated) (Yamada et al. 2005). The diet was not controlled prior to the subjects’ visits. The RS amount in the treatment bread is about 2 g less than the Li et al. (2010) and Behall et al. (2002) studies, but this amount still had significant effects. However, the subjects in this study were pre-
diabetic; therefore, it could be possible that effects are shown at lower RS amounts in pre-diabetic or even T2DM individuals. Ethnicity could also be a factor in glycemic response.

A fourth study confirmed that 6-8 g RS is a therapeutic dose of RS postprandially. Hallstrom et al. (2011) tested high amylose whole grain wheat bread with 7.7 g RS compared to standard whole grain wheat bread in 14 healthy adults (7 males, 7 females, aged 20-35 years, mean BMI of 22.2 kg/m², ethnicity not stated). The high amylose whole grain wheat bread was a novel wheat genotype with elevated amylose content. The subjects consumed a standardized low fiber meal the night before each visit. The high amylose whole grain wheat bread had a significantly lower postprandial glucose response over the course of 2 hours compared to the conventionally baked white wheat control bread. However, no change was found in plasma insulin response. A limitation in this study is that unlike the whole grain treatment bread, the control was white wheat bread. The whole grains in the treatment bread could also be causing the results seen, in addition to the RS, because a higher whole grain intake can lower fasting glucose concentrations, and is associated with a reduced risk of T2DM (Ye et al. 2012). The RS amount is 7.7 g, a little less than the previous studies, and had an effect on blood glucose response, but no effect on insulin response.

In addition, another study tested the effects of high amylose breakfast and lunch meals on postprandial glucose and insulin responses (Weststrate et al. 1993). Twenty-two healthy adult males (mean age 38, mean BMI of 23.4 kg/m², ethnicity not stated) consumed high amylose bread with 9.2 g RS with other items at breakfast, and a high amylose pizza crust with 10.4 g RS with other items at lunch. The control breakfast
bread contained 1.2 g RS, and the control lunch pizza crust contained 6.3 g RS. No control diet was given prior to the study visits. Insulin AUC significantly decreased after the breakfast meal, while both glucose and insulin AUC significantly decreased after the lunch meal compared to the low amylose control meals. Though not stated by the authors, this could be due to an additive effect of the two meals or second meal effect. However, there was still a change in glucose and insulin AUC, which could be a dose-response effect. In addition, the control lunch pizza crust contained 6.3 g RS, which is a moderate dose compared to the studies discussed previously.

The effects of other solid foods with RS on postprandial plasma glucose and insulin response have also been studied. One study investigated the effects of muffins with different amounts of high amylose cornstarch in both 10 normal (mean age 43 years, mean BMI of 22.0 kg/m², ethnicity not stated) and 10 overweight females (mean age 43 years, mean BMI of 30.4 kg/m², ethnicity not stated) (Behall et al. 2006). The muffins contained 0.9, 3.4, and or 6.5 g RS. For 2 days prior to their study visits, subjects consumed a standard equilibration diet containing 30% fat, 55% carbohydrate, and 15% fat. Glucose and insulin AUC decreased as RS content increased in the muffins for both the normal and overweight females. Postprandial glucose plasma concentrations were significantly decreased at 1 hour, and insulin concentrations were significantly decreased at 2 hours in both groups after the 6.5 g RS muffin intake compared to the low- and mid-RS muffins. Additionally, as RS amount in the muffins increased, insulin response decreased within a 2 hour time period. This trend reaches significance at 1 hour, and remains significant at 2 hours. At 3 and 4 hours, there is no significant difference in insulin response among the muffin treatments. This finding shows that RS may have a
dose-effect relationship with insulin response in a short time period. In this study, there were significant effects with 6.5 g RS (lower than the previously discussed studies) in both normal and overweight women. Though the sample size was small, this study shows that RS can have similar effects in normal and overweight individuals.

In another study, 25 healthy adults (13 males, 12 females, aged 28-58 years, weight within 20% of desired weight as determined by BMI, ethnicity not stated) consumed crackers with high amylose cornstarch compared to a control starch cracker (Behall et al. 1988). The amount of RS per cracker serving was not stated, but the treatment crackers were 70% amylose and 30% amylopectin. The control crackers were 30% amylose and 70% amylopectin. No control diet was given to subjects. Peak plasma glucose concentrations were significantly lower at 30 minutes after the high amylose starch cracker consumption, and plasma insulin concentrations were significantly lower at 30 minutes and 60 minutes after the high amylose starch cracker consumption, compared to the low-amylose starch cracker. Again, because gram amount of RS and serving size were not given, it is difficult to compare results to other studies. However, the sample size in this study is larger than others.

Arepas (corn bread cakes) with high amylose corn flour, containing 11 g RS per serving, significantly lowered postprandial AUC glucose and insulin response in 9 healthy adults (4 males, 5 females, mean age 34, mean BMI of 23 kg/m², ethnicity not stated) compared to standard arepas containing 1.2 g RS (Granfeldt et al 1995). No control diet was given to subjects prior to study visits. This study’s sample size is very small, but it is consistent with the previously discussed studies.
Finally, Al-Tamami et al. (2010) researched the effects of a “nutrition bar” with RS on postprandial plasma glucose and insulin concentrations in 13 healthy adults (6 males, 7 females, mean age 27, mean BMI of 25 kg/m², ethnicity not stated) compared to a control bar. The treatment bar contained cross-linked RS₄, with corn syrup, wheat germ, brown sugar, water, gum acacia, and Panodan 150 K (an emulsifier). The control bar contained the same ingredients, with puffed wheat instead of RS₄. The treatment bar contained 15.6 g RS. No control diet was given to the subjects prior to study visits. The peak glucose and insulin concentrations and AUC were significantly decreased after the RS bar intake compared to the control bar. However, both bars contained 4.4 g gum acacia. Gum acacia is a soluble fiber, and gums have shown to attenuate blood glucose and insulin response in some studies (Institute of Medicine 2005). Therefore, the gum acacia in the treatment bar could have had an additive effect with RS on blood glucose and insulin, and may have not been in a great enough amount in the control bar to show effects.

These studies overall show that RS in food can attenuate blood glucose and insulin responses postprandially in subjects without T2DM. The RS dose per serving showed significant effects at around 8 g in the studies, with 4.4 g being too low to show effects (Chiu et al. 2013). The studies used different sources of RS and types of solid foods, but similar results were found. The sources and food types with significant effects on blood glucose and insulin were: high amylose rice, genetically modified high RS rice, high amylose bread, bread with tapioca flour, high amylose whole grain wheat bread, a lunch meal with high amylose pizza crust, muffins with high amylose cornstarch, crackers with high amylose cornstarch, arepas with high amylose corn flour, and a
“nutrition bar” with cross-linked RS₄. However, more research needs to be done in two areas. The effects of the same food form with different RS types on blood glucose and insulin, and the effects of the same RS type in different food forms on blood glucose and insulin need to be investigated. In the Behall et al. (2006) study, overweight and normal weight women had similar results in blood glucose and insulin response after RS intake, showing that RS intake may have the same effects in normal and overweight individuals, but more studies are needed. An amount of 6 g RS had significant effects on blood glucose and insulin response in subjects with untreated borderline T2DM (Yamada et al. 2005), showing that a lower dose of RS in solid food is possibly needed to show effects in pre-diabetic individuals. Though again, more studies are needed to investigate effects of RS intake in pre-diabetic individuals. Long term studies on chronic intake of RS in solid foods in the diet are needed to investigate whether RS continues to have similar effects on blood glucose and insulin response. Finally, ethnicity and effects of RS intake should be investigated. Native Hawaiians may need a different amount of RS to see effects compared to Japanese Americans, for example. Native Hawaiians have a high prevalence of obesity, while Japanese Americans have a relatively low body weight (Maskarinec et al. 2009).

To investigate the relationship between ethnicity and glycemic response, Kataoka et al. (2013) studied glycemic response to five rice varieties in healthy Chinese adults (17 males, 15 females, mean age 33, mean BMI of 22.9) vs. healthy European adults (15 males, 16 females, mean age 34, mean BMI of 25.7). The postprandial blood glucose AUC after each treatment was measured to compare glycemic response between treatments and ethnic groups. Treatments were jasmine, basmati, brown, Doongara, and
parboiled rice, and a glucose beverage control. The blood glucose AUC for the Chinese adults was significantly higher after intake of all rice varieties and the glucose beverage than the blood glucose AUC for the European adults. Therefore, glycemic response was different between ethnic groups. However, although physical activity was included in the study, previous dietary intake was not measured. The two ethnic groups may have had different dietary intake before treatments that may have influenced blood glucose levels during the study visits. The European group had a slightly higher BMI than the Chinese group, which could influence results. Also, it is not stated whether these groups were habitual rice eaters. Depending on whether the individuals habitually eat rice, glycemic response may differ after rice intake. From these findings by Kataoka et al. (2013), the relationship between ethnicity and glycemic response should continue to be researched. Also, it is interesting to note that the only significant difference in GI for the rice varieties was seen in the basmati rice, which had a significantly lower GI than the other rice varieties. Doongara was used in this study, which is a high amylose rice variety, but it did not have a significantly lower GI than the other rice varieties.

Resistant Starch and Glucose and Insulin Control in T2DM

Only a few clinical studies have investigated the relationship between RS in solid foods and T2DM management. Two of these studies investigated the postprandial glycemic response to RS in subjects with T2DM. Lintas et al. (1995) fed 10 adults with T2DM (7 males, 3 females, mean age 60, mean BMI of 24, ethnicity not stated, T2DM duration mean of 2 years) a lunch meal of either pasta, barley, or rice with the same tomato sauce. Blood draws were taken postprandially. Lintas et al. (1995) determined
that the pasta had the most RS, containing 14% RS, compared to the rice and barley, which each contained 6% RS. The gram amount per serving is not stated, but the total starch amount in the pasta serving was 65.4 g, so 14% RS is about 9.2 g RS. The total starch amount in the rice serving was 68.3 g, so 6% RS is about 4.1 g RS. The barley had 68.8 g total starch, with 6% RS being about 4.1 g RS as well. The subjects’ glucose response was lowest after the barley meal compared to the pasta and rice meals, although it contained less RS than the pasta. This could be due to the fact that barley contains different fiber, beta-glucan, that could be attributing to the effects on glucose response.

In another study, 12 adults (7 males, 5 females, mean age 58, mean BMI of 30, ethnicity not stated, T2DM duration mean of 4 years) with T2DM consumed low (12%) and high (27%) amylose rice, parboiled and non-parboiled, and white bread as a control (Larsen et al. 1996). The serving size of the low amylose rice was 65.3 g, so 12% RS dose was about 7.8 g. The serving size of the high amylose rice was 65.2 g, so the 27% RS dose was about 17.6 g. The subjects received their treatments in the morning after an overnight fast, and had postprandial blood draws taken. There were no significant differences in blood glucose and insulin response among the rice treatments. All rice treatments had lower glucose and insulin responses than the white bread control. The lack of significant difference may have been due to dose: the low 7.8 g RS dose was similar to the high 6-8 g RS dose that had therapeutic effects in previously mentioned studies.

Two studies investigated the effects of chronic intake of solid food with RS on adults with T2DM, impaired fasting glucose (IFG), or impaired glucose tolerance (IGT). In one of these studies, 85 adults (47 males, 38 females, mean age 50, mean BMI of 25,
Korean) with T2DM, IFG, or IGT consumed a serving of rice with 6.51 g RS compared to a control rice (0 g RS) daily for 4 weeks (Kwak et al. 2012). Post-treatment, subjects came fasted to a study visit, and consumed a morning standard meal. The high RS rice treatment significantly decreased fasting insulin and insulin resistance (IR), postprandial glucose and insulin levels at 30 minutes, and glucose and insulin AUC after the standard meal in the diabetic subjects compared to the control rice treatment. Insulin resistance (IR) was measured via homeostasis model assessment-IR (HOMA-IR = (fasting insulin concentration x fasting glucose concentration) / 0.25)). The subjects also had improved endothelial function and reduced oxidative stress after the chronic RS rice treatment, compared to the control rice. Endothelial function was measured by finger pulse wave amplitude, and oxidative stress was measured by plasma superoxide dismutase activity and serum nitric oxide concentration. Endothelial dysfunction can occur in patients with T2DM (Hadi et al. 2007). In endothelial dysfunction, the endothelial derived relaxing and contracting factors of blood vessels are no longer balanced, which can lead to vascular and end-organ damage. Therefore, improved endothelial function is beneficial in patients with T2DM. Oxidative stress, with production of reactive oxygen species, also occurs in T2DM (Wright et al. 2006). Oxidative stress can cause macro- and microvascular complications, and reducing oxidative stress in T2DM is beneficial. This study had a large sample size, and was one of the first studies to look at chronic RS intake in subjects with IFG, IGT, and T2DM. The results on insulin and glucose response were significant, indicating that research on chronic RS intake in T2DM patients should be continued.
In another study, 15 African American adults (8 males, 7 females, mean age 36, mean BMI of 37) at risk for T2DM with IR consumed bread with high amylose cornstarch (12 g RS per serving) daily for 14 weeks (Penn-Marshall et al. 2010). Post-treatment, the study subjects arrived fasted to a study visit in the morning and consumed a standard meal. There were no significant differences in fasting glucose, and insulin levels between the chronic RS bread treatment and the control bread treatment (with 0 g RS per serving). The subjects’ IR decreased to normal values post-RS bread treatment, but the change was not significant.

So far, studies on RS intake and glucose and insulin response in T2DM patients are inconsistent. Kwak et al. (2012) had significant findings with therapeutic effects of chronic RS rice (6.51 g RS) intake for 4 weeks, but Penn-Marshall et al. (2010) had no significant findings after RS bread (12 g RS) intake for 14 weeks. The differences in findings could be that Kwak et al. (2012) included participants with T2DM, impaired fasting glucose (IFG), or impaired glucose tolerance (IGT), while Penn-Marshall et al. (2010) only included participants with IR. The participants with one of the listed conditions may have had different reactions to the treatment compared to participants with one of the other listed conditions. Also, the sample size between studies is different, with 85 adults in the Kwak et al. (2012) study, and 15 adults in the Penn-Marshall et al. (2010) study. Ethnicity could also be a confounder, with only African Americans in the Penn-Marshall et al. (2010) study. Ethnicity is unknown in the Kwak et al. (2012) study, though the study was performed in Korea. Finally, the treatment length was 4 weeks (Kwak et al. 2012) vs. 14 weeks (Penn-Marshall et al. 2010). It could be that chronic intake of RS is less effective over time.
More studies are needed on the effects of both short term and chronic RS intake on blood glucose and insulin response in T2DM patients in order to make any conclusions based on findings. Additionally, patients of different ethnicities with T2DM and the effects of RS intake need to be compared as well.

In 2012, a meta-analysis and systematic review was published on white rice consumption and its relation to T2DM (Hu et al. 2012). This study reviewed 7 prospective cohort studies from 4 articles, and concluded that a higher white rice consumption is associated with increased risk of T2DM, in Asian (Chinese and Japanese) populations in particular. The association was concluded after pooling relative risks using a random effects model, and evaluating dose-response relations. However, this study was met with much criticism. Three comments were published in response to Hu et al. (2012) (Naqvi et al. 2012, Neal 2012, Kadoch 2012). Naqvi et al. (2012) criticized that the methods were not clearly presented, only written as “self-reported.” In addition, there may have been bias because only prospective cohort studies published in English were analyzed. The data quality assessment used was not a standard assessment. Hu et al. (2012) stated that the results of the reports were significantly heterogeneous, but this heterogeneity was not discussed in the paper. Neal (2012) stated that large scale studies like Hu et al. (2012) rely on inexact tools for the measurement of dietary factors. Errors in measured individual levels of consumption can be large, such as total rice consumption. Hu et al. (2012) compared rates of T2DM between a high white rice consuming group and low white rice consuming group. Yet the specified high and low levels of rice consumption varied greatly between the studies. For example, the difference of one study between high and low white rice consumption groups was 33 g of
white rice, while the difference in another study was 250 g. These two studies were placed on the same scale in the meta-analysis. In the third comment, Kadoch (2012) wrote that white rice has been consumed for thousands of years in Asian populations. However, diabetes was rare during these years, until Asia became introduced to the Western diet and lifestyles. In addition, Kadoch (2012) wrote that many studies have been published showing the beneficial health effects of diets that incorporate white rice.

There are other limitations to the Hu et al. (2012) study. White rice can include many varieties, especially across countries, but white rice variety was not mentioned in the paper. Different varieties could have different effects. The prospective cohort studies used were not critiqued for confounding factors (such as other diet factors or physical activity) or bias. Finally, Hu et al. (2012) mentions that white rice has a lower amount of many nutrients such as magnesium and vitamins compared to brown rice. They state that some of these nutrients have been associated with a lower risk of T2DM, and thus high white rice consumption may lead to increased risk of T2DM due to low intake of beneficial nutrients. This conclusion is unwarranted. Many white rice varieties consumed are enriched, providing some of the nutrients. Additionally, the authors did not look at nutrient intakes of these studies, and did not compare them to the nutrient intakes of low white rice consumers or even brown rice consumers. The Hu et al. (2012) study does not provide convincing evidence that higher white rice consumption is associated with risk of T2DM.
Resistant Starch and Appetite

The viscosity and bulking of dietary fiber can both create a feeling of fullness and satiation (Institute of Medicine 2005, Slavin 2009). Therefore, satiation caused by dietary fiber can decrease food intake (Slavin 2009). Not all fibers are viscous, such as RS. However, RS increases fecal bulk (Institute of Medicine 2005), creating a feeling of fullness. The release of insulin is also related to appetite; insulin is a negative feedback regulator of body fuel stores (Morton et al. 2006). Because insulin is released due to increase of blood glucose after RS consumption, insulin may influence appetite as well.

Few studies have researched the effects of solid foods containing RS on postprandial appetite, and findings are not conclusive. Weststrate et al. (1993), mentioned previously, found that the high amylose breakfast and high amylose lunch had no impact on appetite ratings compared to the control meals in 22 healthy adult males (mean age 38, mean BMI of 23.4 kg/m², ethnicity not stated). In addition, the high amylose meals were less pleasurable. Appetite was evaluated by visual analogue scales (VAS). However, this study had RS incorporated into an entire meal, instead of one food treatment. If only the RS baguette or RS pizza crust were eaten, without the other foods, appetite results may have been different. Yet this study may be more realistic in studying RS in foods and appetite, because a single food is not usually eaten at one sitting.

In another study, 20 healthy adults (7 males, 13 females, aged 18-65 years, mean BMI of 23, ethnicity not stated) consumed muffins with different types of fiber (Willis et al. 2009). Appetite was evaluated using VAS. No control diet was given prior to study visits. The muffins were low fiber (1.6 g total fiber), corn bran (9.6 g total fiber), beta-glucan and oat fiber (9.4 g total fiber), polydextrose (9.5 g total fiber), and RS (8 g RS).
The RS muffin and the corn bran muffin were more satiating than the other fiber-type muffins. The appetite outcomes measured by VAS were hunger, satisfaction, fullness, and prospective food intake. For palatability, outcomes were visual appeal, taste, smell, and overall pleasantness. The RS muffin was the most satisfying of the muffin types. However, the subjects preferred the polydextrose muffin compared to the other muffin types due to taste and overall pleasantness. This study is useful for consumer purposes, because although RS was the most satisfying and more satiating than the other muffins, consumers preferred the polydextrose muffin, which had little effect on satiety.

In a similar study, 22 healthy women (mean age 25, mean BMI of 23, ethnicity not stated) consumed different fiber-type bars (Karalus et al. 2012). The bars contained one of the following fibers: RS, inulin, oligofructose, corn fiber, or no added fiber. All fiber bars had 10 g of the fiber stated, and each bar had the same ingredients, except for fiber-type. A visual analogue scale was used to evaluate appetite, and no control diet was given previously. The RS fiber bar, with 10 g resistant wheat starch, had no effects on postprandial appetite ratings compared to the other bars. There were no differences in postprandial appetite ratings between bars. However, the oligofructose bar caused the most bloating and flatulence. Although the control bar contained no added fiber, it is unknown what type of fiber it already contained. The fiber already present in the bars before addition of fiber types could have influenced appetite.

It is inconclusive whether RS in solid foods is satisfying and satiating compared to other fiber types and foods without RS, based on these studies’ findings. Therefore, more studies are needed. Also, different solid foods with RS should be compared to see if one solid food with RS is more satiating and satisfying than other solid foods with RS.
However, two of the studies showed that the RS treatment was not preferred. For future research, different solid foods with only RS as the fiber type should be compared to determine which solid food with RS is preferred. In addition, sources of RS in solid foods should be compared to determine preference as well. Again, ethnicity, RS and appetite should be investigated, because there could be differences between ethnic groups such as Native Hawaiians, Japanese Americans, and Caucasians, for example.

**Conclusion**

The high prevalence of T2DM in HI is costly and causes numerous health complications. An alternative rice variety to white rice, which is a high GI staple food in HI, could be helpful in glycemic control, as well as appetite control. Because RS in solid foods has been shown to improve blood glucose and insulin response in studies, a rice variety with RS could be an alternative to white rice. Research is needed to determine whether high amylose rice could take on this role as an alternative to white rice for improved glycemic control.
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Chapter 2

The glycemic response to high amylose rice study
Abstract

Rice, a high glycemic index (GI) food, is a staple carbohydrate in many countries. Previous studies have indicated that solid foods with resistant starch (RS) can attenuate glycemic response. The present study compared three types of rice varieties on their effects on glycemic control. A single-blind, randomized, crossover clinical trial was performed with 18 healthy subjects, 9 males and 9 females. Three treatments were administered at three separate study visits: short grain rice, high amylose (HA) rice 1, and HA rice 2. Postprandial capillary blood glucose, venous blood glucose and insulin measurements, and appetite visual analogue scale (VAS) surveys were done over the course of two hours. The capillary blood glucose concentrations were significantly lower for HA rice 2 compared to short grain rice at 30 min, and for HA rice 1 and HA rice 2 compared to short grain rice at 45, 60, and 120 min. Capillary blood glucose area under the curve (AUC) was significantly lower for HA rice 1 and HA rice 2 compared to short grain rice. Venous insulin concentrations were significantly lower for HA rice 1 and HA rice 2 than short grain rice at 60 min, and for HA rice 1 than short grain rice at 120 min. Subjects were significantly more hungry at 30 minutes after HA rice 1 intake than HA rice 2 intake, but there were no other significant effects in appetite ratings. Subjects significantly preferred the palatability of the short grain rice over HA rice 1 and HA rice 2. The present study determined that intake of HA rice can attenuate postprandial blood glucose and insulin response in comparison to short grain rice.
Introduction

All rice varieties contain some dietary fiber. Dietary fiber is defined as non-digestible carbohydrates that are intrinsic and intact in plants (Institute of Medicine 2005). Resistant starch (RS) is a type of dietary fiber, and is present in high amylose rice varieties. It is defined as all types of starch and starch degradation products that resist digestion and absorption in the small intestine when consumed, and enter the large intestine (Topping et al. 2001, Cummings et al. 2007).

Current knowledge shows that RS in solid foods can have therapeutic effects on blood glucose and insulin response. In 10 studies, high RS rice, or other solid food sources with high RS such as muffins and bread, significantly attenuated blood glucose and insulin concentrations postprandially (Goddard et al. 1984, Li et al. 2010, Behall et al. 2002, Behall et al. 2006, Behall et al. 1998, Granfeldt et al. 1995, Hallstrom et al. 2011, Al-Tamimi et al. 2010, Westrate et al. 1993). In one study, after chronic high RS intake, subjects with T2DM had improved postprandial blood glucose and insulin response (Kwak et al. 2012). Resistant starch in solid foods can also affect appetite; in one study, high RS muffins were more satisfying and satiating than other fiber-type muffins (Willis et al. 2009).

White rice, a high carbohydrate food, is a staple in Hawaii (HI) (Leon Guerrero et al. 2009, Braginsky et al. 2011, Shortridge et al. 1998, Finucane et al. 2008), and a major energy source across ethnic groups in HI (Sharma et al. 2012, Leon Guerrero et al. 2009). Rice contributes to 15.8% of total energy intake in Native Hawaiian men and 11.8% in Native Hawaiian women, and 22.9% in Japanese American men and 19% in Japanese American women (Sharma et al. 2012). Rice contributes to 18% of total energy intake in
Filipino men (Leon Guerrero et al. 2009). Caucasians consume the least, with 6.4% of total energy intake from rice in men, and 5.3% in women. As white rice is a staple and part of culture in HI, efforts to limit or remove white rice from the diet, although it is a high carbohydrate food source, would be difficult. Instead, the best rice for glycemic control and appetite needs to be investigated.

The objective of this randomized, single-blind, crossover clinical trial study was to investigate the effects of two varieties of high amylose (high RS) rice on postprandial blood glucose, insulin, and appetite in healthy adults, compared to a control short-grain conventional white rice. Palatability of the rice varieties was also investigated. It was hypothesized that high RS rice consumption would result in lower blood glucose and insulin concentrations and would be more satiating, compared to the control rice.

**Methods**

**Subjects**

All aspects of this study were approved by the University of Hawaii at Manoa Institutional Review Board (CHS #19457) and registered through clinicaltrials.gov (registration #NCT01685879). A total of 18 subjects (9 males and 9 females) participated in the study. To recruit subjects, fliers were placed around the University of Hawaii at Manoa and Queen’s Medical Center. Subjects were screened by telephone or email for eligibility. After passing the initial screening, subjects completed a health history questionnaire to confirm eligibility. Inclusion criteria were if the subject was male or female, in good general health, 18-40 years old, non-vegetarian, non-smoking, had a BMI below 30, a habitual breakfast eater, habitually eats rice, able to fast for 12 hours, and
available in the morning on weekdays for study visits. Exclusion criteria were if the subject had diabetes (type I or II), hyper- or hypoglycemia, hyperinsulinemia, anorexia nervosa, bulimia nervosa, binge-eating disorder, or a gastrointestinal condition. A subject was also excluded if she was pregnant or lactating, he or she was taking any medications that controlled blood glucose or insulin, appetite, or weight, or if the subject had any known food allergies. After eligibility was confirmed, the first study visit was scheduled, and study visit and food record instructions were given.

Treatments

The HA rice varieties were Dixie Bell (HA rice 1) and Rondo (HA rice 2), obtained from the USDA Dale Bumpers National Rice Research Center in Stuttgart, Arkansas. These rice varieties were bred to contain more amylose, but were not genetically modified. The conventional short grain rice (control) used was Tamanishiki brand, available at grocery stores in the Honolulu, HI area. The portion size for rice treatments were matched for volume.

Rice treatments were prepared using a conventional rice cooker. A ½ cup rice and ¾ cup water were placed in the rice cooker. When finished cooking, a treatment of HA rice was weighed to 150 g, and a treatment of conventional short grain rice was weighed to 175 g. These weights corresponded to a 1¼ cup (300 mL) portion size. The RS and available carbohydrate amounts per rice serving, determined in a laboratory setting, are listed in Table 1. After rice preparation, the rice treatments were stored in a refrigerator until the study visit. Rice was prepared up to 3 days before a study visit. The rice treatments were reheated in a microwave for 1 minute on high power directly before
consumption. Subjects consumed the rice in a paper bowl with a plastic spoon, with no other ingredients. Throughout the study visit, subjects were allowed to drink water.

A glucose beverage treatment was administered at one of the four study visits. However, due to a possible error in the glucose dose of the beverage, the data from the glucose beverage treatment was not included in analysis (Appendix A).

Study visits

The day prior to the study visit, subjects kept a 1-day food record to document habitual diet. Subjects were instructed to fast after midnight (except for water), and were instructed to drink plenty of water the night before and the morning of the visit to assist with venous blood draws. The subjects were instructed on how to keep a food record by phone or in person, and the food record also included instructions and an example food record. At the visit, the project coordinator identified and fixed any missing information or errors on the food records by asking the subjects questions on its content.

Subjects completed a total of 4 study visits in this randomized, single-blind crossover study. At each visit, subjects consumed HA rice 1, HA rice 2, conventional short grain rice, or a glucose beverage. A timeline of the study visits is shown in Figure 1.

Each visit lasted approximately 2.5 hours at Queen’s Medical Center. Study visits were held on Monday and Friday mornings. If it was the subjects’ first visit, subjects gave consent after reading through a consent form.

Directly before time 0 minutes, subjects had their height and weight taken at each visit. At time 0 minutes, the subjects had a venous blood draw, a capillary glucose
measurement, and completed a visual analogue scale (VAS) to assess baseline appetite. Next, subjects consumed 1 of the 3 treatments and were instructed to finish the treatment within 15 minutes. At time 15 minutes, a second glucose finger prick was done, an appetite VAS was given, as well as a palatability VAS on the treatment. At times 30, 45, 60, 90, and 120 minutes, another finger prick was done and appetite VAS was given. At times 60 and 120 minutes, an additional blood draw was taken.

Subjects worked quietly, rested, or watched television during their time in the study clinic. If subjects were cold, blankets were offered, and if necessary, a heating pad was used in between venous blood draws to aid with the draws. When the visit was completed, subjects were given juice and granola bars. Subjects also received a compensation of $75 to Ala Moana Shopping Center (Honolulu, HI) after each visit.

A flow diagram depicting the passage of subjects through the intervention is shown in Figure 2.

Visual analogue scales

Appetite was evaluated using a 100 mm VAS. After reading a question, subjects marked where they felt their answer belonged on a 100 mm line, using it as a scale (0 mm to 100 mm). Questions were: How hungry do you feel? Response options: Not hungry at all (0 mm) to I have never been more hungry (100 mm); How satisfied do you feel? Response options: I am completely empty (0 mm) to I cannot eat another bite (100 mm); How full do you feel? Response options: Not full at all (0 mm) to Totally full (100 mm); How much do you think you can eat? Response options: Nothing at all (0 mm) to A lot
Flint et al. (2000) determined appetite VAS scores to be reproducible and valid for appetite research studies.

At time 15 minutes, palatability of the treatment was assessed by five characteristics, from bad (0 mm) to good (100 mm). These characteristics were visual appeal, smell, taste, texture, and overall pleasantness of the treatment given.

**Blood analysis**

Blood glucose concentrations at 0, 15, 30, 45, 60, 90, and 120 minutes were measured by finger prick with a One Touch Ultra glucose meter (Life Scan, Inc., Milpitas, CA). The blood samples from the venous blood draws at 0, 60, and 120 minutes were analyzed by Diagnostic Lab Services for blood glucose and insulin concentration.

Capillary blood glucose area under the curves (AUC) were calculated using the trapezoid rule (Wolever 1990).

**Food record analysis**

The Nutrition Data System for Research (NDSR) 2012 (Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN) was used to determine total nutrient and calorie intakes for each food record. If a food was not listed in the NDSR program, the best match for the food was selected.
Statistical analysis

Data were analyzed with SAS statistical software (Version 9.3, SAS Institute, Cary, North Carolina). Results are presented as mean ± standard error of the mean. Treatment effects on biochemical parameters, appetite ratings, and dietary intake were determined using PROC MIXED to control for subject variation. Significant differences were determined at $p < 0.05$.

Results

Demographics

The demographic information on the study subjects is presented in Table 2.

Glucose response

The mean capillary blood glucose concentration at 30 min was significantly higher for the short grain rice than HA rice 2 (Table 3). At 45, 60, and 120 min, the mean capillary blood glucose concentrations were significantly higher for the short grain rice than both HA rice 1 and HA rice 2 (Table 3). In addition, the mean AUC for capillary blood glucose concentrations was significantly higher for the short grain rice than both HA rice 1 and HA rice 2 (Table 3). Finally, the mean venous blood glucose concentration at 60 min was significantly higher for the short grain rice than HA rice 2 (Table 4).

Insulin response

The mean venous insulin concentration at 60 min was significantly higher for the short grain rice than both HA rice 1 and HA rice 2 (Table 4). At 120 min, the mean
insulin concentration was significantly higher for the short grain rice than HA rice 1 (Table 4).

**Appetite**

Subjects were significantly more hungry at 30 minutes after HA rice 1 intake than HA rice 2 intake (Table 5). Before treatments, at 0 min, subjects were significantly more satisfied before HA rice 2 intake than before short grain rice intake (Table 6).

There were no significant differences between fullness and treatment intakes, and between ability to eat more and treatment intakes (Table 7, Table 8).

**Dietary intake**

Dietary intake 24 hours prior to study visits among treatments was not significantly different (Table 9). Previous total energy intake, total carbohydrate intake, or total available carbohydrate intake did not influence fasting glucose the day of the study visit.

**Palatability**

Visually, subjects significantly preferred the short grain rice over HA rice 2 (Table 10). The taste, texture, and pleasantness of the short grain rice were all significantly preferred over both HA rice 1 and HA rice 2 (Table 10). There were no significant differences in smell between the rice treatments (Table 10).
Discussion

Solid foods containing RS have shown therapeutic effects on postprandial blood glucose response and insulin in healthy individuals. The HA rice varieties in the present study significantly attenuated postprandial blood glucose response with an RS dose amount of 2.25 g (HA rice 1) and 2.10 g (HA rice 2), compared to the short grain rice. In a previous study, the RS dose per serving of rice that significantly improved postprandial blood glucose response in healthy adults (Chinese, 9 males, 7 females aged 23-26 years, BMI of 18-24 kg/m²) was 8.05 g, about 6 g more than the present study (Li et al. 2010). Therefore, an 8.05 g RS dose in a serving of rice may be unnecessary. In addition, Li et al. (2010) used a transgenic rice, while HA rice 1 and HA rice 2 are not genetically modified. However, Chiu et al. (2013) found that a 4.4 g RS dose in a serving of rice had no effects on postprandial blood glucose response in healthy adults (12 males, 9 females, mean age 29, mean BMI of 22.9, ethnicity not stated). The effective RS dose in rice on postprandial blood glucose response needs to be further investigated.

The present study also found that insulin response was significantly lower at 60 min with an RS dose of 2.25 g (HA rice 1) and 2.10 g (HA rice 2), and at 120 min with the RS dose of 2.10 g (HA rice 1), compared to the short grain rice. The RS dose value of 8.05 g in a serving of rice significantly decreased insulin concentrations after intake starting at 45 min, then at 60, 90 and 120 min in the Li et al. (2010) study. Because insulin concentration was not measured at 45 min in the present study, it is unknown whether HA rice 1 and HA rice 2 affected insulin response at 45 min. For rice, an RS dose of 2.10 g per serving may be enough to reduce postprandial insulin response at 60
and 120 min. Whether this dose is enough to reduce postprandial insulin response at 45 min needs to be determined.

In addition, the subjects in the present study were habitual rice eaters, determined at the initial screening for eligibility. The Li et al. (2010) study was done in China where rice is also a staple. Non-habitual rice eaters may have a different glycemic response to RS in rice. A study should investigate the effects of RS in rice on non-habitual rice eaters vs. habitual rice eaters.

For other solid foods (muffins, bread, a nutrition bar, and corn cakes), a range from 6.5 g-15.6 g RS dose per serving significantly lowered postprandial blood glucose response, and insulin response from 30 min to 2 hours in healthy adults (Behall et al. 2006, Behall et al. 2002, Hallstrom et al. 2011, Al-Tamimi et al. 2010, Granfeldt et al. 1995). However, 7.7 g RS in a serving of bread had no significant effects on insulin response in healthy adults (7 males, 7 females, aged 20-35 years, mean BMI of 22.2 kg/m², ethnicity not stated) (Hallstrom et al. 2011). The RS dose in rice of the present study is much lower than the RS dose in these studies. It could be that an RS dose as low as 2.10 g in rice may attenuate postprandial glycemic response, whereas a higher amount of RS, such as 6.5 g or more, is needed in other solid foods. However, because Hallstrom et al. (2011) found no effects of 7.7 g RS in bread on insulin response, RS could have different or no effects on glycemic response depending on the food source.

Studies have investigated the effects of intake of RS in solid foods on individuals with T2DM. Individuals with T2DM are afflicted with abnormally high fasting blood glucose concentrations, so postprandial blood glucose attenuation from RS intake may help with self-management. A treatment of rice with 7.8 g RS had no significant effects
on postprandial blood glucose and insulin response in T2DM patients (7 males, 5 females, mean age 58, mean BMI of 30, ethnicity not stated, T2DM duration mean of 4 years) (Larsen et al. 1996). But when subjects with untreated borderline T2DM (9 males, 11 females, mean age 50.5 years, fasting blood glucose 100-140 mg/dL, BMI not stated, Japanese) consumed bread with 6 g RS, postprandial blood glucose and insulin responses were significantly reduced (Yamada et al. 2005). Individuals with borderline T2DM may need a lower dose of RS to see effects, while diabetic individuals may need a higher RS dose. Also, ethnicity may influence glycemic response. In the Yamada et al. (2005) study, subjects were Japanese, but ethnicity is not stated for the subjects in the Larsen et al. (1996) study.

Additionally, studies have investigated the effects of chronic intake of rice with RS on glycemic response in those with or at risk for T2DM. Kwak et al. (2012) fed a serving of rice with 6.51 g RS daily for 4 weeks to subjects with T2DM, impaired fasting glucose, or impaired glucose tolerance (47 males, 38 females, mean age 50, mean BMI of 25, Korean). This chronic intake significantly reduced postprandial glucose and insulin AUC, and fasting insulin. However, in another study, subjects at risk for developing T2DM with insulin resistance (8 males, 7 females, mean age 36, mean BMI of 37, African American) consumed bread with 12 g RS daily for 14 weeks, but no significant differences in blood glucose or insulin response were found (Penn-Marshall et al. 2010). These findings are inconclusive; chronic intake of RS may have a threshold length of its effect on glycemic response, but further study is needed. Also, ethnicity may be a factor here.
Studies on RS in solid foods and its effects on appetite are limited. Willis et al. (2009) found that among muffins with different fiber types (RS, low fiber, corn bran, beta-glucan and oat fiber, polydextrose), the RS muffin (8 g RS) was the most satiating in healthy adults (7 males, 13 females, aged 18-65 years, mean BMI of 23, ethnicity not stated). However, in another study, there were no significant differences in appetite ratings after consumption of different fiber-type bars (RS (10 g), inulin, oligofructose, corn fiber) in healthy women (22 females, mean age 25, mean BMI of 23, ethnicity not stated) (Karalus et al. 2012). Chiu et al. (2013) found no significant differences in appetite between short grain rice and the rice containing 4.4 g RS in healthy adults (12 males, 9 females, mean age 29, mean BMI of 22.9, ethnicity not stated). In the present study, the only significant difference found was at 30 min, where subjects were more hungry after HA rice 1 treatment than after the HA rice 2 treatment. However, HA rice 1 had more RS g amount than HA rice 2 (2.25 vs. 2.10). It could be that subjects significantly visually preferred short grain rice over HA rice 2, and subjects may have had a loss of appetite from HA rice 2 due to a lower rating of visual appearance. All other ratings (fullness, satisfaction, how much can you eat) had no significant differences. However, subjects were significantly more satisfied before HA rice 2 intake than before short grain rice intake, which may have influenced their appetite after treatment intake. In addition, the serving sizes of were 175 g for the HA rice treatments, and 150 g for the short grain rice. It could be this weight difference that is acting as a confounder on appetite, though both weights corresponded to a 1¼ cup portion size.

To assess reliability of RS dose in rice cultivars, Patindol et al. (2010) compared rice cultivars grown in the southern United States. The RS amount in Dixie Bell and
Rondo cultivars was stable across growing locations in Arkansas, Louisiana, Missouri, Mississippi, and Texas, while other cultivars were not stable in RS amounts.

Limitations

There are some limitations to this study. First, only three measurements of venous blood glucose and insulin concentrations were taken, thus AUC for venous blood glucose and insulin was not calculated. The study visit protocol originally had serial venous blood draws (at 0, 15, 30, 45, 60, 90, and 120 min). However, after six study visits, the research staff realized that administering seven venous blood draws was difficult. Subjects were uncomfortable, some were bruising, and the venous draws became difficult after the first few draws within a study visit. Therefore, study visits were put on hold until the study visit protocol was modified to have only three venous blood draws (at 0, 60, and 120 min) for subject comfort and study visit ease.

Visit was a significant predictor for the VAS hunger values at time 0 minutes, and for the hunger AUC values (Table 5). Visit number may have made a difference in these outcomes due to nervousness or discomfort of subjects on the first visit. This could have affected the subjects’ feeling of hunger, even though they arrived fasted. In addition to the invasiveness of venous blood draws, the location of the study clinic in the hospital was secluded and windowless. Also, the study clinic was highly air-conditioned, which may have influenced study subject response, depending on the warmth of the clothes they were wearing. On this note, because the study clinic was highly air-conditioned, the venous blood draws were more difficult when the subject was cold.
When screening subjects for eligibility, although questions relating to blood glucose were asked, a fasting blood glucose measurement was not done due to cost. For future research, this measurement should be taken to control for subjects with normal fasting blood glucose levels.

Conclusion

The present study demonstrated that HA rice 1 and HA rice 2 are capable of attenuating postprandial blood glucose and insulin response compared to short grain rice. The serving size of these rice varieties that had significant effects was practical and can be easily incorporated into the diet. Future work should include an investigation on the RS dose in rice needed to have effects on postprandial glucose and insulin response in pre-diabetic and diabetic individuals.
References


Figure 1. Timeline of the study visits.
**Figure 2.** Flow diagram depicting the passage of subjects through the intervention.

- **Assessed for eligibility (n=29)**
- **Excluded (n=3)**
  - Did not meet inclusion criteria (n=3)
  - Declined to participate (n=0)
- **Randomized (n=26)**
- **Allocated to intervention (n=26)**
  - Males (n=12)
  - Females (n=14)
- **Lost to follow-up**
  - Did not arrive for study visit (n=1)
- **Discontinued intervention**
  - Schedule conflict (n=2)
  - Adverse event (fainting) (n=2)
  - Did not finish rice in 15 min (n=1)
  - Uncomfortable to return (n=1)
  - Requested to withdraw (difficult blood draw)
- **Analyzed (n=18)**
  - Males (n=9)
  - Females (n=9)
Table 1. RS and available carbohydrate amount per rice treatment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Amount (g)</th>
<th>RS (g)</th>
<th>Available carbohydrate (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HA rice 1</td>
<td>150</td>
<td>2.25</td>
<td>46.95</td>
</tr>
<tr>
<td>HA rice 2</td>
<td>150</td>
<td>2.10</td>
<td>57.30</td>
</tr>
<tr>
<td>Control</td>
<td>175</td>
<td>1.40</td>
<td>46.95</td>
</tr>
</tbody>
</table>

Table 2. Study subject demographics

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Total (n=18)</th>
<th>Men (n=9)</th>
<th>Women (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years) (Mean, Range)</td>
<td>26, 21-37</td>
<td>26, 25-30</td>
<td>27, 21-37</td>
</tr>
<tr>
<td>Height (m) (Mean, Range)</td>
<td>1.69, 1.57-1.88</td>
<td>1.74, 1.65-1.88</td>
<td>1.63, 1.57-1.73</td>
</tr>
<tr>
<td>Weight (kg) (Mean, Range)</td>
<td>66, 47-86</td>
<td>77, 68-86</td>
<td>57, 47-70</td>
</tr>
<tr>
<td>BMI (kg/m²) (Mean, Range)</td>
<td>23.2, 20.1-26.8</td>
<td>25.2, 23.9-26.8</td>
<td>21.2, 18.4-23.3</td>
</tr>
</tbody>
</table>

Table 3. Capillary blood glucose values (mg/dL, mean±SEM) and AUC (mg*min/dL, mean±SEM) before (0 min) and after treatment intake in healthy adults (n=18)*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Short Grain Rice</th>
<th>HA Rice 1</th>
<th>HA Rice 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 min</td>
<td>94±3</td>
<td>98±2</td>
<td>94±3</td>
<td>0.2791</td>
</tr>
<tr>
<td>15 min</td>
<td>99±3</td>
<td>101±4</td>
<td>98±3</td>
<td>0.5769</td>
</tr>
<tr>
<td>30 min</td>
<td>137±5**</td>
<td>126±5</td>
<td>122±6B</td>
<td>0.0555</td>
</tr>
<tr>
<td>45 min</td>
<td>144±5A</td>
<td>127±5B</td>
<td>129±7B</td>
<td>0.0470</td>
</tr>
<tr>
<td>60 min</td>
<td>142±7A***</td>
<td>125±6B***</td>
<td>118±5B****</td>
<td>0.0010</td>
</tr>
<tr>
<td>90 min</td>
<td>117±4</td>
<td>112±5</td>
<td>111±3</td>
<td>0.4173</td>
</tr>
<tr>
<td>120 min</td>
<td>112±4A***</td>
<td>104±4B***</td>
<td>104±2B****</td>
<td>0.0402</td>
</tr>
<tr>
<td>AUC</td>
<td>3519±390A***</td>
<td>2170±371B***</td>
<td>2419±433B****</td>
<td>0.0063</td>
</tr>
</tbody>
</table>

*Some data have missing values.
**Within a row, cells with different superscript letters are significantly different (p<0.05).
***No value for 1 subject.
****No value for 2 subjects.
Table 4. Venous blood glucose (mg/dL, mean±SEM) and insulin (μIU/mL, mean±SEM) values before (0 min) and after treatment intake in healthy adults (n=18)*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Short Grain Rice</th>
<th>HA Rice 1</th>
<th>HA Rice 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose, 0 minutes</td>
<td>83±2</td>
<td>83±2</td>
<td>85±1</td>
<td>0.3436</td>
</tr>
<tr>
<td>Glucose, 60 minutes</td>
<td>114±6**</td>
<td>105±6</td>
<td>103±5^H</td>
<td>0.0790</td>
</tr>
<tr>
<td>Glucose, 120 minutes</td>
<td>91±3</td>
<td>95±4</td>
<td>95±2</td>
<td>0.3650</td>
</tr>
<tr>
<td>Insulin, 0 minutes</td>
<td>5.6±0.7</td>
<td>6.1±0.9</td>
<td>6.5±0.7</td>
<td>0.4334</td>
</tr>
<tr>
<td>Insulin, 60 minutes</td>
<td>38.3±6.7***</td>
<td>24.3±3.8^H</td>
<td>29.2±6.3^H***</td>
<td>0.0009</td>
</tr>
<tr>
<td>Insulin, 120 minutes</td>
<td>21.0±4.3^A</td>
<td>15.2±2.5^B</td>
<td>18.4±4.0</td>
<td>0.0467</td>
</tr>
</tbody>
</table>

*Some data have missing values.
**Within a row, cells with different superscript letters are significantly different (p<0.05).
***No value for 1 subject.

Table 5. Hunger values (mean±SEM) and AUC (mean±SEM) before (0 min) and after treatment intake from VAS hunger question* in healthy adults (n=18)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Short Grain Rice</th>
<th>HA Rice 1</th>
<th>HA Rice 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 min***</td>
<td>59±6</td>
<td>61±6</td>
<td>52±7</td>
<td>0.1655</td>
</tr>
<tr>
<td>15 min</td>
<td>41±5</td>
<td>45±5</td>
<td>38±6</td>
<td>0.4946</td>
</tr>
<tr>
<td>30 min</td>
<td>42±5</td>
<td>49±5^A**</td>
<td>38±5^H</td>
<td>0.0774</td>
</tr>
<tr>
<td>45 min</td>
<td>45±5</td>
<td>49±5</td>
<td>47±5</td>
<td>0.8566</td>
</tr>
<tr>
<td>60 min</td>
<td>47±5</td>
<td>52±6</td>
<td>50±5</td>
<td>0.5775</td>
</tr>
<tr>
<td>90 min</td>
<td>57±6</td>
<td>54±6</td>
<td>55±5</td>
<td>0.8814</td>
</tr>
<tr>
<td>120 min</td>
<td>57±6</td>
<td>56±6</td>
<td>57±5</td>
<td>0.9689</td>
</tr>
<tr>
<td>AUC***</td>
<td>-18±11</td>
<td>-17±8</td>
<td>-6±9</td>
<td>0.3197</td>
</tr>
</tbody>
</table>

* How hungry do you feel? “Not hungry at all” (0 mm) to “I have never been more hungry” (100 mm)
**Within a row, cells with different superscript letters are significantly different (p<0.05).
*** Visit was a significant predictor at this time point and included in the statistical model.
Table 6. Satisfied values (mean±SEM) and AUC (mean±SEM) before (0 min) and after treatment intake from VAS satisfied question* in healthy adults (n=18)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Short Grain Rice</th>
<th>HA Rice 1</th>
<th>HA Rice 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 min</td>
<td>21±4**</td>
<td>26±6</td>
<td>30±6**</td>
<td>0.1191</td>
</tr>
<tr>
<td>15 min</td>
<td>46±5</td>
<td>54±6</td>
<td>51±6</td>
<td>0.2901</td>
</tr>
<tr>
<td>30 min</td>
<td>51±4</td>
<td>51±5</td>
<td>51±5</td>
<td>0.9984</td>
</tr>
<tr>
<td>45 min</td>
<td>48±4</td>
<td>52±5</td>
<td>52±5</td>
<td>0.5799</td>
</tr>
<tr>
<td>60 min</td>
<td>47±5</td>
<td>48±5</td>
<td>50±5</td>
<td>0.7968</td>
</tr>
<tr>
<td>90 min</td>
<td>44±5</td>
<td>46±6</td>
<td>50±5</td>
<td>0.4664</td>
</tr>
<tr>
<td>120 min</td>
<td>38±5</td>
<td>43±6</td>
<td>44±5</td>
<td>0.3746</td>
</tr>
<tr>
<td>AUC</td>
<td>46±8</td>
<td>42±9</td>
<td>38±8</td>
<td>0.5369</td>
</tr>
</tbody>
</table>

*How satisfied do you feel? “I am completely empty” (0 mm) to “I cannot eat another bite” (100 mm)
** Within a row, cells with different superscript letters are significantly different (p<0.05).

Table 7. Fullness values (mean±SEM) and AUC (mean±SEM) before (0 min) and after treatment intake from VAS fullness question* in healthy adults (n=18)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Short Grain Rice</th>
<th>HA Rice 1</th>
<th>HA Rice 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 min</td>
<td>23±5</td>
<td>19±4</td>
<td>26±6</td>
<td>0.4609</td>
</tr>
<tr>
<td>15 min</td>
<td>50±5</td>
<td>55±6</td>
<td>54±6</td>
<td>0.7479</td>
</tr>
<tr>
<td>30 min</td>
<td>55±4</td>
<td>53±5</td>
<td>53±5</td>
<td>0.9250</td>
</tr>
<tr>
<td>45 min</td>
<td>50±5</td>
<td>49±5</td>
<td>47±5</td>
<td>0.8841</td>
</tr>
<tr>
<td>60 min</td>
<td>48±5</td>
<td>42±5</td>
<td>47±4</td>
<td>0.3195</td>
</tr>
<tr>
<td>90 min</td>
<td>43±5</td>
<td>39±5</td>
<td>42±5</td>
<td>0.5938</td>
</tr>
<tr>
<td>120 min</td>
<td>41±6</td>
<td>35±6</td>
<td>38±5</td>
<td>0.4398</td>
</tr>
<tr>
<td>AUC</td>
<td>45±12</td>
<td>47±8</td>
<td>39±7</td>
<td>0.6477</td>
</tr>
</tbody>
</table>

*How full do you feel? “Not full at all” (0 mm) to “Totally full” (100 mm)
**Table 8.** How much can you eat values (mean±SEM) and AUC (mean±SEM) before (0 min) and after treatment intake from VAS how much can you eat question* in healthy adults (n=18)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Short Grain Rice</th>
<th>HA Rice 1</th>
<th>HA Rice 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 min</td>
<td>71±4</td>
<td>65±6</td>
<td>62±7</td>
<td>0.1482</td>
</tr>
<tr>
<td>15 min</td>
<td>48±6</td>
<td>45±6</td>
<td>46±6</td>
<td>0.7241</td>
</tr>
<tr>
<td>30 min</td>
<td>49±5</td>
<td>53±5</td>
<td>48±6</td>
<td>0.4260</td>
</tr>
<tr>
<td>45 min</td>
<td>51±5</td>
<td>53±6</td>
<td>53±5</td>
<td>0.8615</td>
</tr>
<tr>
<td>60 min</td>
<td>53±6</td>
<td>57±6</td>
<td>53±5</td>
<td>0.4706</td>
</tr>
<tr>
<td>90 min</td>
<td>59±6</td>
<td>59±7</td>
<td>57±6</td>
<td>0.8169</td>
</tr>
<tr>
<td>120 min</td>
<td>63±6</td>
<td>66±5</td>
<td>58±6</td>
<td>0.1758</td>
</tr>
<tr>
<td>AUC</td>
<td>-30±9</td>
<td>-16±7</td>
<td>-17±9</td>
<td>0.2074</td>
</tr>
</tbody>
</table>

*How much do you think you can eat? “Nothing at all” (0 mm) to “A lot” (100 mm)

**Table 9.** Dietary intake during 24 hours prior to study visit (mean±SEM) in healthy adults (n=18)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Short Grain Rice</th>
<th>HA Rice 1</th>
<th>HA Rice 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total energy (kcal)</td>
<td>1851±196</td>
<td>2046±123</td>
<td>2207±270</td>
<td>0.3251</td>
</tr>
<tr>
<td>Total fat (g)</td>
<td>74±9</td>
<td>85±8</td>
<td>94±15</td>
<td>0.3581</td>
</tr>
<tr>
<td>Total carbohydrate (g)</td>
<td>215±24</td>
<td>240±16</td>
<td>241±25</td>
<td>0.4629</td>
</tr>
<tr>
<td>Total protein (g)</td>
<td>81±12</td>
<td>82±8</td>
<td>97±14</td>
<td>0.4579</td>
</tr>
<tr>
<td>Total fiber (g)</td>
<td>19±2</td>
<td>20±2</td>
<td>17±2</td>
<td>0.5292</td>
</tr>
<tr>
<td>Total available carbohydrate (g)</td>
<td>196±23</td>
<td>220±15</td>
<td>222±24</td>
<td>0.4339</td>
</tr>
<tr>
<td>% kcal from carbohydrate</td>
<td>46±2</td>
<td>47±3</td>
<td>45±2</td>
<td>0.7788</td>
</tr>
<tr>
<td>% kcal from fat</td>
<td>34±2</td>
<td>35±2</td>
<td>36±2</td>
<td>0.8196</td>
</tr>
<tr>
<td>% kcal from protein</td>
<td>17±1</td>
<td>16±1</td>
<td>17±1</td>
<td>0.7834</td>
</tr>
<tr>
<td>% kcal from alcohol</td>
<td>2±1</td>
<td>1±1</td>
<td>2±1</td>
<td>0.7590</td>
</tr>
</tbody>
</table>
Table 10. Treatment palatability (mean±SEM) from VAS assessment* in healthy adults (n=18)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Short Grain Rice</th>
<th>HA Rice 1</th>
<th>HA Rice 2</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual</td>
<td>73±3A**</td>
<td>68±4</td>
<td>65±5B</td>
<td>0.1260</td>
</tr>
<tr>
<td>Smell</td>
<td>69±3</td>
<td>64±5</td>
<td>67±5</td>
<td>0.5021</td>
</tr>
<tr>
<td>Taste</td>
<td>69±3A</td>
<td>55±5B</td>
<td>59±5B</td>
<td>0.0421</td>
</tr>
<tr>
<td>Texture</td>
<td>75±3A</td>
<td>52±6B</td>
<td>56±5B</td>
<td>0.0023</td>
</tr>
<tr>
<td>Pleasantness</td>
<td>73±3A</td>
<td>65±5B</td>
<td>63±4B</td>
<td>0.0322</td>
</tr>
</tbody>
</table>

* Each characteristic was assessed as “bad” (0 mm) to “good” (100 mm).
**Within a row, cells with different superscript letters are significantly different (p<0.05).
Appendix
Appendix A: Glucose beverage limitation

The randomized controlled crossover trial described in chapter 2 was originally designed as a four treatment crossover. The treatments were a glucose beverage, short grain rice, high amylose rice 1, and high amylose rice 2. Due to concerns regarding the glucose beverage dose, the data from the glucose beverage treatment was not included in the chapter 2 analysis and discussion. The data is presented here in Appendix A along with a brief description of the situation.

Nursing staff were responsible for ordering the glucose beverage, with a 50 g dose of glucose. Part way through the study, glucose beverages were re-ordered. Upon completion of the study, the glucose beverage product information provided by the nursing staff indicated that the beverage contained 100 g glucose. There is no record of the orders, because the vendor does not save invoices past 30 days. Study staff (principal investigator (PI) and study coordinator) never confirmed that the correct 50 g glucose beverage was ordered in the initial order or in the reorder. Additionally, the study staff has no record of the product consumed at the glucose treatment study visits for the individual subjects. Due to the abnormally high glucose AUC for five subjects, and the inconsistent product information, the PI questioned the glucose dose, and removed it from the data analysis. This study was conducted at a clinical research center that facilitated other studies. Thus, it is possible that the glucose beverages of this study were mixed up by researchers from other projects.

The data shows that five subjects had a very different response to the glucose beverage than the other 13 subjects. These five subjects may have received 100 g glucose. Their capillary blood glucose values are very high up to 60 min after glucose
beverage intake, while the glucose response to the beverage for the other 13 subjects had similar trend lines to the rice treatment glucose responses.

In Figures A.1 and A.2, the blood glucose AUC values after glucose beverage intake for the subjects of this study are compared to the blood glucose AUC values of subjects after glucose beverage intake from another masters thesis study project (Miller 2002). In the Miller (2002) study, all 8 subjects specifically received a 50 g glucose beverage. The subjects had three visits with the glucose beverage treatment. In Figure A.1, the mean blood glucose AUC of the 8 subjects’ three study visits is plotted. In Figure A.2, the blood glucose AUC from all three visits of the 8 subjects is plotted.

When the glucose AUC values from this study are compared to the Miller 2002 study, the five subjects’ AUC values are higher than the subjects from the Miller 2002 study, and the other 13 subjects of this study. In Figure A.1, all five subjects’ AUC are greater than an AUC of 6000 mg*min/dL. In Figure A.2, two points are above an AUC of 6000 mg*min/dL from the Miller study (6233 and 6435 mg*min/dL). These points are from the third visit of two different subjects of the Miller study. Because these high values happened in these two individuals, it could be that the 5 subjects in this study may have reacted similarly to these two individuals after 50 g glucose intake. However, because the dose cannot be confirmed, we cannot be certain that this was a natural response to the same dose.

It was thought that these 5 subjects might have had high fasting blood glucose levels to begin with, which may have been the reason for the high blood glucose AUC after the glucose beverage intake. The mean capillary fasting blood glucose values from the 4 study visits for the five subjects were: 107.5 (range 100-114), 99.8 (range 76-117),
96.6 (range 96-102), 95 (range 88-107), and 90.3 mg/dL (range 80-104). These values are consistent with the range of fasting glucose values for the other 13 subjects’ individual study visits (range 71-124 mg/dL). A normal fasting blood glucose level is defined as 99 mg/dL or below (National Institutes of Health 2013). A pre-diabetic fasting blood glucose level is between 100-125 mg/dL. According to this definition, two of the subjects with high glucose AUC may be pre-diabetic (107.5 mg/dL, 99.8 mg/dL), and therefore these subjects may have reacted differently to the glucose beverage. The subject with the mean 107.5 mg/dL value (all 4 fasting glucose values were 100 mg/dL or greater) had a similar fasting time to the other subjects prior to the study visits, but did have a higher refined carbohydrate intake compared to others. The subject with the mean 99.8 mg/dL had a family history of diabetes, but also had two fasting glucose values below 100 mg/dL (76 and 90 mg/dL). In addition, some of the 13 other subjects may also be pre-diabetic (e.g., one subject had one fasting glucose value of 124 mg/dL, and a mean fasting glucose value of 106 mg/dL). Due to this finding, in future research, subject screening should be more precise. When subjects of this study were screened for eligibility, the only questions related to blood glucose were if the subject took medications to control blood sugar, or if the subject was diagnosed with diabetes, hyperglycemia, or hypoglycemia. For future reference, subjects should have a fasting blood glucose measurement done to test for eligibility.

Palatability of the treatments was measured through a VAS survey on visual appearance, smell, taste, texture, and pleasantness. It was thought that a 100 g glucose beverage may be less palatable than a 50 g glucose beverage. But two of the five subjects with the high glucose AUC gave the glucose beverage a range of 82-93 (0-100 mm scale,
bad to good) on the five characteristics. Therefore, these two subjects believed the glucose beverage to be palatable. However, the other three subjects gave similar ratings as the 13 subjects with normal blood glucose AUC, all of whom did not prefer the glucose beverage. Thus, the palatability measurements are inconclusive in determining whether these 5 subjects may have received 100 g glucose.

To prevent this mishap in the future, thorough follow-up and re-checking must be done. Instead of giving a supply order to the clinical research nurse staff and trusting that the order will be correct, more steps should be taken. First, supply invoices should be copied and faxed to the research staff. Once the supplies are delivered, they should be checked by research staff for accuracy. Finally, during study visits, supplies should be double-checked that they are correct before use.

Reference

Figure A.1. Comparison of blood glucose AUC after glucose beverage intake in Zenel 2013 study (•, subjects 1-18) and Miller 2002 study (■, subjects 19-26). The Miller AUC values are the mean AUC from 3 study visits.

Figure A.2. Comparison of blood glucose AUC after glucose beverage intake in Zenel 2013 study (•, subjects 1-18) and Miller 2002 study (Δ=visit 1, □=visit 2, O=visit 3, subjects 19-26).
Appendix B: Study visit materials

Initial Health Screening Questionnaire
The Glycemic Response to High Amylose Rice Study
This questionnaire is to be administered by telephone or email to screen subjects for initial eligibility.
Thank you for your interest in our study. I have a few short questions to ask you so I can determine if you are eligible for a preliminary visit. All of this information will be stored confidentially. If you are not eligible for a preliminary visit, this information will be destroyed.

What is your age? ____________  

Yes       No

Do you smoke or chew tobacco?

Do you eat breakfast?

How many days per week do you eat breakfast? ________

Are you able to fast for 12 hours (nothing to eat or drink besides water)?

Are you available from 7:00am -10:30 am on weekdays for study visits?

Are you willing to participate in a research study?

Subjects who are 18-40 yrs old, nonsmokers, nonvegetarians, eat breakfast at least 4 times per week, are available for study visits and are willing to participate in a research study are eligible to attend a preliminary visit.

Eligible?  Yes  No

If YES, study staff will schedule a preliminary visit.

Name ___________________________          Email _____________________

Phone_________________     Prelim. Visit Date/Time____________________

If subject is not eligible for a preliminary visit, this form will be destroyed.
Glycemic Response to Rice

Health History Questionnaire

Thank you for your interest in participating in our study. We need to confirm your eligibility for this study. You will be answering a health history questionnaire, but you do not need to answer any questions which you do not feel comfortable answering. If you do not meet the criteria for the study, we will destroy the information collected during this interview.

SUBJECT ID_____________________________DATE ____________________

DATE OF BIRTH _______ AGE_________________

HT   WT               (office use : BMI _____)

Yes   No

Do you smoke or chew tobacco?  

For women, are you currently pregnant or lactating?  

For women, have you been pregnant or lactating within the last 6 months?  

For women, have you missed a menstrual cycle in the last 6 months?  

Are you a vegetarian?  

Do you eat rice?  
If YES, how often?  

Do you have any food or other allergies?  

If YES, what are they?  

Are you taking any medications to do the following:  

Yes   No

Control blood sugar  

Control insulin  

Control appetite  

Lose Weight
Control depression

Antibiotics

Have you taken any medication in the past month (over the counter or prescription) or are you currently taking any medication?

Medications: Dose/Frequency:

Have you ever been diagnosed with the following diseases or conditions:

- Diabetes (type I or type II)?
- Hyperglycemia?
- Hyperinsulinemia?
- Hypoglycemia?
- Anorexia nervosa?
- Bulimia nervosa?
- Binge eating disorder?
- Any gastrointestinal conditions?

If so, please explain:

Have you lost or gained weight in the past 3 months?

If yes, how much?

Do you consume alcohol?
If YES, how many drinks per week do you typically consume? (One drink = 12 oz beer or 4 oz wine or 1 oz hard liquor)

In the past 6 months, have you sought treatment for drug or alcohol abuse? 

How would you rate your present state of health compared to other people about your age?
Excellent______Good______Fair______Poor______

Have you participated in a research study before? Yes No

If yes, when?

This study requires you to consume rice or a sweet beverage and give blood samples for 2 hours. Are you willing and able to do this? Yes No

This study will include 4 morning visits to Queens Medical Center. Each visit will last approximately three hours.

Are you willing to come to Queens Medical Center in a fasted state (nothing to eat from midnight until visit) to have your blood drawn? Yes No

This study requires you to record all the food that you eat for 24 hours before your study visit. This will be repeated 4 times. Are you willing and able to do this? Yes No

Do you have reliable transportation? ____ ____
Do you travel out of the Honolulu area frequently?  

Are there specific dates you will not be available?  

Are you planning on living in the Honolulu area for the next 3 months?  

Are you able and willing to give blood samples?  

Have you ever had problems with giving blood?  

If yes, describe:  

After hearing about the study, how do you feel about the time commitment and effort involved to complete the study?  

ADDRESS_______________________________________________________  

CITY____________________ STATE________ ZIP___________  

TELEPHONE NUMBERS:  work (daytime):_____________________

Home (evening):_______________________________________  

Email: _________________  

Best time of day to be reached ______________________  

Comments:
Informed Consent

You are being asked to participate in a research study, The Glycemic Response to High Amylose Rice Study. This is a consent form. It is to provide you with information about this study. The research staff will talk with you about this information. Please take your time to review this consent form and discuss any questions you may have with the study staff. You may take your time to make your decision about participating in this study and you may discuss it with your regular doctor, friends and family before you make your decision. If there are any words or sections in this consent form that you do not understand, please ask the research staff to explain them. If you agree to take part in this study, you will be asked to sign this consent form.

It is important that you understand that taking part in this study is of your own free will. You may decide not to participate, or you may decide to stop being in the study at any time, and it will not affect your regular medical care now, or in the future.

Why is this Study Being Done

This study is being conducted to study how different types of rice affect blood glucose. You are being asked to take part in this study because you are a healthy, normal weight, nonsmoker between 18 and 40 years of age. A total of 18 participants will participate in this study.

The purpose of this study is to find out what effects (good and bad) rice has on you and your blood glucose response.

This research is being done to determine the best rice to control blood glucose. Blood glucose control is very important for people with diabetes. The results from this study will help develop new dietary choices for diabetics.

Subject Eligibility and Preliminary Visit

In this study, you will first attend a preliminary visit at the University of Hawaii at Manoa. At this visit you will provide informed consent. If you understand and agree with the statements in the consent form, you will sign your name and date on the last page, giving your consent to participate in the study. After you have
provided informed consent, you will be weighed, your height will be measured, and your blood glucose will be measured. You will also complete a health history questionnaire and an eating habit questionnaire. If you meet all of the criteria at the preliminary visit, you will be enrolled in the study. At this time, you will schedule your first study visit and receive instructions for preparing for your study visit including instructions for completing a Food Record. If you do not meet all of the criteria at the preliminary visit, all documents containing personal information about you will be destroyed.

**Study Procedures**

In this study you will complete 4 study visits. At the study visits you will receive 1 of 4 treatments (control beverage or rice) in a random order. The “control” beverage contains 50 g of glucose (sugar) dissolved in 250 mL (approximately 8 oz) of water. The “control” beverage is a standard beverage to assess your normal blood glucose response. The rice treatments are commercially produced white rice, grown in the United States. You will be asked to eat approximately 1 cup of plain rice. This rice will be prepared in a certified kitchen at the University of Hawai’i at Manoa, refrigerated, and reheated at Queens Medical Center in a microwave. This study is investigating the effect of three types of rice on blood glucose. This study is single-blind, meaning you will not know the identity of rice you are consuming, but the study coordinator and principal investigator will know the identity of the rice. In an emergency, this information will be made available to you and your health care provider.

**If you take part in this study, you will have the following tests and procedures at each study visit:**

During the 24 hours prior to the study visit, you will write down the identities and quantities of all foods and beverages consumed in a Food Record. This Food Record will be submitted to study staff at the study visit. You will fast for 12 hours before each study visit. When you arrive at your study visit, you will be seated quietly. Next you will have your blood glucose measured with a standard blood glucose meter to verify that you fasted for 12 hours. A trained nurse will use a glucose meter for a finger stick (FS) measure of blood glucose, and will do a venous blood draw for blood glucose and insulin. The nurse will obtain the first blood sample (4 mL or approximately ¾ of a teaspoon). After your blood glucose is measured, you will be presented with a control beverage (250 mL) or one of three test rices (approximately 1 cup). This when the timing of the study visit will start (time = 0 minutes). You will have 15 minutes to consume the beverage or test rice. You will have your blood glucose measured at the following time points: 15 (FS), 30(FS), 45(FS), 60(FS and venous), 90(FS), and 120(FS and venous) minutes. At the same time points, you will complete an appetite questionnaire. During the study visit you will be allowed to listen to music using headphones, read, write, work on a laptop computer, or sit quietly. After your last blood sample is taken, you will be offered juice and snacks. One study visit will take 3 hours.
Sequence of events at a study visit.

<table>
<thead>
<tr>
<th>Actual time (start time subject to change)</th>
<th>Visit time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00am</td>
<td></td>
<td>Subjects arrive fasted (12 hours) to Queens Hospital. Subjects are seated quietly</td>
</tr>
<tr>
<td>7:10am</td>
<td>0 min</td>
<td>Fasting glucose measured (FS and venous), appetite questionnaire. Test meal is served immediately upon completion of glucose measurement.</td>
</tr>
<tr>
<td>7:25am</td>
<td>15 min</td>
<td>Test meal is completed, tables are cleared. Blood glucose measured (FS), appetite questionnaire</td>
</tr>
<tr>
<td>7:40am</td>
<td>30 min</td>
<td>Blood glucose measured (FS), appetite questionnaire</td>
</tr>
<tr>
<td>7:55am</td>
<td>45 min</td>
<td>Blood glucose measured (FS), appetite questionnaire</td>
</tr>
<tr>
<td>8:10am</td>
<td>60 min</td>
<td>Blood glucose measured (FS and venous), appetite questionnaire</td>
</tr>
<tr>
<td>8:40am</td>
<td>90 min</td>
<td>Blood glucose measured (FS), appetite questionnaire</td>
</tr>
<tr>
<td>9:10am</td>
<td>120 min</td>
<td>Blood glucose measured (FS and venous), appetite questionnaire</td>
</tr>
<tr>
<td>9:15am</td>
<td>--</td>
<td>Study visit completed. Subjects are offered snacks and refreshments. Study staff may monitor subjects for approximately 30 minutes post visit, to ensure safety, if necessary.</td>
</tr>
<tr>
<td>10:00am</td>
<td></td>
<td>End of study visit</td>
</tr>
</tbody>
</table>

Study visits will be completed no less than three days apart.

FS=Finger stick
This page included in the consent form for subjects:
Expected timeline for one subject from enrollment to completion

Week 1
- Telephone initial eligibility questionnaire

Week 2
- Preliminary visit to verify medical history questionnaire at UH-Manoa. Qualifying subject receives study materials and instruction

Week 3
- Visit 1 (arriving fasted, 7:00am)

Week 4
- Visit 2 (arriving fasted, 7:00am)

Week 5
- Visit 3 (arriving fasted, 7:00am)

Week 6
- Visit 4 (arriving fasted, 7:00am)
Participation in the study will last approximately five weeks or until all four study visits are completed.

The principle investigator may decide to take you off this study if you fail to comply with study procedures such as arriving on time to study visits, completing study questionnaires, providing blood samples, remaining at the study visit for two hours or until the final blood sample and questionnaire are administered.

You can stop participating at any time.

Results from this study will not be provided to the study participants.

Risks
You may experience discomfort and/or bruising and may be at risk of infection as a result of the IV catheter insertion. You may experience dizziness or loss of consciousness during blood draws or with insertion/removal of the IV catheter. You may experience nausea, vomiting, hypoglycemia or hyperglycemia as a result of being in a fasting state or with treatment ingestion. You are also asked to provide personal identifiers for the purpose of study communication and contact, which introduces a slight risk for information disclosure. There may be other unforeseen risks as a result of participation in the study. You may decline participation in the study to avoid these risks altogether.

Benefits
By participating in this study, you will be providing information to the study staff that will show the effects of rice variety and cooking method for the control of blood glucose and appetite. You will be provided a report of your diet analysis and blood glucose measurements. There may or may not be direct medical benefit to you from participating in this study. This study will provide preliminary data to continue researching if high resistant starch rice can be used as a diet treatment for diabetes.

Costs
All clinic and professional fees, diagnostic and laboratory tests which will be performed as part of this study are provided at no cost to you. There will be no cost for the study meal that you will receive. Parking fees beyond 3 hours are your responsibility. The study cannot reimburse parking fees.

Compensation
You will receive a $75 Ala Moana gift card for your time and participation in each of the four study visit (excluding the preliminary visit).

Alternatives
You do not have to participate in this study.
Confidentiality
All research information about you will be held confidential to the extent allowed by state and federal law. Your personal information will not be given to anyone without your written permission. A code, which will be known only to study personnel, will be used instead of your name on medical records in this study. Research records which may be identifiable to you will be kept in a secure locked file when not being used.

A summary of information gathered in this research study may be published or presented in public forums; however your name and other identifying information will not be used or revealed. Agencies with research oversight, who may review your records include: the University of Hawaii Committee on Human Studies (IRB), U.S. Food and Drug Administration (FDA), the National Institutes of Health (NIH), and study staff. Confidentiality does not prevent you from releasing information about yourself and your participation in the study.

Voluntary Participation
Your decision to take part in this study is voluntary. You may refuse to participate or you may withdraw from the study at any time. If the study staff feels that it is in your best interest to withdraw you from the study, your study staff will remove you without your consent. We will tell you about any new information that may affect your health, welfare, or willingness to stay in this study.

If you are a student, grade status, performance evaluation, or class standing at the University of Hawaii at Manoa will not be affected by your decision to participate or not to participate in this study. If you are an employee, job status or performance evaluation at the University of Hawaii at Manoa will not be affected by your decision to participate or not to participate in this study.

Injury Related to the Study
If you are injured as a result of being in this study, you will be provided what immediate treatment is available for your injuries. You will then be told where you may get other treatment. The cost for this treatment will be charged to your insurance company or to you. Your insurance company may not pay for these costs. If your insurance will not pay for these costs, they will be your responsibility. The University of Hawaii and The Queen’s Medical Center has no program to pay you or compensate you in any way for your injuries.

Questions
You are free to ask questions that you may have about your treatment and your rights as a research participant at any time. If you have questions about this study, or a research-related injury you should contact the investigator Dr. Maria Stewart at 956-9114, 1955 East West Rd, Ag Sci 314M, Honolulu, HI, 96822. If you have questions about your rights as a research subject, contact the UH Committee on Human Studies at:
Statement of Consent

I agree to participate in the research project entitled, “The Rice Study,” and I understand that I can change my mind about participating in this project at anytime, by notifying the researcher.

<table>
<thead>
<tr>
<th>Subject’s Name (print)</th>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Signature and Title of Person Obtaining Consent and Identification of Role in the Study</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Rice Study Visit Instructions

<table>
<thead>
<tr>
<th>Study Visit</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Steps to Follow For Your Visit:

1. Fill out your food record the day before your study visit at Queen’s Medical Center. Start with the first thing you eat or drink in the morning.

2. Do not eat or drink anything, with the exception of water, after midnight (the night before your visit). In the morning of your visit, drink at least 20 oz of water before you arrive.

3. Arrive at the Queen’s Medical Center main lobby by your assigned time. Study staff will be waiting to greet you in front of the Women’s Clinic in the main lobby. Please see attached sheet for parking or drop-off/pick-up instructions. We will cover your parking costs for the duration of your study visit.

4. Your visit will last about 3 hours. You are welcome to bring your laptop, iPod or mp3 player, a book, schoolwork, etc. You will be able to sit and work quietly. There is also a TV available for your use. Snacks will be provided when you are finished.

Questions?
Please contact: Alison Zenel
nutrires@hawaii.edu
808-956-7035
Queen’s Medical Center Parking or Drop-off/Pick-up Instructions:

The Queen’s Medical Center main lobby is located at:
1301 Punchbowl Street
Honolulu, HI 96813

Please see map attached.

**Miller Garage**
- Miller Garage is located at the corner of Punchbowl, Vineyard and Miller Streets and provides quick and easy access to the H-1 freeway.
- The Garage has two public entrances and is open from Monday 12:01am to Saturday 12:00 Midnight (with an attendant present).
- Entrance directly off Miller Street or off Punchbowl Street, into QMC Main Lobby, and via an underground tunnel past Porte Cochere.
- Pick-up and drop-off of visitors and patients are accommodated at this Main Lobby Porte Cochere area, as space permits.

**Physicians Office Building (POB) Garages I and II**
- Visitor and patient parking is available at the POB I and II Garages located on Lusitana Street, adjacent to the POB Office Buildings. The POB I Garage is open from Monday 12:00 a.m. to Saturday 12:00 Midnight (with an attendant present). Access to the hospital from POB I Garage is only up to 8:00 p.m.
- POB II Garage is open from 6:00 a.m. to 9:00 p.m., Mondays through Saturdays.
- POB III Garage, at the corner of Lauhala and Beretania Streets, is restricted to only POB III patients. Please do not park at POB III Garage.

**Handicapped Parking**
- Handicapped parking stalls are available at all Garages.

**Porte Cochere (Drop-off and Pick-up)**
- Porte Cochere area (in front of the main lobby area) is restricted to patient drop off and pick up. No parking, stopping, or waiting in vehicle is allowed at this area. Unattended vehicles will be towed.
FOOD RECORD

Subject ID ____________________

SPECIAL INSTRUCTIONS:

Begin completing this food record on ______________ at 7:00am.
Record your food intake until you arrive at the study visit.

The Glycemic Response to High Amylose Rice
PI: Dr. Maria Stewart
808-956-9114
mstew@hawaii.edu
FOOD RECORD INSTRUCTIONS

In order to calculate your nutrient intake, a complete record must be kept of your food and beverage consumption for the period specified. Following are some rules in recording food intake that will help you to provide accurate intake data.

1. All meals and snacks MUST be recorded, whether they are eaten at home or away.

2. Be as specific as possible in recording food items. If the brand name of the product is available, please include it.

3. Measure food items when possible or estimate the quantities closely. You should estimate portions either in weight, such as grams or ounces, or in volume, such as teaspoons, tablespoons, cups etc.

4. Be sure to specify the method of preparation for each food item. If additional products are used in preparation, such as oil to pan-fry a food, be sure they are included.

5. Make sure that all condiments, such as ketchup, gravy, or sauces, are recorded.

6. The abbreviations used for food intake weight and measures are as follows:
   
   `tsp` = teaspoon  
   `Tbsp` = tablespoon  
   `c` = cup  
   `oz` = ounce  
   `ml` = milliliter

7. Please use the following sample food record as a guide.
# Sample Food Record

<table>
<thead>
<tr>
<th>Time</th>
<th>Food Eaten</th>
<th>Amount</th>
<th>Food Description and/or Preparation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:30am</td>
<td>Frosted Mini Wheats cereal</td>
<td>1 ¼ cup</td>
<td>Kellogs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1/3 cup</td>
<td>Lucerne</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 oz</td>
<td>Meadow Gold</td>
</tr>
<tr>
<td></td>
<td>Milk- 2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>POG juice drink</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:00am</td>
<td>Coffee Equal</td>
<td>12 oz</td>
<td>from break room</td>
</tr>
<tr>
<td></td>
<td>Coffeemate</td>
<td>1 pkt</td>
<td>Original flavor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 tsp</td>
<td></td>
</tr>
<tr>
<td>12:00pm</td>
<td>Roast beef sandwich</td>
<td>3 slices</td>
<td>deli slices, thin, roasted, no salt</td>
</tr>
<tr>
<td></td>
<td>Beef</td>
<td>2 slices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Whole wheat bread</td>
<td>1 tsp</td>
<td>Promise margarine</td>
</tr>
<tr>
<td></td>
<td>Margarine</td>
<td>1 leaf</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lettuce</td>
<td>20 oz</td>
<td>snack size bag, Nacho Cheese</td>
</tr>
<tr>
<td></td>
<td>Diet Coke</td>
<td>1 bag</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Doritos</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6:00pm</td>
<td>Chicken Stirfry</td>
<td>6 pc</td>
<td>At friends house</td>
</tr>
<tr>
<td></td>
<td>Chicken pieces</td>
<td>½ c</td>
<td>cooked in canola oil</td>
</tr>
<tr>
<td></td>
<td>Broccoli</td>
<td>¼ c</td>
<td>White meat, ~ size of thumb</td>
</tr>
<tr>
<td></td>
<td>Onion</td>
<td>2 Tbsp</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bamboo shoots</td>
<td>2 Tbsp</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carrots</td>
<td>1 ½ c</td>
<td>White, cooked in rice cooker</td>
</tr>
<tr>
<td></td>
<td>Rice</td>
<td>1 tsp?</td>
<td>Chinese 5-spice, garlic</td>
</tr>
<tr>
<td></td>
<td>Seasoning</td>
<td>3 Tbsp</td>
<td>Aloha brand</td>
</tr>
<tr>
<td></td>
<td>Shoyu</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Beer</td>
<td>2- 12 oz cans</td>
<td>Miller Lite</td>
</tr>
<tr>
<td></td>
<td>Chocolate bar</td>
<td>1 oz</td>
<td>Cadbury Milk Chocolate</td>
</tr>
<tr>
<td>9:00pm</td>
<td>Water</td>
<td>16 oz</td>
<td>Tap, no ice</td>
</tr>
<tr>
<td>Time</td>
<td>Food Eaten</td>
<td>Amount</td>
<td>Food Description and/or Preparation Method</td>
</tr>
<tr>
<td>------</td>
<td>------------</td>
<td>--------</td>
<td>------------------------------------------</td>
</tr>
</tbody>
</table>

*Date* ________________________________

*S M T W T F S*
**Survey 1- Appetite Assessment**

Subj ID_____

Date_____

Time 0 minutes

How hungry do you feel?

Not hungry at all ________________________________ I have never been more hungry

How satisfied do you feel?

I am completely empty ________________________________ I cannot eat another bite

How full do you feel?

Not at all full ________________________________ Totally full

How much do you think you can eat?

Nothing at all ________________________________ A lot
Appetite Assessment

Subj ID_____
Date_____
Time 15 minutes

How hungry do you feel?

Not hungry at all ____________________________ I have never been more hungry

I am completely empty ____________________________

How satisfied do you feel?

I cannot eat another bite ____________________________

I am completely empty ____________________________

How full do you feel?

Not at all full ____________________________ Totally full

I am completely empty ____________________________

How much do you think you can eat?

Nothing at all ____________________________ A lot

A lot
Palatability Assessment

Subj ID_____
Date_____
Time 15 minutes

Visual appeal

Bad   Good

Smell

Bad   

Taste

Bad   Good

Texture

Bad   

Overall Pleasantness

Bad   Good
Appetite Assessment

Subj ID_____
Date_____
Time 30 minutes

How hungry do you feel?

Not hungry at all

I have never been more hungry

How satisfied do you feel?

I am completely empty

I cannot eat another bite

How full do you feel?

Not at all full

Totally full

How much do you think you can eat?

Nothing at all

A lot
Appetite Assessment

Subj ID____
Date____
Time 45 minutes

How hungry do you feel?

Not hungry at all ________________________________ I have never been more hungry

How satisfied do you feel?

I am completely empty ________________________________ I cannot eat another bite

How full do you feel?

Not at all full ________________________________ Totally full

How much do you think you can eat?

Nothing at all ________________________________ A lot
Appetite Assessment

Subj ID_____
Date_____
Time 60 minutes

How hungry do you feel?

Not hungry at all ___________________________________________ I have never been more hungry

How satisfied do you feel?

I am completely empty ___________________________________________ I cannot eat another bite

How full do you feel?

Not at all full _________________________________________________ Totally full

How much do you think you can eat?

Nothing at all _________________________________________________ A lot
Appetite Assessment

Subj ID_____
Date_____
Time 90 minutes

How hungry do you feel?

Not hungry at all __________________________________________________________________________
I have never been more hungry

How satisfied do you feel?

I am completely empty __________________________________________________________________________
I cannot eat another bite

How full do you feel?

Not at all full _________________________________________________________________________________
Totally full

How much do you think you can eat?

Nothing at all _________________________________________________________________________________
A lot
Appetite Assessment

<table>
<thead>
<tr>
<th>Question</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>How hungry do you feel?</td>
<td>Not hungry at all</td>
</tr>
<tr>
<td></td>
<td>I have never been more hungry</td>
</tr>
<tr>
<td>How satisfied do you feel?</td>
<td>I am completely empty</td>
</tr>
<tr>
<td></td>
<td>I cannot eat another bite</td>
</tr>
<tr>
<td>How full do you feel?</td>
<td>Not at all full</td>
</tr>
<tr>
<td></td>
<td>Totally full</td>
</tr>
<tr>
<td>How much do you think you can eat?</td>
<td>Nothing at all</td>
</tr>
<tr>
<td></td>
<td>A lot</td>
</tr>
</tbody>
</table>
### Table C1. Glycemic index, glycemic load, and T2DM\(^1\).

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Study design</th>
<th>Study details</th>
<th>Demographics</th>
<th>Key Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hodge et al. 2004</td>
<td>Prospective cohort study</td>
<td>Investigation on association of high GI diet with T2DM risk in older females.</td>
<td>N=36,787 females without T2DM aged 40-69 years.</td>
<td>GI positively associated with T2DM. Association weakened when adjusted for obesity.</td>
</tr>
</tbody>
</table>

1. T2DM = Type 2 diabetes mellitus.
2. GI= Glycemic index.
3. GL= Glycemic load.
<table>
<thead>
<tr>
<th>Author Year</th>
<th>Study Design</th>
<th>Study Details</th>
<th>Demographics</th>
<th>Key info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finucane et al. 2008</td>
<td>Qualitative study: 2 rounds of semistructured focus groups and interviews.</td>
<td>15 patients with type 2 diabetes. Filipino Americans in HI.</td>
<td>Age range: 33-60, 12 women, 3 men</td>
<td>Filipino Am in HI consistently have 2-3 times the age adjusted prev. of T2DM compared to Caucasians. 45% of Fi.HI are overweight or obese. Culturally driven self-management education is needed.</td>
</tr>
<tr>
<td>Grandinetti et al. 2007</td>
<td>Cross-sectional survey of multi-ethnic rural comm. In HI</td>
<td>1,452 men and non-pregnant women.</td>
<td>Caucasians (n=295), Japanese Americans (n=190), Filipino Americans (n=186), Native Hawaiians (n=526), Other (n=155). Age mean range: 44-59 years.</td>
<td>Prevalence of diabetes 3-fold higher among Asian and Native HI ancestry groups than among Caucasians in rural community (Kohala, Big Island).</td>
</tr>
<tr>
<td>Gray et al. 2000</td>
<td>Randomized control trial</td>
<td>23 UK hospital clinics. Cost effectiveness of intensive blood glucose control</td>
<td>N=3867, mean age = 53 years. Length = 15 years.</td>
<td>Complications cost of T2DM was sig. dec. with intensive blood glu control, but sig inc. treatment costs</td>
</tr>
<tr>
<td>Look et al. 2008</td>
<td>Training curriculum intervention</td>
<td>Training of community health workers in HI serving Native HI. and Pac. Is. on diabetes prevention, control, and management.</td>
<td>4-hr training, 19 health organizations, 111 community health workers, completed in 3 years.</td>
<td>Post-training, workers gained sig more knowledge on diabetes compared to pre-training diabetes knowledge.</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mau et al. 2010</td>
<td>Community based participatory research</td>
<td>Informant interviews (n=15) and focus groups (n=15) in HI. Adapt Diabetes Prevention Program Lifestyle Intervention in HI, see effectiveness of 12 week pilot study.</td>
<td>n=112 Native HI and other Pac. Isl.</td>
<td>Able to culturally translate DPP into a DPP Lifestyle Intervention for HI, weight loss was achieved in those who completed program.</td>
</tr>
<tr>
<td>Sinclair et al. 2012</td>
<td>2-armed randomized controlled trial</td>
<td>Culturally adapted diabetes self-management lifestyle intervention in HI (diet, physical activity). Intervention length = 3 months Control (n=34) Intervention (n=48) Participants: Type-2 diabetes, Native HI, Pac. Is., Filipino</td>
<td>Intervention: 63% female, mean age = 53 Control: 62% female, mean age = 55.</td>
<td>HI= 1.3 million residents, 26% are Native HI or Pac.Is. 2008 T2DM prevalence = 8.2% (comparable to overall US) Native HI = highest prevalence. 19-22%, 16-35% impaired glu tol. Japanese=7% Caucasian = 3% Native HI = ave. 7 yrs younger when diagnosed</td>
</tr>
</tbody>
</table>

1. T2DM= Type 2 diabetes mellitus.  
2. HI= Hawaii.
### Table C3. Rice intake in HI.

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Study design</th>
<th>Study details</th>
<th>Demographics</th>
<th>Key Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finucane et al.</td>
<td>Qualitative study. 2 rounds of semistructured focus groups and interviews.</td>
<td>Looking at cultural impacts on diabetes self-management of Filipinos in HI.</td>
<td>N =15 patients with T2DM. 12 women, 3 men. Filipino Americans in HI. Ages 33-60.</td>
<td>Rice is a cultural staple, a symbol. Eliminating it may be perceived as rejecting culture.</td>
</tr>
<tr>
<td>Leon Guerrero et</td>
<td>1. Survey of white rice varieties and proportion of enriched to non-enriched white rice sold in retail stores in HI, Guam, and Saipan. 2. Nutrient analysis of certain varieties of rice collected in stores.</td>
<td>Survey of 8 stores in Saipan, 5 stores in HI, and 7 stores in Guam. Nutrient analysis on enrichment nutrients in most common brands found.</td>
<td>N=19 varieties of white rice analyzed, such as long-grain, medium-grain, calrose, jasmine. 12 were labeled as enriched.</td>
<td>Rice varieties sold and enrichment labeling varied between stores and countries. Rice labeled as enriched in HI and Guam seldom met minimum enrichment standards for U.S.</td>
</tr>
<tr>
<td>al. 2009</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharma et al.</td>
<td>Multi-ethnic cohort study, prospective</td>
<td>Quantitative food frequency questionnaire. Focus on dietary sources of 5 nutrients.</td>
<td>N=215,251 Mean age range = 56-62 JpAm, Nat.HI, AfAm, Caucasian, Latino, Other = ethnic makeup.</td>
<td>Dietary source of energy= most contributing from rice (and bread) across ethnic groups Rice = major source of energy</td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharma et al.</td>
<td>Multi-ethnic cohort study, prospective</td>
<td>Quantitative food frequency questionnaire. Focus on grain consumption.</td>
<td>N=215,251 Mean age range = 56-62 JpAm, Nat.HI, AfAm, Caucasian, Latino, Other = ethnic makeup.</td>
<td>White rice is the major contributor of refined grains in Native HI and Jp Am men. Most commonly consumed refined grain among all ethnic groups (except Latinos).</td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Takata et al. 2004</td>
<td>2 cross-sectional studies (Hawaii and Japan), data pooled and analyzed</td>
<td>Comparison of dietary habits of women in Japan and Hawaii.</td>
<td>HI: n=164 caucasian, 146 Jp. Am. women</td>
<td>Jp. Am. women in HI consume significantly more rice than Caucasian women. Jp Am women in HI consume significantly more grains (primarily rice) than Jp women in Japan. Rice intake in Japan has decreased.</td>
</tr>
</tbody>
</table>

1.HI= Hawaii
<table>
<thead>
<tr>
<th>Author Year</th>
<th>Subjects</th>
<th>Treatment</th>
<th>Method</th>
<th>Key Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Tamimi et al. 2010</td>
<td>13 subjects, 7F and 6 M. 27 years old</td>
<td>Glu bev, control “nutrition bar,” or “nutrition bar” with RS type 4 (15.6 g RS).</td>
<td>Randomized crossover. Serial blood samples for 2 hours.</td>
<td>Peak glu and ins concentrations and incremental AUC[^2] sig. lower after RS4 bar intake.</td>
</tr>
<tr>
<td>Behall et al. 1988</td>
<td>12 F, 13 M. Healthy, 28-55 years (61 avg age)</td>
<td>Starch crackers. 70:30% amylase: amylopectin ratio and vice versa. RS dose not stated.</td>
<td>Blood drawn at 0, 30, 60, 120, and 180 min. Randomized crossover.</td>
<td>HA[^3] cracker: Sig dec glucose peak at 30 min; plasma insulin response sig dec 30 min and 60 min.</td>
</tr>
<tr>
<td>Behall et al. 2002</td>
<td>25 subjects (13M, 12F) Healthy, aged 25-58</td>
<td>After fasting: Bread with standard cornstarch (30% amylase: 70% amylopectin; 2 g RS), HA cornstarch (70:30; 13.4 g RS), or blends (40, 50, 60% amylase with 3.8, 8.2, 11.5 g RS respectively).</td>
<td>Latin-square design. Blood samples at Fasting, and postprandially: 30, 60, 120, 180 min.</td>
<td>Peak glucose response lowest after breads with 50-70% amylase; lowest glucose AUC after 60-70% amylase; 2hr insulin AUC significantly lower after 60-70% amylase. Plasma insulin: sig. lower after 70% amylase at 0.5 hr and after 60 &amp; 70% amylase at 1 hr.</td>
</tr>
<tr>
<td>Behall et al. 2006</td>
<td>10 normal weight females, 10 overweight females, mean=43 years old</td>
<td>After fasting overnight: glucose drink, or muffins with 3 levels of RS (HA[^2] cornstarch) and/or beta-glucan. The RS dose in the muffins were 6.5 g RS (high), 3.4 g RS, or 0.9 g RS (low).</td>
<td>Latin-square design. 10 study visits with different treatments. Blood samples at fasting, and postprandially at 1, 2, 3, and 4 hr.</td>
<td>Glucose conc. at 1 hr lowest after mid and high RS muffins; Insulin concentration at 2hr was sig. lower after high RS muffin; overweight subjects had higher insulin concentrations. Glucose and insulin AUC decreased as RS content increased in muffins.</td>
</tr>
<tr>
<td>Chiu et al. 2013</td>
<td>21 healthy adults. (12 M, 9F). Mean age 29.</td>
<td>High RS rice (4.4 g RS), Low RS rice (0.4 g RS), or glucose beverage.</td>
<td>Randomized, single-blind crossover study. Blood glu at 0, 15, 30, 45, 60, 90, 120 min.</td>
<td>No difference in glu AUC between HRS and LRS. (both sig. lower than glu beverage).</td>
</tr>
<tr>
<td>Study</td>
<td>Subjects (M:F)</td>
<td>Description</td>
<td>Blood draws</td>
<td>Treatment Notes</td>
</tr>
<tr>
<td>-------------------</td>
<td>----------------</td>
<td>-------------</td>
<td>-------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Goddard et al. 1984</td>
<td>33 subjects, 16M and 17F. Healthy, 27-81 years</td>
<td>Rice varieties with 0, 14, 17, 23, or 25% amylose. RS dose and serving size not stated.</td>
<td>Blood draws at 0, 30, 60, 120, 180 min. Latin square design.</td>
<td>HA rice (23-25%): serum glucose sig. decreased at 30 min, dropped more gradually by 180 min; sig. decreased insulin levels at 30 min and 60 min.</td>
</tr>
<tr>
<td>Granfeldt et al. 1995</td>
<td>9 subjects (4M, 5F). Healthy, 34 years.</td>
<td>Arepas (corn bread cakes) with 29g or 45 g RS from HA corn flour.</td>
<td>Finger prick blood samples at 0, 30, 45, 75, 95, 120, 180 min.</td>
<td>HA arepas: Sig. lower AUC glucose and insulin response.</td>
</tr>
<tr>
<td>Hallstrom et al. 2011</td>
<td>14 subjects, 7M and 7F. Healthy, 20-35 years</td>
<td>7.7 g RS in whole grain wheat bread (EAW: elevated amylose content wheat bread) vs three other breads (RS with lactic acid, whole grain wheat, and reference white bread).</td>
<td>Randomized crossover. Finger prick for glu and ins: 15, 30, 45, 60, 90, 120, 180.</td>
<td>EAW bread: sig. lower postprandial glucose response during first 120 min.</td>
</tr>
<tr>
<td>Li et al. 2010</td>
<td>16 subjects, 9M and 7F. 24-26 years old.</td>
<td>Genetically modified RS rice with 8.05 g RS or wild-type rice with 0.97 g RS (control).</td>
<td>Randomized crossover trial. Blood draws at 0, 15, 30, 45, 60,90,120,180,240.</td>
<td>After RS rice treatment: glucose concentration and glu AUC sig. decreased, insulin conc. and AUC sig decreased.</td>
</tr>
<tr>
<td>Weststrate et al. 1993</td>
<td>22 normal weight healthy males. 24-59 years, 38.9 mean age</td>
<td>HA breakfast (baguette with HA corn maize. 9.2 g RS) and lunch (pizza dough with HA corn maize, 10.4 g RS). Consumed with as a meal with other ingredients.</td>
<td>Latin square design. Blood samples at 0, 0.5, 1, 2, and 4 hr</td>
<td>Insulin AUC sig dec after HA bkfst, ins and gluc AUC sig dec after HA lunch.</td>
</tr>
</tbody>
</table>

1. RS=Resistant starch; 2. AUC= Area under the curve; 3. HA= high amylose
Table C5. RS\textsuperscript{1} in solid foods and T2DM\textsuperscript{2}.

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Subjects</th>
<th>Treatment</th>
<th>Methods</th>
<th>Key Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hu et al. 2012</td>
<td>Meta-analysis: four articles, 7 prospective cohort studies in Asian and Western populations</td>
<td>Summarize evidence of association between white rice consumption and T2DM risk</td>
<td>Relative risks pooled, does-response relations</td>
<td>Higher consumption of white rice sig. increased risk of T2DM, especially in Asian populations</td>
</tr>
<tr>
<td>Kwak et al. 2012</td>
<td>90 M and F, adults with IFG\textsuperscript{3}, IGT\textsuperscript{4}, or new T2DM, mean age 50</td>
<td>210 g cooked rice with 6.51 g RS</td>
<td>Rice consumed daily for 4 weeks. Study visit: Anth. and clinical measurements, standard meal, postprandial glu/ins blood samples</td>
<td>RS rice sig. decreased fasting insulin and insulin resistance, postp. glu and ins levels at 30 min, gluc and ins AUC\textsuperscript{5} after standard meal. Improved endothelial function, reduced oxidative stress.</td>
</tr>
<tr>
<td>Larsen et al. 1996</td>
<td>12 T2DM outpatients, 7 M, 5F, mean age 58</td>
<td>Low (12%, 7.8 g RS, 65.3 g serving size) and High (27%, 17.6 g RS, 65.2 g serving size) amylose rice, non-parboiled or parboiled, compared to white bread.</td>
<td>Treatment in morning after 12 hr fast. Blood draws taken at timepoints until 180 min.</td>
<td>There no difference in ins or glu response among rices. All rices had lower response compared to white bread.</td>
</tr>
<tr>
<td>Lintas et al. 1995</td>
<td>10 T2DM, 7 M, 3F, mean age 60</td>
<td>Pasta (9.2 g RS), barley (4.1 g RS), or rice (4.1 g RS) with same sauce. Serving size not stated.</td>
<td>Treatment given at lunchtime. Blood draws taken at timepoints until 120 minutes.</td>
<td>The pasta had the most RS (14% in pasta, 6% in rice, barley). Glucose response was lowest after barley treatment.</td>
</tr>
<tr>
<td>Penn-Marshall et al. 2010</td>
<td>8 M, 7 F. African American adults that are IR\textsuperscript{6}</td>
<td>Bread w/ 12 g RS (high amylose cornstarch)</td>
<td>Bread consumed daily for 14 weeks, dbl blind crossover. Study visit- anth and clinical measures, glu/ins after standard meal</td>
<td>No sig. diff. in fasting plasma glu levels, insulin, c-reactive protein levels. IR decreased to normal values, not sig.</td>
</tr>
</tbody>
</table>
1. RS = Resistant starch
2. T2DM = Type 2 diabetes mellitus
3. IFG = Impaired fasting glucose
4. IGT = Impaired glucose tolerance
5. AUC = Area under the curve
6. IR = Insulin resistant
<table>
<thead>
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<tr>
<td>Karalus et al. 2012</td>
<td>22 adult women, non-restrained eaters. Mean age = 25.</td>
<td>5 different visits. 4 different fiber type bars and a control bar- one with 10 g RS.</td>
<td>One bar eaten night before, same bar in morning. VAS² for satiety: fasting, and postprandially 15, 30, 45, 60, 90, 120, 180 min.</td>
<td>No difference in satiety scales.</td>
</tr>
<tr>
<td>Weststrate et al. 1993</td>
<td>22 normal weight, healthy males 24-59 years</td>
<td>HA³ breakfast (baguette with HA corn maize, 9.2 g RS) and lunch (pizza dough with HA corn maize, 10.4 g RS). Consumed as a meal with other ingredients.</td>
<td>2 x 2 factorial, meal crossed with latin square design. Fasted overnight. VAS appetite: fasting, postprandially 0.5, 2, 4 hr after breakfast. 6 hr after lunch.</td>
<td>No difference in VAS appetite ratings but RS was less pleasurable.</td>
</tr>
<tr>
<td>Willis et al. 2009</td>
<td>20 subjects: 7 M, 13 F. Healthy, 19-26 years</td>
<td>5 visits. 4 muffins with different fiber types and 1 low fiber muffin. One with 8 g RS.</td>
<td>Fasted overnight. Muffin in morning with coffee, water, or tea (decaf, black). Same beverage at each visit. VAS appetite at: fasting, and postprandially 15, 30, 45, 60, 120, 180 min.</td>
<td>RS muffin was more satiating than low fiber and polydextrose. It was the most satisfying muffin. Palatability: RS muffin not preferred.</td>
</tr>
</tbody>
</table>

1. RS=Resistant starch
2. VAS=Visual analogue scale
3. HA=High amylose