ABSTRACT

Title of document: OBSERVATIONS REGARDING CONSUMPTION OF PERUVIAN NATIVE GRAINS (QUINOA, AMARANTH AND KAÑIWA), WEIGHT STATUS, AND PERCEPTIONS OF POTENTIAL RISK FACTORS, WARNING SIGNS AND SYMPTOMS OF TYPE 2 DIABETES AMONG PERUVIAN ADULTS: A CASE STUDY

Katherine A Sanchez, Master of Science, 2012

Directed by: Retired Associate Professor and Extension Specialist Dr. Mark A Kantor, Nutrition and Food Sciences Department

Wheat flour-based foods and rice have replaced native cereals in the diets of many urban-living Peruvians. Urban areas have also seen increases in overweight, obesity, and type 2 diabetes mellitus prevalence in recent years. The focus of this research is to describe observations regarding consumption of quinoa, amaranth and kañiwa cereals; weight status; and self-described experiences of potential risk factors and warning signs for, and symptoms that may represent complications of, type 2 diabetes mellitus in Peruvian adults living in the city of Arequipa. A survey instrument was developed and administered to 110 subjects (22 diabetics, 88 non-diabetics), middle-aged and over. Participants with normal BMIs consumed quinoa, amaranth, and kaniwa more frequently than overweight or obese participants. Diabetics reported more frequent consumption of Andean cereals, particularly amaranth, and less frequent consumption of white flour than non-diabetics. Most participants reported eating a diet high in carbohydrates and leading a sedentary lifestyle.

OBSERVATIONS REGARDING CONSUMPTION OF PERUVIAN NATIVE GRAINS (QUINOA, AMARANTH AND KAÑIWA), WEIGHT STATUS, AND PERCEPTIONS OF POTENTIAL RISK FACTORS, WARNING SIGNS AND SYMPTOMS OF TYPE 2 DIABETES AMONG PERUVIAN ADULTS: A CASE STUDY

By

Katherine A Sanchez

Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Master of Science
2012

Advisory Committee:
Mark Kantor, PhD, Chair
Nadine Sahyoun, PhD, RD
Mira Mehta, PhD

Dedication

To Pachamama, Tata Inti, Wayra, Uno and the many Apus close to my heart in Peru and the US.

To the wise and generous spirit of the Inka people and their many descendents in Tawantinsuyo, especially the Q’eros—and to Native peoples around the world—thank you.

To my amazing family—especially my husband, Ricardo, and sons, Max and Nico; and to my mom and dad, Virginia and James McCall, and mother and father-in-law, Samuel Sanchez and Betty Pérez de Sánchez—you inspire me.

Acknowledgements

There are many people who have been instrumental in bringing this thesis to fruition, and to whom I am most grateful. Above all, I'd like to thank the Divine Creator for answering every request for help and for the many blessings bestowed every day on all of us. I am also blessed to have benefited from the excellent guidance of my advisory committee, headed by Dr. Mark Kantor, along with Dr. Nadine Sahyoun and Dr. Mira Mehta, who generously shared their exceptional experience, knowledge and wisdom with me. Many thanks to the wonderful, resourceful, and generous people who helped me do the groundwork for this thesis in Peru, especially Dr. Sonia Medina Quiroga de Hijar, head of the Nutrition Department and the Universidad San Augustín, Professor Evaristo Pfuture Consa, Lic. Dina Varges Guillen, Lic. Saulo Ramón Cuno Montalvo, Lic. Alexander Alberto Zuñiga Quiroz, Dr. Ronald Sánchez Pérez, MD, Mrs. Betty Pérez de Sánchez, Mrs. Dayana Sánchez de Peralta, Mrs. Margot Cabrera de Sánchez, Dr. Walter Medina Rueda, MD, and the gracious, helpful, professional staff at the diabetes patient education center in the Hospital Regional Honorio Delgado in Arequipa. In the US, I'm grateful for the tremendous help and data processing and analysis support from Kylie Wheelock, as well as the sound advice from Lic. E. Noelia Williams, food scientist. Finally, I am eternally grateful for my wonderful husband, Ricardo Sánchez Pérez, for his support and help in every phase of this project.

Table of Contents

Figures

Tables

I. Introduction

Quinoa, amaranth and kañiwa are among the most important “grains” of the Andean region of South America. For centuries, they were so vital to the local food supply that the Inka culture considered them to be sacred; indeed, the Quechua name for quinoa means “mother grain.” Quinoa, amaranth and kañiwa have long been—and still are today—major sources of protein for people in the region, sometimes replacing meat in the diet.

Although they are used like grains in Andean cooking, quinoa, amaranth and kañiwa are technically not grains; they are actually seeds, which is why they are sometimes called “pseudo-grains” or “pseudocereals.” While true cereals are botanically classified as grasses, pseudocereals are considered to be broadleaf plants (non-grasses). Seeds are generally better sources of high-quality protein than true cereal grains, such as wheat, rice and corn. Compared to popular refined grain products, (e.g., white bread, cooked white rice and regular pasta), foods made from quinoa, amaranth and kañiwa generally have higher levels of fiber, essential fatty acids, antioxidants, and other phytochemicals, defined as bioactive, non-nutritive plant compounds. Among the health benefits of these components, the fiber content of quinoa, amaranth and kañiwa may help control appetite and induce satiety.

Nevertheless, the popularity of these traditional pseudo-grains has waned in the past five or six decades, due to their association with indigenous cultures and the perception that only people of low socioeconomic status eat them. Instead, foods made from refined wheat flour, white rice and other refined grains have become more dominant on the Andean plate. This is especially true in urban areas of Peru such as Lima and

Arequipa, where wheat-based foods and rice are customarily purchased, served and eaten. Because these foods were brought to Peru by the Spaniards, Peruvians associate them with European origins and "whiteness." Thus, regularly consuming such foods confers a higher social status, whereas purchasing, serving and consuming quinoa, amaranth and kañiwa have become associated with a low socioeconomic class. This attitudinal shift set the stage for the replacement of native grains with refined grains in the staple diets of many Peruvians (Martínez-Zuñiga, 2007).

In recent years, Peru's urban population has experienced an increase in overweight, obesity, and the prevalence of type 2 diabetes and other chronic diseases (Ministerio de Salud, Peru, 1996). Given the evidence that whole grain intake may lower the risk of overweight, obesity and some chronic diseases, it is important to explore the nutritional consequences of the trend toward decreased consumption of traditional grains among Peruvians living in urban areas. Such information may be useful in developing national nutritional guidelines or informing public health policy in Peru.

The focus of this research is to describe observations regarding the consumption of native Peruvian grains (quinoa, amaranth and kañiwa), weight status, and self-described experiences of potential type 2 diabetes risk factors, warning signs and symptoms that may represent complications in Peruvian adults living in the city of Arequipa. Descriptions are also provided regarding the habitual consumption of a diet comprised largely of refined grains or foods high in starch, such as white bread, white rice, white flour-based foods, and starchy tubers including potatoes, chuño and cassava.

II. **Literature Review**

A. Peru and the people of Arequipa

Home to almost 30 million people, Peru is an ethnically, culturally and ecologically diverse country consisting of three distinct regions: the mostly urban, relatively wealthy coast; the poor, rural Andean highlands; and the poor and even less densely populated Amazon jungle (Huynen et al., 2005). The country has experienced rapid economic growth over the course of just a few decades, as evidenced by the steep rise in per capita gross national income (purchasing power parity method), which almost tripled between 1991 and 2010, from $3,110 to $8,940 (World Bank, 2011). This economic growth caused rapid migration from the rural highlands to urban coastal areas, as people sought better living conditions and financial opportunities. While a little over half the country's population lived in urban areas in 1965, that number had risen to 75% by 2005, and the trend toward increasing urbanization is expected to continue growing, albeit more slowly, in the coming decade (Baiocchi and Marin, 2000 and US Department of State, 2010).

Like many other cities in Peru, Arequipa has experienced rapid growth in recent years, both demographically and economically. Arequipa is considered to be comparable to other urban areas in Peru (particularly the most populous cities on the coast and in the Andean highlands)—economically, ethnically and to a lesser extent, culturally—since such cities tend to be wealthier on average than other areas of the country, and comprised of people with similar ethnic make-ups (Medina Lezama et al., 2008). Arequipa is the country's second-largest city after the capital city of Lima, with a current population of over 800,000 residents. While its population has grown by 21% between 1993 and 2007, the influx of migrants has brought more wealth to the city. Arequipa's poverty rate has declined from almost 34% in 2004 to 21% in 2009, which compares favorably to the national decline in poverty rates from 49% to 35% (Instituto Nacional de Estadística e Información, 2011).

In terms of ethnicity, Arequipa's population consists mainly of mestizos of Andean Amerindian descent (principally from the Quechua and Aymara nations), along with a small number of whites of Spanish descent and an even smaller number of people of African descent. In a 2006 survey of 1,878 individuals living in Arequipa, 92.5% self-identified as "mestizo," while 7.3% identified themselves as "white," and less than 1% self-identified as "black" or "other." However, such general categories hide the rich ethnic and cultural diversity of Arequipa and other urban centers in Peru. Among the many ethnicities and cultures represented in Peru's cities are a host of Native American peoples (Quechua and Aymara being the largest of these), as well as descendants of the Spanish, Italians, Japanese, Chinese, Africans, Germans and Dutch, among others.

B. Peru's history and shifts in dietary patterns

Before the arrival of the Spaniards in Peru in the sixteenth century, the Inkas had a sophisticated food production and distribution system that allowed the residents of what was then called Tawantinsuyo (comprising Peru, Bolivia, Ecuador and parts of Colombia, Chile and Argentina) to enjoy a varied, plentiful and nutritious diet, year-round. The traditional diet at the time of the Inkas was rich in high carbohydrate foods, including many varieties of tubers and root vegetables such as potatoes (which are native to Peru), sweet potatoes, cassava, and other foods not found in the US. There was also a large array of cereals, including quinoa, amaranth, kañiwa, corn, and many types of legumes and fruits from both tropical and temperate climates. The Inkas consumed protein derived from seafood and animal sources, including dried and fresh meat from camelids such as llamas and alpacas, deer, and guinea pigs, which are still considered a delicacy in modern day Peru. (Interestingly, the English word "jerky" can be traced back to the Quechua [language of the Inkas] word *charki,* which means dried meat). The Inkas also obtained significant quantities of protein from plant sources, especially cereal grains and legumes. Important fat sources in the Inka diet included fatty fish, avocados, corn, peanuts, and other legumes. They also made extensive use of roots, flowers, leafy greens, vegetables, seeds, and herbs in cooking, including the preparation of teas and infusions, which in some cases were used for medicinal purposes (Hurtado Fuertes, 2000 and Ramírez Angulo, 2009).

With the arrival of the Spaniards in the late sixteenth century, food traditions in Peru and other parts of Tawantinsuyo began to change. Whereas the Inkas preferred to eat boiled corn and drink a corn-based beverage called "chicha," the Spaniards insisted on making and eating wheat flour breads with olive oil, and drinking wine (Ramirez Angulo, 2009). Historians may refer to the Spanish conquest of South America, but in food terms, what happened was more of a blending of traditions and customs rather than a conquest of one culture over another. The Spaniards and other Europeans readily adopted native Peruvian and South American foods, such as potatoes, tomatoes, beans and corn. In turn, the Inkas were exposed to wheat flour, white rice, beef, pork, lamb, dairy products, vegetable oil and wine (Ramirez Angulo, 2009 and Rose et al., 2009).

In the struggle for power and control over their country, the Inkas suffered many abuses at the hands of the Spanish, some of which were directly related to food consumption. Spanish and Inka chroniclers recorded numerous attempts by the Spaniards—some of which were successful—to eliminate some of the Inkas' most important crops, including quinoa, kañiwa, amaranth and other grains. The motives were to physically weaken the Inkas by restricting their most nutritious foods, as well as to inhibit Inkan spiritual practices, which gave ceremonial importance to such native seeds and grains as quinoa and corn (Hurtado Fuertes, 2000). As part of this struggle, many Inkas were enslaved or taken as servants, and most were denied access to nutritious foods, resulting in compromised immune system function, which made the Inkas vulnerable to disease. Diseases such as smallpox killed millions, and induced protein-energy malnutrition and stunting (a measure of low height for age and an indicator of chronic childhood malnutrition) among the survivors.

The consequences of this subjugation are still evident today. Peru's rate of chronic childhood malnutrition was 18% nationally among children under age 5 in 2010. In rural regions of the Southern Andes, which are inhabited almost entirely by indigenous peoples, malnutrition affects 43% of the population. The rate of stunting among children <5 years of age was 17.9% nationally in 2010, and 31% in rural areas. In 2009, 39% of the total population lived below the national poverty level, as well as over two-thirds of the rural indigenous population (Mejía Acosta, 2011; Pan American Health Organization, 2010 and INEI, 2011).

Peruvian cuisine today continues to be strongly influenced by the country's indigenous roots as well as by Spanish, Italian, Chinese and Japanese traditions (the latter two from Asian migration to South America during the 20th century) (Agri-food trade service, 2010). Even though almost 200 years have passed since Peru gained its independence from the Spaniards, Peruvians still tend to associate food choice and diet with social status and prestige, particularly in urban areas. Families who consume or serve to guests native grains and legumes are seen as lower class “Indians,” while those who eat wheat flour breads, pasta, rice and sugar (foods favored by the Spaniards), are conferred the higher status of “mestizos” or “whites” (Bastien, 1998; Martinez-Zuniga, 2007; Ayala, 2003 and Rose et al., 2009).

C. Macronutrient content of the typical Peruvian diet

The stigmatization of some traditional indigenous foods in Peru has led to a partial shift in the types and quality of macronutrients consumed in the country, particularly among people living in urban areas. As people gravitated toward a preference for new and different types of carbohydrates, they also increased the amount of dietary fat, sugar and animal-sourced foods they consumed, particularly in recent decades.

The traditional diet, which is still consumed in rural areas such as the Andes highlands, makes abundant use of tubers such as potatoes and cassava, as well as grains native to Peru, such as quinoa, barley, amaranth and kañiwa. Modern, urban Peruvians continue to enjoy potatoes, cassava and other tubers in their daily diets, but their grain preferences have shifted significantly in that they now prefer to eat rice, bread, pasta and other foods made from refined wheat flour, in place of the native grains that their ancestors enjoyed. Rose et al. (2009) reported that the main sources of energy in the Peruvian diet today are rice, potatoes and sugar. In a study of Peruvian Amerindians living in rural areas and the capital city of Lima, Lindegarde et al. (2004) found that rural residents continue to consume significant amounts of potatoes, quinoa, and barley, while urban dwellers tend to substitute white rice and white bread for traditional grains. Even in 1971-72, the Peruvian national food consumption survey (Encuesta Nacional de Consumo de Alimentos – ENCA) reported that rural residents ate three to four times more tubers than urban residents (Baiocchi and Marin, 2000; Bastien, 1998). A possible reason is that potatoes are more expensive than rice and wheat flour for urban consumers, but are more affordable for the rural residents who grow them (Rose et al., 2009).

Most urban Peruvians consume refined wheat flour rolls for both breakfast and dinner, along with a sweetened, hot beverage, cereal and other breakfast foods (Food by Country, 2009 and Euromonitor International, 2009). Bread is eaten less frequently at lunch when it is replaced by broth-based soups containing potatoes, cassava, white rice and/or pasta, chuño (freeze-dried potatoes) and a small amount of meat, legumes and vegetables. After eating a large bowl of soup, many urban Peruvians also consume a plate of "dry" food at lunch (and sometimes dinner, as well), typically containing some type of meat and a large serving of white rice and potatoes or pasta. (Food by Country, 2009)

Like potatoes, quinoa, amaranth and kañiwa are typically more expensive in urban areas than in the rural areas where they are grown, which may help explain declines in consumption among urban residents (Ayala, 2003). According to one survey, the main forms in which Peruvians eat quinoa are in stews (67%), desserts (36%), drinks (35%), soups (34%) and breakfast cereals (22%). About 10% of nursing mothers eat quinoa due to the common belief that it improves lactation (Ayala, 2003). Amaranth is consumed in similar forms as quinoa, although amaranth is less popular and versatile than quinoa. Kañiwa is typically ground into flour and eaten as a cold cereal, either dry or with milk (Bastien, 1998).

As has been alluded, the traditional Peruvian diet is high in carbohydrates and relatively low in protein and fat, a pattern that continues today.   The traditional Peruvian diet consists of 65-75% carbohydrates, 10-15% protein, and 14-18% fat. Urban-dwelling, wealthier people tend to be on the low end of the carbohydrate spectrum and consume larger amounts of protein and fat, compared to rural-dwelling, poorer subjects (Baiocchi and Marin, 2000). This may be due to rural residents' tendency to eat traditional foods that they produce themselves, whereas urban residents consume more imported foods, such as foods containing refined wheat flour, sugar, vegetable oils and dairy products (Mispireta et al., 2007 and Baiocchi and Marin, 2000).

A nationwide nutrition survey conducted by the Peruvian government in 2006 reported similar numbers: on average, Peruvians obtain 74% of their daily energy intake from carbohydrates, 17% from fat and 13% from protein. However, this survey also reported very low calorie intakes (mean caloric intake=1577 calories/day) as well as low intakes of dietary fiber. The mean fiber consumption was 9.8 g/day for men and 8.3 g/day for women, which equates to 39% and 33%, respectively, of the daily 25 g recommended by the World Health Organization and the Food and Agriculture Organization of the United Nations (WHO/FAO) (Centro Nacional de Alimentación y Nutrición, 2006). This low dietary fiber intake likely stems from the aforementioned high consumption of refined cereals and grains, which account for about 40% of energy intake in Peru, followed by foods made from sugar and/or starchy vegetables such as potatoes and cassava, which account for 27% of average total energy intake (Baiocchi and Marin, 2003).

Common micronutrient deficiencies reported in the survey included calcium intake, which averaged 34% of the Dietary Reference Intake (DRI) for women and 41% for men, folic acid, with average intakes of less than 20% of the DRI for both men and women, and iron. Only women were found to be deficient in iron, with mean intakes of 45% of the DRI (Centro Nacional de Alimentación y Nutrición, 2006). Such findings may be due to a reduced consumption of fruits and vegetables in Peru, which according to the *1964-1996 Country Food Balance Sheets*, decreased from 10.4% to 2.4%, and from 1.8% to 1.2%, respectively, of total daily energy intake. Also noteworthy is the finding that total energy consumption from starchy roots decreased from 10.9 % to 6.4%, which suggests that Peruvians obtain more than 20% of their daily energy intake from foods containing added sugars (Food and Agriculture Organization of the United Nations, 2001). This is likely due to the increased availability and affordability of soft drinks and other sweetened beverages, and increased consumption of foods high in added sugars such as candy, sweetened yogurt and desserts.

Over recent decades, there has been an increase in fat consumption in urban areas in the Andean region. Fat consumption increased from about 15% of total energy in 1964 to about 24% in the mid 1990s (WHO/FAO, 2003 and Baiocchi and Marin, 2000). This is consistent with national survey data indicating that 87% of the population reported eating fried foods at least once per week, while less than 2% said they never eat fried foods. In addition, the survey reported that over 30% of Peruvians said they eat fast food at least once per week, while 63% indicated doing so at least once per month (Centro

Nacional de Alimentación y Nutrición--CNAN, 2006). This survey defined “fast food” as food purchased from street vendors, rotisserie chicken establishments, or restaurants such as McDonalds, Pizza Hut, Dunkin Donuts, and similar establishments.

Residents of Arequipa are similar to inhabitants of other urban areas across Peru in that many tend to consume high fat diets. The PREVENCION study of cardiovascular risk factors carried out in Arequipa corroborates the finding that urban residents tend to consume substantial amounts of fat in their diets. The study found that almost 43% of the city’s residents consume high fat diets according to guidelines from the American Heart Association (AHA). AHA recommends limiting total fat, saturated fat and trans fat consumption to less than 36%, 7% and 1% of calories per day, respectively (AHA, 2012). There is a significant inverse relationship between consumption of high fat diets and age: 48% of the 20-34 year-old group consumed a high-fat diet, compared to 31% of the group aged 56-80 years. The same study reported low fruit and vegetable intake among residents of Arequipa. About 38% of the younger age group (20-34 years) reported a low fruit and vegetable intake, while fruit and vegetable intake among the older (65-80 years) group was 24% and 29%, respectively. This finding is especially noteworthy because “low” fruit and vegetable consumption was defined as consuming fruits or vegetables less than three times per week, which is a low bar (Medina-Lezama et al., 2008).

D. Epidemiological and nutrition transitions

Like many developing countries, Peru has had many hurdles to navigate as it makes the transition from a poverty-stricken society to becoming a thriving, prosperous nation. Thanks to globalization and advances in modern technology, this shift is occurring within a matter of decades, rather than over the course of centuries as it did in most of today's developed countries. In Peru, as in many other developing countries in transition, this rapid shift has changed peoples' lives in many ways. While some changes have been for the better and have afforded families increased access to jobs, economic opportunities, food, medicine, health care and other goods and services, other changes have been less desirable.

Omran was the first to describe the trajectory of the rapid transition, which he called "epidemiological transition theory," in which countries move from a national public health situation with high prevalence of infectious disease and malnutrition, to one with high prevalence of chronic and degenerative diseases associated with lifestyle choices (CENAN, 2006). Omran's theory was that developing countries have undergone a transition that differs from the one that occurred in today's industrialized countries. While developed and developing nations alike experienced the first two stages of Omran's epidemiological transition model, which he coined "the age of pestilence and famine" and "the age of receding pandemic" (characterized by a declining mortality and fertility rates), respectively, Omran posited that the third stage, "the age of triple health burden," is unique to developing countries (Omran, 1971). Huynen et al. (2005) and Huicho et al. (2009) presented data showing that Peru is currently experiencing this third stage of the epidemiological transition. They point to high rates of acute respiratory infections, tuberculosis and intestinal infections, as well as high maternal mortality rates, as indicators that infectious diseases (which are responsible for one-third of the deaths in Peru, as of 2009) are still a health challenge in Peru. They say that the rising prevalence of diseases such as cardiovascular diseases, cancer and diabetes, is evidence that chronic diseases (which are now responsible for more than half of all deaths in Peru), the second 'health burden,' are gaining a foothold in Peru. Third, they point to a lack of healthcare facilities and low health insurance coverage among the Peruvian population, as evidence that the country's health system is ill-prepared to deal with the new health challenges that are arising out of the rapid transition between the stages (Huynen et al., 2005).

The concept of a "nutrition transition" in developing countries arose out of Omran's epidemiological transition theory in the 1990s. Nutrition transition is characterized by a shift from undernourishment and malnutrition, to rising rates of overweight and obesity, as countries undergo rapid economic development and growth. It occurs as a plethora of rapid changes take root in a given country, including: increased urbanization, the adoption of technologies that minimize the need for physical labor and give people more free time, the growth of food processing and communications technologies, and increased availability and consumption of high-fat , sugary and processed foods. As people become less physically active and increase their energy intake, biochemical and anthropometric changes occur in the population, such as changes in stature, genetic expression and body composition. Such changes lead to overweight and obesity, as well as a rise in chronic degenerative diseases, which are quickly become important public health problems in countries undergoing nutrition transitions (Popkin, 1994).

Popkin, et al. were the first to note a rise in obesity rates among stunted children living in developing countries following large-scale acceptance of the new dietary patterns that tended to accompany rapid economic growth in those countries. In their study that looked at almost 44,000 individuals in four developing countries in transition

(China, Brazil, Russia and South Africa), the researchers found that of the almost 31% of young children who showed signs of stunting, a full 13% were reported to be both stunted and obese, compared to just 5% of same-aged children who were only obese, but not stunted (Popkin et al., 1996). To explain this phenomenon, Popkin points to the biological impact of shifts from periods of prolonged malnutrition, hunger and food deprivation, particularly when suffered during childhood, to periods of dietary abundance in later life. Such shifts tend to induce people who have experienced them to consume high-calorie, high-fat foods in excess, as the body attempts to prepare for times of potential future food deprivation, and to store the excess energy as fat (Popkin, 2001). Worse still, the biological damage and stunting resulting from early malnutrition is irreversible after age 3. Thus, the populations of developing countries that have a high prevalence of stunting are more biologically vulnerable than those of developed countries, where stunting has not been a major public health concern (Popkin, 2002).

E. **Peru's nutrition transition experience**

Peru has experienced both positive and negative consequences as a result of the country's rapid transitions and recent economic development. On the positive side, development has lead to a greater availability, affordability and variety of foods. However, as a result of new employment opportunities for women (who typically are responsible for preparing meals for their families) outside the home, changes have occurred in families' eating patterns and food preferences. There has been a shift away from the consumption of traditional foods, which are time-consuming to prepare and stigmatized due to their association with Peru's poor indigenous cultures, particularly in urban areas. Instead, Peruvians have increasingly begun to favor the so-called "Western" diet, which typically contains substantial quantities of refined grains, sugars, animal products and high-fat foods (Wanden-Berghe, 2010, and Bermudez and Tucker, 2003).

In the US, Europe and other parts of the world, the "Western" diet has been associated with overweight and obesity, as well as the development of chronic diseases such as heart disease and type 2 diabetes mellitus. The consequences of shifting to a "western" diet are magnified in Peru due to the rapid rate of this nutrition transition and the large gaps in income and access to affordable food and healthcare between urban residents and people living in marginalized, rural areas. These gaps help to explain why some subgroups within the population continue to experience high rates of malnutrition and hunger, while others grapple with rising chronic disease rates, sometimes even within the same region (INEI, 2007 and Mispireta, 2007).

As food has become more available, Peruvians have adopted the Western-type diet and more sedentary lifestyles, particularly in urban areas of the country. National food intake surveys conducted by the Peruvian government confirm that whereas people living in rural areas primarily consume traditional plant-based foods (such as quinoa, kañiwa and amaranth) they produce themselves, urban residents rely increasingly on foods derived from wheat and wheat flour, sugar, vegetable oil and dairy products instead of the traditional foods (CENAN, 2009). Leonard and Thomas (1988) reported an exponential drop in quinoa consumption from the mid-1960s to the mid-1980s, from 238 Kcal/day to just 20 Kcal/day. Although urban communities are leading this trend, spending nearly 2.5 times more on food than rural households in 2005, even rural communities are beginning to make such changes (Maltsoglou, 2007). In 1984, processed meat products, canned tuna, powdered milk, yogurt, instant coffee, powdered chocolate and mayonnaise were typically absent in the diets of rural communities, but by 1996, these types of processed foods contributed between 6-13% of calories, on average, in such communities (Bermudez and Tucker, 2003).

Not surprisingly, many urban Peruvians are overconsuming the newly available foods that are high in calories and low in nutrient density. Thus, as seen in other developing countries, Peru continues to experience high rates of stunting, overweight and undernutrition (Mispireta et al., 2007). According to the results of a recent household survey, more than 53% of households reported having at least one overweight adult family member, and over 15% of families reported experiencing concurrent overweight and undernutrition problems. Fewer than 17% of families reported a total absence of any nutrition-related conditions, which in this survey included malnutrition, undernutrition, stunting, overweight, obesity, or any combination of these conditions (CENAN, 2009). However, stunting among urban children < 5 years of age has dropped dramatically, from 27.6% in 1991-2, to 14.1% in 2005, due to increased food availability in Peru's cities (INEI, 2007 and Mispireta, 2007).

The increased rates of overweight, obesity and diet-related chronic diseases in Peru are attributed to the westernization of the Peruvian diet. WHO estimates that almost 79% of Peruvian females over age 30 are overweight or obese, defined as having a body mass index (BMI) of 25-29.9 or ≥ 30, respectively, while nearly 70% of Peruvian men over age 30 are overweight or obese (Ono et al., 2005).

F. Health and chronic disease in Peru

Over the past 45 years as average life expectancy has increased from 44 years to over 70 years, public health concerns in Peru have shifted. There have been dramatic reductions in communicable and perinatal diseases and notable increases in non-communicable diseases such as cardiovascular disease, cancer and diabetes (Huynen et al., 2005; Perez, 2006). Peru has experienced health issues similar to those of other transitioning developing nations. Health-related changes include a decline in fertility rate (from 6.0 children/family in the early 1970s to 2.5 in 2002-2005) and mortality rate (from 6.85 per 1,000 persons in 1990-1995, to 6.09 in 2000-2005) and increasing rates of overweight, obesity, and chronic diseases. For example, cardiovascular disease was responsible for 5.4% of deaths in 1967, compared with 16.3% in 1994-98. Overweight and obesity affected 31.1% and 8.8%, respectively, of the population in 1992, and rose to 33.7% and 13.0% by 2000 (Mispireta et al., 2007). A survey conducted by the Peruvian governmental health authority in 2006 indicated that the average BMI of all Peruvian adults is 25.8, suggesting that being overweight may be the norm in Peru today. Further, the average waist circumference for all Peruvians is 90.3 cm. A waist circumference >90 cm for men and >80 cm for women is considered an independent risk factor for diabetes and other chronic diseases, according to criteria of the International Diabetes Foundation (IDF) (CENAN, 2006; Soderberg et al., 1999).

To better understand the weight status of Peruvians, it is helpful to examine trends within specific age-groups, geographical areas and socioeconomic strata. Among all Peruvians, BMI increases with age, reaching a peak average of 27.3 among the 50-59 year-old age group, with over 25% of that age-group classified as obese. Women have higher BMIs than men; national averages are 26.5 and 25.1, respectively (CENAN, 2006). Almost 47% of all Peruvian men (regardless of age) are overweight and about 16% are obese. Among all Peruvian adult women, about 40% are overweight and 20-24% are obese. However, among women >35 years of age, overweight and obesity affect around 70% of the population, with the 40-49 age group showing the highest prevalence (CENAN, 2009 and Cortez et al., 2002).

Overweight and obesity are continuing problems in Peru. The prevalence of obesity increased by 8-12% for all Peruvian women between 1991 and 2005 (Timar, 2009). In addition, 54.5% of Peruvian women exhibit abdominal obesity, as defined by a waist circumference >80 cm (CENAN, 2006). A similar trend exists among Peruvian children. A 2009 study by the Institute of Nutritional Research found that about 20% of children in grades 3-6 living in the capital city of Lima is overweight, and about 14% is obese (Reyna Liria et al., 2009). Another Lima-based study found that about 31% of children 6-10 years of age were overweight or obese, with boys and girls equally affected (Bustamante et al., 2007).

Unlike the situation in the U. S., the prevalence of overweight is greater among higher-income families. For example, in a recent survey, over 65% of "non-poor" households reported having overweight members, while 43% of "poor" households reported an overweight family member. Surprisingly, even 14% of households living in conditions of extreme poverty reported having overweight members (CENAN, 2009).

Obesity is more common in urban areas than in rural areas of Peru. Results of a 2009 survey indicated that 67% of urban households reported at least one overweight member, while 27% of rural households report having overweight members (CENAN, 2009). The more developed the city, the higher the prevalence of overweight and obesity for both men and women: the rates were highest in Lima, followed by Arequipa and Ica. In Arequipa, the city where our study was conducted, 46% of women and 47% of men are overweight, and 13% of women and 17% of men are obese (Jacoby et al., 2003). Among men and women ages 35-80 living in Arequipa, more than 7 out of 10 (71.4%) are either overweight or obese (Medina et al., 2006).

Geographic area of residence has also been associated with waist circumference (WC). While people living in the rural highland areas have an average WC of 86.6 cm, residents of urban areas such as Lima have larger waists, with an average circumference of 92.3 cm (CENAN, 2006). The average BMI and waist circumference of men ages 35-80 living in Arequipa are 27.1 and 95.6 cm, respectively, while for women in this age group the respective averages are 27.8 and 90.7 cm (Medina et al., 2006). Using the IDF criteria, 86% and 63% of women and men, respectively, between 35-64 years of age living in Arequipa exhibit abdominal obesity (Alberti et al., 2005; Medina et al., 2006).

As seen in the U.S. and other developed countries, the high prevalence of overweight and obesity in Peru seem to be stubbornly entrenched, particularly in urban areas, and is not abating. Whereas one in five women met the WHO criteria for obesity (BMI>30) in 1991-92, that number had risen to one in four women by 2000 (Mispireta, 2007). Further, even normal-weight, urban-living Peruvians, particularly women, have more body fat (4 Kg on average) and higher levels of diastolic blood pressure, blood glucose, and insulin levels than their normal-weight, rural counterparts (Lindegarde et al., 2004).

Peru's National Institute of Statistics and Information directly attributes the urban trend toward larger BMIs and WCs to changes in dietary intake patterns, lower physical activity, increased television viewing, rapid urbanization, better access to food and economic development (INEI, 2007). One study that looked at physical activity levels by urban vs. rural areas of residence found a strong correlation between urban living and low physical activity levels. In this study, while 2.2% of lifetime rural residents reported having a lifestyle marked by low physical activity, that number rose to 32.2% in rural-to-urban migrants and to about 80% among lifetime urban residents (Grupo de Opinión Pública, 2009). A national survey conducted by CENAN also found starkly different levels of physical activity between urban and rural residents. In that survey, 18.8% of rural residents over the age of 14 years old reported having a sedentary life, compared to more than half (50.1%) of urban residents (CENAN, 2006). In Arequipa, age-standardized prevalence of insufficient physical activity in the 20-69 year-old population was reported to be 58% (Medina et al., 2008).

Gender is an important determinant of participation in exercise and sports; while 41.2% of men report exercising or playing sports, only 14.3% of women do so (CENAN, 2009). Overall, 72% of Peruvians reported that they do not exercise or participate in sports (CENAN, 2006). In addition, a large number of Peruvians reported being physical inactive in daily life. More than a third (35%) of Peruvian men have sedentary lifestyles, and almost half (46%) of Peruvian women lead sedentary lives. In Arequipa, the prevalence of physical inactivity is also significantly higher in women than in men (63% vs 52% among people ages 20-69) (Medina et al., 2008). Participation in exercise and sports also declines significantly with age in Peru. While almost 60% of 15-19 year-olds engage in such activities, only 21.5% of people ages 30-39 and less than 8% of those ages 60-69 do so (CENAN, 2009).

Taken together, the rise in overweight and obesity with the decline in physical activity have increased the risk of chronic diseases among Peruvians. While obesity itself is considered a chronic disease (WHO, 2000), overweight and obesity are also associated with cardiovascular disease and type 2 diabetes risk factors, including dyslipidemia (high triglyceride and low HDL levels), abnormal lipid and glucose metabolism, hypertension, insulin resistance (i.e., impairment in the cells' ability to recognize the hormone insulin), and decreased age-associated glucose tolerance (Soderberg et al., 1999; Medina et al., 2006). Peruvian government health data suggest that such risk factors are common among Peruvians, especially among older individuals. For example, 22.5% of 40-49 year-olds report suffering from high blood cholesterol levels, and almost 20% have elevated triglyceride levels. However, those number rise to 33.6% and 24.1%, respectively, in the 60 and over age-group (CENAN, 2006).

Physical activity is positively associated with increased insulin sensitivity and a reduced risk of developing diabetes, even after adjustment for BMI (Schulze and Hu, 2005). The authors of the Nurses' Health Study predicted that 30% of new cases of obesity and 43% of new cases of diabetes could be prevented by adopting a relatively active lifestyle (e.g., <10 h/wk of TV watching and ≥30 min/day of brisk walking) (Hu et al., 2003).

In addition to overweight, abdominal obesity, physical inactivity and age, a number of other factors put Peruvians—particularly urban residents—at risk of developing chronic diseases including type 2 diabetes mellitus during their lifetimes.

These include genetics; limited support from health professionals and institutions; and possibly, living at lower altitudes. As mentioned earlier, over 90% of the population self-identifies as “mestizo” (meaning a mix of Native American and Spanish ancestry). Research shows that Native Americans are twice as likely to develop diabetes as Caucasian non-Natives (Ohio State University Medical Center, 2011).

Peruvian public health efforts aimed at promoting healthy lifestyles have been inadequate. The first such effort was the 2010 launch of a national campaign called “Por tu salud, muévete Perú (For your health, let’s move Peru) (Agri-Food Trade Service, 2010). However, access to health services remains limited or unavailable to many Peruvians.

As Peruvians migrate to urban areas, they move from higher to lower elevations since most cities are located in relatively low-lying areas. Barraco et al. (2007) reported that residing at a high altitude was associated with an improved risk factor profile for metabolic syndrome, including low blood glucose levels, increased glucose uptake into cells and peripheral tissues, and greater insulin sensitivity, even after controlling for diet and physical activity as potential confounders. In addition, residence in high-altitude areas has been associated with greater hyperglycemic hormone secretion and caloric expenditure, due to adaptive changes in the body related to living in a chronic hypoxic state. In that study, people living in urban Rimac had fasting plasma glucose levels of 92.3 mg/dL compared to 88.5 mg/dL among those living in the rural highland area of San Pedro de Cajas. Interestingly, this difference was particularly evident in women; while 11% had high fasting glucose levels in rural San Pedro de Cajas, almost 31% of those living in urban Rimac had high fasting glucose levels, compared to 19% of men in both locations (Baracco et al., 2007). These results suggest that living at a low altitude may be an additional risk factor for type 2 diabetes among people living in urban areas in Peru. Even Arequipa, located at 2,300 m above sea level, can be considered “low altitude” compared to the rural highland areas from where many of its migrants originate.

With so many risk factors present in the population, diabetes is a growing problem and is now estimated to be the seventh leading cause of death in Peru (Loaiza et al., 2006). In rural areas, the prevalence of type 2 diabetes mellitus affects about 1% of the population. In Arequipa, the prevalence is 4-5%, and in Lima and in some other coastal cities, prevalence has reached 8% (INEI, 2007). However, many Peruvians are probably unaware that they have the disease. Researchers from Johns Hopkins University estimated that 50% of Peruvian diabetics have not been diagnosed by a physician and are probably unaware of their disease status. In their Lima-based study sample, 17% of the women and 19% of the men were found to have diabetes, based on glucose tolerance tests (Goldstein et al., 2005). However, the diagnosis of diabetes has been increasing. In Arequipa’s Horacio Delgado Hospital, the number of new cases reported increased from 128 in 2003 to 276 in 2004, and 174 cases of diabetes were diagnosed during the first six months of 2005 (Loaiza et al., 2006).

The prevalence of type 2 diabetes mellitus is especially increasing among older Peruvians. While prevalence is about 1% below age 39, it rises to 2.2% in the 40-49 year-old age-group, 6.3% in the 50-59 year-old age-group, and 11.4% among Peruvians ages 60 and above (CENAN, 2006). It is unclear why prevalence is so low among in the youngest age-group. It may just be that type 2 diabetes hasn’t been on the medical community’s radar screen until just recently for younger people. Indeed, in a radio interview on October 7, 2010, Dr. Herald Manrique Hurtado, Medical Director at the Diabetes, Obesity and Nutrition Research Center at Loayza Hospital in Lima, said that only 2% of type 2 diabetics in Peru were children as recently as 10 years ago. Unfortunately, that number had risen to 8% by 2010 (Radio Programas Peruanos, 2010).

Research also suggests that diabetes is not a well-controlled disease in Peru and is accompanied by other heart disease risk factors. A 2008 study found that 96% of type 2 diabetics living in Arequipa exhibited abdominal obesity, 79% were hypertensive, 71% had high blood triglyceride levels, and 69% had low HDL cholesterol levels (Oporto Salas and Rojas Flores, 2008).

G. Overview of type 2 diabetes mellitus

Diabetes mellitus has been described as "a group of diseases characterized by high blood glucose concentrations resulting from defects in insulin secretion, insulin action, or both" (Mahan and Escott-Stump, 2008). The most common types of diabetes include type 1 (considered an autoimmune disease), gestational (generally occurs during pregnancy and usually self-resolves once the pregnancy ends), and type 2—by far the most common type, accounting for 90-95% of all cases—which often combines cellular insulin resistance and pancreatic insulin deficiency resulting from beta cell failure. Although type 2 diabetes mellitus and other non-communicable chronic diseases (NCDs) used to be considered diseases affecting primarily wealthy, developed countries, they now are also a growing threat to the developing world. The World Health Organization reported that 79% of worldwide deaths attributable to NCDs occurred in developing countries (WHO, 2002).

The development of type 2 diabetes involves multiple factors, including genetics, the environment, and lifestyle choices. Approximately 87% of cases are attributable to modifiable risk factors. The single most important predictors for type 2 diabetes are overweight and obesity, which account for over 60% of cases (Hu et al., 2001). According to the WHO, 58% of diabetes mellitus cases worldwide can be attributed to people who maintain a BMI >21. The reason is that certain ethnic groups, such as Native Americans and Asians, are susceptible to chronic diseases at BMIs much lower than those considered "normal" for Caucasians. For Native Americans, chronic disease risk begins to increase with BMI >21, while for Caucasians, risk begins to increase with BMI ≥ 25 (WHO, 2002). A study of female nurses found that even among Caucasians, women with BMIs of 23.0-24.9, considered the high end of "normal," are 20 times more likely to develop diabetes than women with BMIs < 23. Further, women with BMIs > 35 were about 40 times more likely to develop the disease (Hu et al., 2001).

Abdominal obesity and weight gain are additional risk factors for developing type 2 diabetes. Snijder et al. (2006) reported that abdominal obesity—especially in the form of visceral fat deposits—is an additional risk factor independent of overall overweight and obesity for insulin resistance and type 2 diabetes. Results of the Nurses' Health Study, which controlled for BMI and other potential confounders, indicated that women in the 90^{th} percentile of waist circumference were more than 5 times more likely to develop diabetes compared to women in the 10^{th} percentile (Carey et al., 1997).

Irrespective of initial body weight (i.e. body weight in late adolescence), progressive weight gain in adulthood is associated with an increasing risk of diabetes. Compared to women who maintained their body weight, those who gained 5-7.9 Kg almost doubled their risk; those who gained 8-10.9 Kg almost tripled their risk; and those who gained 20 kg or more increased their risk more than twelve-fold; In contrast, women who lost more than 5 Kg reduced their risk by 50% or more (Colditz et al., 1995). A similar study in men found that for every kilogram of weight gained, risk increased by 7.3% (Koh-Banerjee et al., 2004).

In addition to maintaining a BMI<25, Hu et al. identified four additional lifestyle factors that, when combined, reduced type 2 diabetes incidence in women by 91%: eating a diet high in cereal fiber and polyunsaturated fat and low in saturated and trans fats and glycemic load; exercising at least 150 hours per week at moderate intensity; not smoking; and moderate alcohol consumption (one drink/day for women and two for men). Even without maintaining a desirable weight, the risk of diabetes can be lowered by about 25% through these lifestyle changes. The same study also found that independent of other risk factors, people who consumed the largest quantities of cereal fiber were 40% less likely to develop diabetes than those who consumed the smallest amounts (Hu et al., 2001). In their review, Schulze and Hu reported that lifestyle interventions were equally effective for both men and women and for a variety of ethnic groups (Schulze and Hu, 2005).

Another study reported similar findings regarding the influence of modifiable risk factors in type 2 diabetes development. Reis et al. reported that men who maintain a healthy body weight, don’t smoke, drink moderate amounts of alcohol (2 drinks per day or less), eat healthfully, and exercise regularly, are 72% less likely to develop type 2 diabetes than men who do not. Women who make healthy choices in all these areas (including ≤ 1 alcoholic drink/day) reduce their risk by 84% (Reis et al., 2011).

Other diabetes risk factors not attributable to lifestyle include family history; Native American, African American, Asian or Hispanic ethnicity; older age; prevalence of dyslipidemia (HDL<35 mg/dL or triglycerides >250 mg/dL); hypertension (>160/90 mmHg); delivering a high birth-weight baby (>4 Kg); impaired glucose tolerance (>140 mg/dL, measured 2 hours after administration of 75 g glucose); and impaired fasting glucose (>100 mg/dL) (Reis et al., 2011, CENAN, 2006, Sharma, 2002 and Soderberg et al., 1999).

It is important to keep in mind that overweight and obesity are associated with many of the above risk factors, including abnormal glucose metabolism, insulin resistance and decreased age-associated glucose tolerance (Soderberg et al., 1999 and Medina et al., 2006). In addition, several studies have found that some so-called 'non-modifiable' risk factors respond to healthy lifestyle choices. For example, a 42-58% reduction in the incidence of type 2 diabetes was reported among people with impaired glucose tolerance who adhered to a diet high in fiber and low in saturated and trans fats, and who exercised regularly (Pan et al., 1997; Toumilelito et al., 2001; National Institute of Diabetes and Digestive and Kidney Diseases, 2001).

Diabetes is a major risk factor for coronary heart disease, stroke, kidney failure, blindness, dementia, Alzheimer's disease, and non-traumatic amputations (Schulze and Hu, 2005; Ohara et al., 2011). Once an individual contracts type 2 diabetes mellitus, ongoing and appropriate treatment is required to prevent the development of debilitating complications, including renal insufficiency, neuropathy that can lead to the amputation of limbs, heart disease and blindness (Harrison and Isselbacher, 2005). With appropriate treatment and lifestyle changes, most diabetics can control their symptoms and prevent such complications. Effective lifestyle changes include daily physical activity, moderate weight loss, reducing saturated fat and energy intakes, and consuming appropriate amounts of whole grains and dietary fiber. Other diabetes management treatments include blood sugar monitoring, insulin therapy, medications and self-management education (Mahan and Escott-Stump, 2008).

H. Diet and diabetes

Although being overweight is associated with type 2 diabetes, and weight loss is a primary strategy for reducing diabetes risk, the optimal macronutrient distribution of weight loss diets has not been established (American Diabetes Association, 2008). Both low-fat and low-carbohydrate diets have lead to weight loss that was sustained after one year (American Diabetes Association, 2008). A 2007 review of the literature concluded that low fat, high-carbohydrate diets are beneficial for weight control and general health because such diets tends to be nutrient dense, particularly when there is an emphasis on consuming cereal fibers (Gaesser, 2007). However, other researchers have disputed this conclusion, pointing to chronic disease risks associated with such a diet. For example, one study reported a correlation between high-carbohydrate, low-fat dietary patterns (especially when accompanied by low physical activity levels) and increased risk of coronary heart disease, because such diets tens to lower HDL levels and increase total cholesterol and triglyceride levels (Hernandez, 2004). Low HDL levels and high total cholesterol and triglyceride levels have also been associated with type 2 diabetes mellitus (American Diabetes Association, 2008).

Another study of low-carbohydrate diets among diabetic subjects reported increased levels in serum HDL and triglycerides, as well as decreases in A1C levels, compared to diabetics who consumed low-fat diets (Stern et al., 2004). A meta-analysis found an association between low-carbohydrate diets and beneficial HDL and triglyceride levels, but higher levels of LDL cholesterol (Nordmann et al., 2006). Further, Willett and Leibel (2002) reported that fat consumption within the range of 18-40% of total energy intake has little if any effect on body fat, since the body has compensatory mechanisms that adjust for fat intake over the long term.

In their literature review on diabetes prevention, Schulze and Hu concluded that metabolic research does not support the hypothesis that high-fat diets negatively affect insulin activity. They concluded that specific types of fat influence insulin sensitivity in different ways in diabetic, overweight and healthy subjects. While polyunsaturated fats are positively associated with insulin sensitivity, saturated and trans fats have a negative influence (Schulze and Hu, 2005). Several studies have found that reducing saturated fat intake improves insulin resistance independent of energy intake, and thus may reduce diabetes risk even in the absence of weight loss (Franz et al., 2002; van Dam et al., 2002; and Vessby et al., 2001).

Gannon and Nuttall looked at the effects of diet composition on blood glucose in diabetics. They reported that although fat in the diet can affect insulin secretion and modify absorption of carbohydrates, it does not significantly affect blood glucose levels. Their study tested the efficacy of diets with varying ratios of carbohydrates: protein: fats, in people with untreated type 2 diabetes. They found that while a 30:40:30 ratio diet brought a moderate, although significant, decrease in blood glucose, 30:20:50 and

30:30:40 ratio diets decreased fasting blood glucose by as much as 38%. It is important to note that the carbohydrates used in their study diet were very low in starch. Instead of eating high-starch foods such as cereals, potatoes, rice or pasta, study participants obtained carbohydrates mainly from fruits, juices, vegetables and dairy products. This was done because the authors reported observing more severe spikes in blood glucose accompanying starch consumption, as compared to ingestion of sugars (i.e. sucrose, lactose, fructose, etc.) in type 2 diabetics (Gannon and Nuttall, 2006). Corroborating these findings, another study reported that among diabetics, low-carbohydrate diets were less helpful in lowering fasting glucose levels compared to low-fat diets; respective reductions were 21 mg/dl and 28 mg/dl (Stern et al., 2004). Thus, it appears that there is some evidence to suggest that low-carbohydrate, moderate-to-high protein, high-fat diets may be beneficial for controlling blood glucose in both type 2 diabetics and healthy adults, even in the absence of weight loss. However, it is important to consider the type of fat consumed in such a diet, not just the quantity of fat. Additional research is needed to determine the metabolic and health effects produced by consuming fats of different types. Gannon and Nuttall (2006) limited saturated fat consumption to approximately 11% of total fat consumption in their study, while Stern et al. (2004) reported no significant difference in saturated fat consumption between the two study groups (the low carbohydrate group and the low fat group). However, neither study included any further details regarding the other types of fat consumed by their intervention groups.

I. Carbohydrates and diabetes

Although Peruvians' preferred sources of carbohydrates have changed over the years—from traditional whole grains, to refined flour breads and white rice—the percentage of their daily energy intake coming from carbohydrates (averaging 65-75%) has changed little. This is significantly higher than the 45-65% recommendation from the American Dietetic Association and the RDA of 130 g/day of digestible carbohydrate, which represents approximately 30% of calories in a 2,000 calorie/day diet. Consumption of such high levels of carbohydrates may increase the risk for overweight and diabetes, particularly because dietary carbohydrate is the major determinant of postprandial glucose levels (American Diabetics Association, 2008).

Both the quantity and the type of carbohydrates consumed influence postprandial glucose levels (Schulze and Hu, 2005) and may affect BMI. A 2007 review concluded that whole-grain intake is generally inversely associated with BMI, while refined grain intake is not (Gaesser, 2007). Therefore, the trend toward lower consumption of whole grain cereals among Peruvians may adversely affect health. Also, evidence suggests that high glycemic foods, such as those derived from refined grains, can increase the risk of type 2 diabetes by producing high blood glucose concentrations and increasing insulin demand. Over time, persistent high demands for insulin can lead to loss of pancreatic function, glucose intolerance and diabetes (Krishnan et al., 2007).

While the total percentage of energy derived from carbohydrates in the diet has not been found to predict diabetes risk (Schulze and Hu, 2005), research has shown a strong inverse association between incidence of diabetes and intakes of whole grains, total dietary fiber, and cereal fiber, even after adjustment for confounders (American

Diabetes Association, 2008 and Hu et al., 2001). One study reported a 59% reduction in risk for type 2 diabetes for people consuming the highest quantities of cereal fiber, compared to those consuming the lowest amounts (Willett et al., 2002). Independent of body weight, whole grain intake has been associated with improved insulin sensitivity, while fiber has been associated both an increase in insulin secretion and improved insulin sensitivity, which are both important in reducing insulin resistance (Liese et al., 2003). High levels of insulin circulating in the blood signal cells to take up glucose, an important aspect of cell metabolism. Cells that do not recognize and respond to high circulating levels of insulin fail to take up glucose, leading to high blood glucose levels due to lack of clearance and low intracellular glucose levels.

In shifting from a whole grain to a refined grain diet, fiber intake among Peruvians has deceased to less than half the amount recommended by the WHO (INEI, 2007). A low dietary fiber intake is associated with a number of adverse health effects, including higher blood glucose levels due to faster gastric emptying after meals, and higher serum cholesterol levels due to more efficient absorption of dietary fats and cholesterol and recirculation of bile acids and hepatic cholesterol (Hernandez, 2004; Cárdenas et al, 2004). Gross et al. (2004) suggested that increased intake of refined carbohydrates, along with decreased intake of fiber, contributes to the increasing prevalence of type 2 diabetes in the US. Pereira et al. (2002) observed 10% lower fasting insulin and 13% lower insulin resistance after 6 weeks of consuming a whole grain diet, compared with a refined grain diet. Berti et al. (2004) compared postprandial glycemic and insulin responses after consumption of regular and gluten-free breads, crackers, pasta and quinoa, and demonstrated that the more highly processed the food, the higher the digestibility of the starch, and the more acute the glycemic response.

When whole grains are refined to produce white wheat flour, white rice and other refined grain products, the outer layers including the bran and germ are removed leaving just the endosperm. Beneficial components including fiber, minerals, vitamins, lignans, and other phytochemicals contained in the bran and germ are lost during the refining process (Slavin et al., 1999). These components have desirable properties, including beneficial effects on glucose metabolism (Weickert et al., 2006).

Other foods in addition to grains may affect the risk of overweight and type 2 diabetes. For example, a low intake of fruits and vegetables increases the risk for chronic diseases, and consumption of vegetables may be inversely associated with the risk for type 2 diabetes mellitus (Ford and Mokdad, 2001; Williams et al., 1999). Bermudez and Tucker (2003) reported that across Latin America, people have reduced their intakes of fruits and vegetables and are eating more fats, particularly saturated fat, and sugar.

A review of overall dietary patterns found that a high consumption of whole grains, legumes, fruits, vegetables, seafood, white meat, nuts and vegetable oils was inversely associated with the risk of type 2 diabetes. Conversely, a Western diet characterized by a high intake of refined grains, red meat, processed meats, fried potatoes, and food high in saturated fat, cholesterol and trans fat, was positively associated with the risk of type 2 diabetes. In the Andean region (which includes Peru), daily caloric intake from fruits declined from 10.9% to 6.4% between the mid-1960s and mid-1990s, while vegetable intake has decreased from 1.8% to 1.2% of total calories during this time (van Dam et al., 2002).

In managing the course of the disease, the American Diabetes Association recommends that diagnosed type 2 diabetics include in their diets carbohydrates from fruits, vegetables, whole grains, legumes and low-fat milk. Specific recommendations are for diabetics to consume at least 14 g fiber/1,000 kcal, including fiber-rich (at least 5 g fiber/serving) whole-grain foods; limiting saturated fat intake to <7% of total calories; eliminating trans fat from the diet; reducing sodium intake (when hypertension is an issue); and adhering to recommendations aimed at lowering cholesterol, such as consuming plant sterols and stanols daily (American Diabetes Association, 2008).

Some of the research corroborating the Association's recommendations includes a study that has shown that consuming a high-fiber diet (~50 g per day) reduces hyperglycemia, hyperinsulemia and hyperlipidemia in type 2 diabetics (Franz et al., 2002). Other research has shown that adding soluble fibers including guar gum, glucomannan, psyllium, pectin, beta-glucan or arabinoxylan, to test drinks or meals induces a low glycemic response in people with and without diabetes (Venn and Mann, 2004). Reducing postprandial glycemic and insulin response has been shown to improve blood glucose and lipid concentrations (Berti et al., 2004).

Additional research has focused on specific food components that lower blood cholesterol levels. For example, Lee et al. (2003) presented evidence that the daily consumption of ~2 g of plant sterols and stanols lowers plasma total and LDL cholesterol levels. Limiting the intake of dietary cholesterol, saturated fat and trans fat is important to reduce risk of cardiovascular disease, which is both a primary complication of diabetes and the leading cause of death among diabetics.

Cereal fiber intake is also inversely associated with cardiovascular disease in diabetics. A prospective study in Canada found that diabetic women with the highest bran intakes were 28% less likely to die from any cause, and 35% less likely to die from cardiovascular disease, compared to diabetic women with low bran intakes. This association held after adjusting for calorie and fat intake, body weight, exercise levels, smoking history and drinking habits (He et al., 2010).

The recommended protein intake for diabetics is 15-20% of daily energy or 0.8 g/Kg/day), the same as for healthy populations (USDA/DHHS, 2010). Several studies have indicated that glucose produced from protein ingestion increases serum insulin responses without increasing plasma glucose concentrations in both diabetics and healthy people (Franz et al., 2002 and Gannon et al., 2001). Several authors have observed that high protein meals stimulate a high insulin response, resulting in lower blood glucose concentrations (Berti et al., 2004; Gannon and Nuttall, 2006).

J. Whole grains, weight status and diabetes

Both the 2005 and 2010 Dietary Guidelines for Americans recommend daily consumption of at least 3 oz of whole grain products, comprising at least half of all grains consumed each day (USDA/DHHS, 2005 and 2010). Whole grains are good sources of a variety of nutrients, including vitamins, minerals, dietary fiber, lignans, beta-glucans, inulin, phytosterols, phytin, sphingolipids, and other phytochemicals (Jonnalagadda et al., 2011) (Fig. 1).

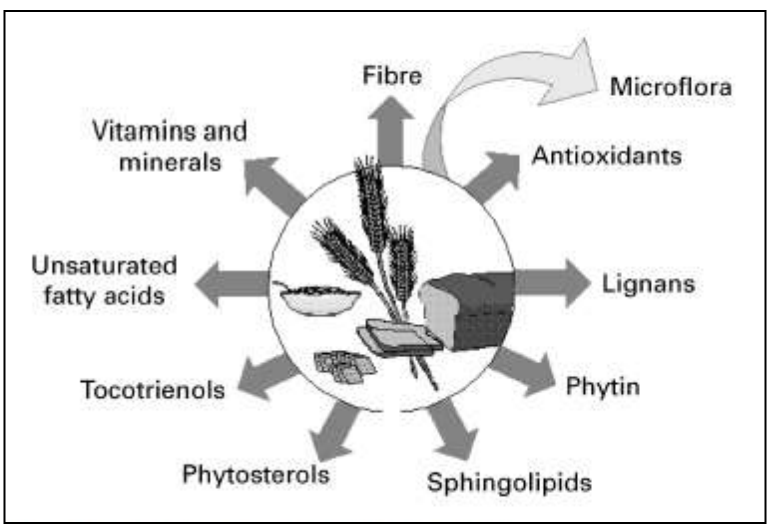
Epidemiological studies suggest an inverse association between whole grain consumption and risk for type 2 diabetes (Pereira et al., 2002; Ezmaillzadeh et al., 2005;

Schulze et al., 2007). In a randomized cross-over trial in hyperinsulinemic overweight adults, consumption of whole grains for 6 weeks increased insulin sensitivity compared to consumption of refined grains (Pereira et al., 2002). Similar findings were reported in studies from Iran and Germany (Ezmaillzadeh et al., 2005; Schulze et al., 2007).

Several authors reported that a two-serving-per-day increment in whole grain and/or bran consumption was associated with a 21% decrease in the risk of diabetes, even after adjusting for BMI and other potential confounders (Jeroen et al., 2007; Meyer et al., 2000). Meyer et al. also reported a strong inverse association between intakes of total dietary fiber, cereal fiber and magnesium and the incidence of diabetes, with the risk of diabetes lowered by 22% for total dietary fiber, 36% for cereal fiber and 33% for magnesium, for subjects with the highest intakes (Meyer et al., 2000). Venn and Mann reported that people who consume three or more servings of whole grain foods per day are 20-30% less likely to develop type 2 diabetes (Venn and Mann, 2004).

Figure 1

Phytochemical content of whole grains



Source: Slavin, 2003

High whole grain intake was associated with a reduced risk of weight gain and a lower BMI (~1 unit) in at least 14 cross-sectional and prospective epidemiological studies. In three of studies, high whole grain intake was associated with a smaller waist circumference (average difference =2.7 cm), an indicator of abdominal obesity (Jonnalagadda et al., 2011, Koh-Banerjee et al., 2004; Liu et al., 2003). Koh-Banerjee et al. (2004) estimated that for every 40-g increase in daily whole grain intake, 8-y weight gain was reduced by 1.1 kg.

Consuming insoluble cereal fiber for 3 days increased insulin sensitivity in a randomized crossover trial (Weickert et al., 2006). In a second, shorter trial, intake of cereal fiber stimulated secretion of glucose-dependent insulinotropic polypeptide (a peptide hormone that plays a role in insulin secretion in response to glucose consumption) and insulin, and reduced the glucose response to a meal the following day (Weickert et al., 2005). Consumption of lignans, which are found in whole grains, has been shown to prevent type 2 diabetes in animal studies although the mechanism for this is not clear (Bhathena et al., 2002). Lignans have antioxidant and phytoestrogen properties and act as a soluble fiber.

In addition to being high in fiber and other phytonutrients, whole grains are rich sources of magnesium, calcium, potassium, and selenium. Minerals are often removed when whole grains are processed into refined grains during milling. Thus, the trend in Peru and elsewhere to replace whole grains with refined grains may be contributing to mineral deficiencies, some of which have been associated with diabetes. For example, hypomagnesemia (low blood levels of magnesium) has been associated with the development of insulin resistance and type 2 diabetes (Tosiello, 1996). A low calcium intake was associated with both insulin resistance and weight gain in longitudinal observational studies (Schulze and Hu, 2005).

Dietary phytochemicals are abundant in the whole grain bran and germ and are associated with reduced risk of chronic diseases including cardiovascular disease, diabetes and certain cancers (Okarter et al, 2010 and Liu, 2004). Subjecting whole grains to food processing mechanisms, such as heat and grinding, can help release phytochemicals bound to dietary fiber components in whole grains and make them more bioavailable (Jonnalagadda et al., 2011). Phenolic compounds, tocotrientols and tocopherols in whole grains function as antioxidants by donating hydrogen atoms to free radicals, thus preventing damage to DNA, cell membranes and other cell components (Okarter et al., 2010; Slavin, 2004).

The antioxidant capacity of whole grain breakfast cereals average 22 to 35 mmol Trulox equivalents (TE)/kg (Fig 2). This is higher than most fruits, which have antioxidant capacities of 6-17 mmol TE/kg (although red plums=22 mmol TE/kg and berries=36 mmol TE/kg) and vegetables, which average 4.5 mmol TE/kg (Miller et a., 2000).

Whole grains also contain antinutrients, including phytic acid, saponins, lectins and enzyme inhibitors. Some of these compounds may act as antioxidants by chelating metals such as iron, suppressing redox reductions, and suppressing oxidative damage caused by oxygen radicals in the colon. Many of these antinutrients have been shown to lower plasma glucose, insulin, cholesterol and/or triglyceride levels (Slavin, 2004). As mentioned earlier, phytosterols and stanols in whole grains have been shown to help regulate blood cholesterol levels by inhibiting cholesterol absorption and increasing its excretion (Okarter et al., 2010).

Figure 2

Average antioxidant activity of vegetables, fruits and cereals

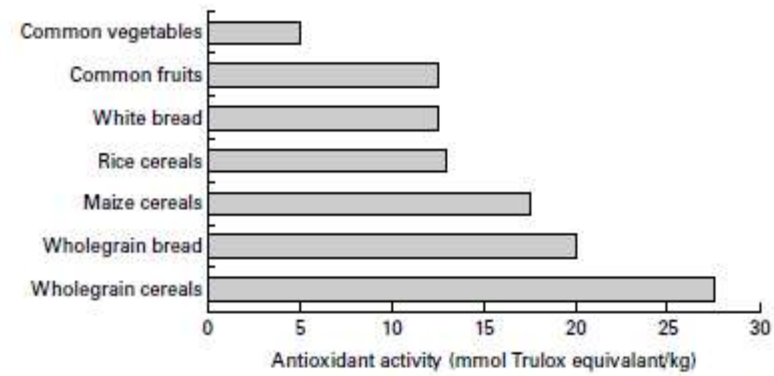


Fig. 3. Average antioxidant activity of vegetables, fruits and cereals determined using a diphenyl picrylhydrazyl radical-scavenging procedure.

Source: Slavin, 2003

Many of the disease-preventing and modulating phytochemical components are lost in the grain refining process, which may explain the large differences in protective effects between whole grains and refined grains. Research has determined that refined wheat flour loses 83% of total phenolic acids, 79% of total flavonoids, 93% of ferulic acid (a phenolic compound), 78% of zeaxanthin, 51% of total lutein, and 42% of total beta-cryptoxanthin, compared to the levels in whole wheat flour (Adom et al., 2005). Conversely, the health benefits of whole grain consumption may stem from various interactions of phytochemical components with microflora in the human gut, as illustrated in Fig. 3 below.

Figure 3. Health effects of whole grains due to interactions with microflora

Health effects of whole grains 131

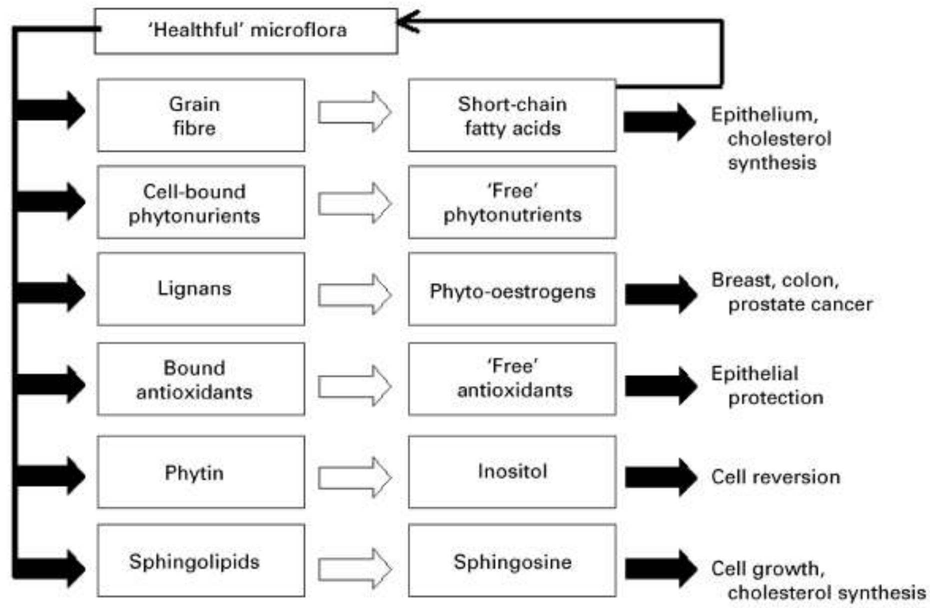


Fig. 2. Interactions between components in whole grains and the microflora that have important implications in health and disease.

Source: Slavin, 2003
Note: Cell reversion refers to inositol's reported ability to revert malignant cells to non-cancerous cells. (Shamsuddin, 1995)

K. Importance of quinoa in Peru and the Andes region of South America

Many regions of the world have their own variety of whole grains. Quinoa is among the most important cereal "grains" of the Andean region of South America. For centuries, it was so vital to the food supply that the Inka culture considered it to be sacred; indeed it's Quechua name means "mother grain." It has served—and still serves today—as a major source of protein for people in that region, sometimes replacing meat in the diet. The major quinoa-producing countries are Bolivia, Peru and Ecuador. In 2003, these three countries combined produced 53,000 tons, which was up from 19,000 tons in 1973 (FAO 2004). Outside South America, quinoa is grown in the U. S. (in

Colorado and California) and Canada, and is cultivated experimentally in Finland and the UK (Lindeboom 2005).

Quinoa is the best-studied cereal of the Andes region. It is a pseudo-cereal rather than a true cereal, due to its dicotyledonous seed structure, which differs from the monocotyledonous structure of true cereal grains. Nevertheless, the quinoa seed is often compared to grains such as wheat, corn and rice due to its cereal-like properties (Fairbanks et al. 1990, Ranhotra, et al. 2002).

Similar in shape and size to millet, quinoa can be used in foods in many ways. The dehulled and washed grain can be boiled, toasted or popped and eaten alone or in stews, soups, porridges, cereals, candies, casseroles and even sushi. It is also used to make hot or fermented drinks, including a beer-like drink called "chicha." The seeds can also be ground into flour and used in a variety of baked products, as well as in pastas, pancakes, tortillas and many other flour-based foods. A number of quinoa products including breads, cereals, pastas as well as several varieties of whole quinoa seeds can be found in U.S. grocery stores.

Although quinoa seeds are high in protein, minerals, vitamins, mono- and polyunsaturated fatty acids, starch and dietary fiber, they also contain a number of anti-nutritional substances (i.e., phytochemicals that can interfere with nutrient absorption or metabolism in humans or animals) including saponins (particularly oleanolic acid) and phytic acid. Therefore, quinoa seeds must be dehulled and washed before consumption (Lindeboom 2005).

In the Americas, Europe and Asia, there is growing interest in quinoa due to its high nutrient content and its hardiness as a food crop. The protein quality of quinoa is similar to that of casein (a milk protein), and the protein content is high compared to that of true cereals (Raules et al. 1993, Ranhotra et al. 1992). In addition, quinoa is not genetically modified and is rarely allergenic because it lacks gluten (Berti et al. 2004). Hence, it can be used in foods designed to reduce allergies in sensitive individuals such as celiac disease patients, and it is ideal for inclusion in specialty foods such as infant formulae (Coulter and Lorenz 1990, Javaid 1997, Morita et al. 2001).

Current research on quinoa is focusing on agronomics, improvements in genotype, and processing methods to encourage the further cultivation of quinoa as a specialty crop in other parts of the world. It is expected that when quinoa is grown in areas to which it has adapted, it could compete with cereals in both human and animal diets. The genetic variability of quinoa is believed to be high, and new cultivars are being developed to grow under various environmental conditions: from sea level to elevations of 4000 m, and from cold, highland climates to subtropical conditions (Lindeboom 2005). Additionally, the quinoa plant is frost-resistant, can tolerate high salinity in soils, and can be grown under conditions of drought (Coulter and Lorenz 1990). As such, quinoa has been selected by the FAO as one of the crops destined to offer food security in the next century.

Nutritional composition of quinoa

The following table (Table 1) describes the chemical and nutrient composition of whole quinoa seed.

Table 1 Composition of whole quinoa seed
Value per 100 g

Proximates		**Minerals**	
Protein (N×6.25)	14.12 g	Calcium	47 mg
Total lipid (fat)	6.07 g	Phosphorus	457 mg
Water	13.28 g	Potassium	563 mg
Carbohydrate (by difference)	64.16 g	Sodium	5 mg
Total dietary fibre	7.0 g	Magnesium	197 mg
Energy	368 kcal	Iron	4.57 mg
		Zinc	3.1 mg

Vitamins

Thiamine	0.360 mg	Vitamin E (α-tocopherol)	2.44 mg
Niacin	1.52 mg	Vitamin D (D2 + D3)	0 mcg
Riboflavin (B2)	0.318 mg	Vitamin C	16.4c
Vitamin B6	0.487 mg	Vitamin A, IU	14 IU
Folate, DFE	184 mcg_DFE	Vitamin A, RAE	1 mcg_RAE

Nutrient values and weights are for edible portion
Source: USDA nutrient database 2007

Protein content of quinoa

Quinoa is rich in protein and its amino acid balance is superior to that in the proteins of most cereal grains (Ranhotra et al. 1993). After dehulling, which is necessary to remove bitter, water soluble, anti-nutritional saponins located in the outer seed coat, quinoa seeds average around 15 percent protein, though some varieties can contain up to 23 percent (National Research Council 2005, Ranhotra et al. 1993, Ahamed et al. 1998). About 37% of the protein in quinoa is comprised of essential amino acids (Koziol 1992).

Of particular interest to researchers, public health officials and the food industry is the fact that the protein in quinoa is high in the essential amino acid lysine (Table 2). This makes quinoa complementary to grains such as wheat, rice and corn, which are deficient in lysine. The high lysine content of quinoa is attributable to its high content of albumins and globulins, which account for 44-77% of the total protein in quinoa seeds (Fairbanks et al. 1990).

With a chemical score of 83-86, quinoa's lysine content is comparable to that of soybeans (Ranhotra et al. 1993, Koziol 1992, Ranhotra 1993, Ruales and Nair, 1992). A protein's chemical score refers to its essential amino acid content, as compared to a reference protein of high biological value, usually egg or milk protein, which is assigned a value of 100. Protein chemical scores can vary according to the choice of reference protein (Seligson and Mackey 1984).

Quinoa protein also contains high levels of methionine, which is the limiting amino acid of soybeans. This makes quinoa a good complement to soybean products (Scanlin et al. 2006, Lindeboom 2005). Quinoa protein is also high in histidine, an essential amino acid for infant development and those with chronic diseases (Ettinger et al. 2000).

Table 2 **Amino Acid Composition of Dehulled Quinoa Flour**

Amino Acid	**Amt (g/100 g protein)**	**FAO/WHO reference patterns**	
		Adult	***Child***
Threonine	3.5- 4.4	0.9	3.4
Valine	3.7- 4.9	1.3	3.5
Methionine & Cysteine	3.8- 4.6	1.7	2.5
Isoleucine	3.6- 4.4	1.3	2.8
Leucine	6.8-6.9	1.9	6.6
Tyrosine & Phenylalanine	6.2- 8.9	1.9	6.3
Lysine	5.1-6.3	1.6	5.8
Tryptophan	0.8-1.2	0.5	1.1
Histidine	2.4- 4.1	1.6	1.9
Aspartic Acid	7.3- 10.5		
Serine	3.7- 5.6		

Glutamic Acid	11.9- 17.3
Proline	3.1- 3.5
Glycine	5.2- 6.3
Alanine	4.1- 5.5
Arginine	7.0- 9.7

Source: Lindeboom, 2005

Scientific opinion varies with respect to identifying the first limiting amino acid in quinoa. Ranhotra et al. (1993) reported that methionine appears to be the first limiting amino acid in quinoa. These authors found that quinoa flour contained 2.27 g of methionine per 100 g of protein, leading them to report that even considering cysteine's contribution, only 46% of the rats' need for methionine was provided by quinoa. As a sulfur-containing amino acid, cysteine can reduce the need for methionine in the diet. Ahamed et al. (1998) reported lysine as the limiting amino acid in quinoa, although they noted that quinoa contains twice as much lysine as whole wheat on a dry weight basis. Amino acid chemical scores of 127 and 125 for methionine/cysteine and phenylalanine/tyrosine, respectively, were cited in that study. Ruales and Nair (1992) found that tyrosine and phenylalanine were the first limiting amino acids in quinoa.

Regardless of which amino acid is determined to be the first limiting one, scientists agree that quinoa contains high-quality protein similar in quality to that of casein (the protein standard in protein efficiency ratio, or PER, analysis). Ranhotra et al. (1993) assessed the protein quality of quinoa by three different methods: PER using rats, apparent protein digestibility and nitrogen balance. There was no significant difference in the weight gain of rats fed quinoa or casein in the PER analysis. In fact, determined and corrected PER values were slightly higher for quinoa than for casein (Table 3). The small but significant differences in protein digestibility of quinoa as compared to casein may be attributable to the tendency of grain-derived foods to be less well-digested than animal-derived foods. The higher dietary fiber content in quinoa compared to milk may account for the higher fecal nitrogen losses in rats fed quinoa (Shah et al. 1982). In a similar study, pigs that were fed cooked quinoa were reported to grow as well as those fed dried skim milk; the removal of saponins from the outer layers of seeds increased the in vitro digestibility of the protein by 7 percent (Ruales et al. 1994).

Table 3 Comparison, protein quality of casein & dehulled quinoa flour

Parameter	**Protein Source**	
	Casein	**Quinoa**
Protein Efficiency Ratio (PER)		
Protein intake, g	36.8	33.1
Weight gain, g	130	126
PER (determined)	3.5	3.8
PER (corrected)	2.5	2.7
Apparent protein digestibility		
Protein intake, g	36.8	33.1
Protein digested, %	88.9	84.3
Nitrogen balance		
Nitrogen intake, g	5.89	5.30
Fecal nitrogen, g	0.65	0.83
Urinary nitrogen, g	1.25	1.02
Nitrogen balance, %	67.8	65.0

Source: Ranhotra et al., 1993

N.T. Ahamed et al. (1998) reported that protein digestibility of quinoa improved when the seeds were toasted or popped (53-65% for raw seeds, compared with 68-78% for toasted or popped seeds). They also reported that processes such as extrusion improved the PER of quinoa flour. Furthermore, they concurred with the results of previous animal experiments that the net protein utilization (NPU) and biological value of quinoa seed protein are comparable with those of other high-quality food proteins, such as soy.

Quinoa protein is high in albumins and globulins, which account for 44-77% of the total protein in quinoa seeds (Fairbanks et al. 1990). It is also low in prolamins (0.5-7.0%), indicating that it is gluten-free (Galwey 1993). Thus, the Celiac Disease Foundation and Gluten Intolerance Group recommend it be included in a gluten-free diet. In addition, quinoa is not genetically modified and is rarely allergenic (Berti et al. 2004). Thus, it may be suitable for use in foods designed for allergy sensitive individuals as well as in specialty foods such as infant formulae (Coulter and Lorenz 1990, Javaid 1997, Morita et al. 2001). Research presented at the International Workshop on Food Supplementation in Food Allergy and Immunity also found that quinoa is immunochemically safe (Berti et al. 2004).

Carbohydrates in quinoa

In terms of carbohydrate composition, starch is the main constituent in quinoa, representing over 58-68% of the total seed components, while simple sugars are present at about the 3-5% level (Ranhotra et al. 1993, Ahamed et al. 1998). Information in the literature suggests that considerable variability exists in the amylose content of quinoa starch (7-27%) (Lorenz 1990, Praznik et al.1999, Inouchi et al. 1999, Tang et al. 2002). In most quinoa varieties, starch consists of 20-30% amylose and 70-80% amylopectin.

Amylose content is a very important factor affecting starch functionality. Starches isolated from sixteen quinoa lines ranged in amylose content from 3 to 20% (Lindeboom 2005). Amylose content affects the functional and physiochemical properties of starch, including its pasting, gelatinization, retrogradation and swelling characteristics (Li et al. 1994, Wootton and Panozzo 1998, Baldwin 2001, Bao et al. 2001, Grant et al. 2001, Svegmark et al. 2002). With the exception of pasting temperature, large variations in pasting characteristics were found among starches and were correlated with amylose content. Swelling, solubility, freeze-thaw stability and water-binding capacity also differed among starches and were correlated with amylose content (Lindeboom 2005).

Quinoa starch granules are small and contain about 20 percent amylose. Gelatinization onset (44.7-53.7 ºC) and peak (50.5-61.7 ºC) temperatures and retrogradation tendencies (19.6-40.8%) are positively correlated with amylose content (Lindeboom 2005). The wide variation in amylose content and physicochemical characteristics among quinoa starches suggests applications in a variety of food and non-food products. For example, starch from quinoa has been shown to be a better thickener for fillings than wheat, potato, barley and amaranth starch (Lorenz 1990). Also, the overall performance of quinoa starch in leavened baked goods is similar to that of other non-cereal starches like amaranth and potato starch, but poor compared to barley and wheat starch (Lorenz 1990).

Quinoa is high in fiber (Ranhotra et al. 1993, Ruales and Nair 1994). According to Ranhotra et al. (1993), whole quinoa seeds consist of 8.9% total dietary fiber, of which more than 80% is insoluble. Ruales and Nair (1994) reported total dietary fiber comprised 13.4% of whole quinoa seed, of which 82.1% is insoluble fiber and 17.9% is soluble fiber. The insoluble and soluble fiber content of quinoa is similar to that found in rye, while higher than those of wheat. Dehulling and washing do not significantly alter the seed's dietary fiber content (Ruales and Nair 1994).

Lipids in quinoa

The fat content of quinoa seeds ranges between 5 and 10 percent of the seeds' composition (Table 4). Approximately 50 percent of the lipids in quinoa consist of linoleic acid (an omega 6 essential fatty acid) (Ahamed et al. 1998). The main saturated fatty acid is palmitic acid, which accounts for around 10% of total fatty acids. In addition to linoleic acid (52%), the main unsaturated fatty acids present in quinoa include oleic acid (25.6%) and linolenic acid (9.8%) (Ando et al. 2002).

Quinoa oil has a composition similar to that of soybean oil (Wood et al. 1990). Given the high quality of its oil and the fact that some varieties exhibit a crude fat concentration up to 10%, quinoa is sometimes termed a pseudo-oilseed (Koziol 1993). The oil is stable due to the presence of high levels of natural antioxidants, including 69-75 mg of α-tocopherol and 76-93 mg of γ-tocopherol in 100 g of crude oil. The refining process reduces those numbers to 45 and 23 mg, respectively, in 100 g of refined oil (Koziol 1992). However, this is sufficient to the lipids in quinoa from rapid oxidation (Ng and Anderson 2005).

Table 4 Fatty acid composition of crude fat from quinoa seeds

Fatty acid	**Structure**	**Quantity (g/100 g fat)**
Myristic acid	C 14:0	0.1
Palmitic acid	C 16:0	9.7
Palmitoleic acid	C 16:1 (n-7)	0.2
Stearic acid	C 18:0	0.6
Oleic acid	C 18:1 (n-9)	24.8
Linoleic acid	C 18:2 (n-6)	52.3

α-Linolenic acid	C 18:3 (n-3)	3.9
Arachidic acid	C 20:0	0.4
Eicosenic acid	C 20:1	1.4
Eicosadienoic acid	C 20:2 (n-4)	0.2
Behenic acid	C 22:0	0.5
Erucic acid	C 22:1 (n-9)	1.4
Lignoceric acid	C 24:0	0.2
Nervonic acid	C 24:1 (n-9)	0.4

Source: Ruales and Nair, 1994

Micronutrients and Antinutrients in quinoa

Quinoa seeds are a good source of sulfur (120-220 mg/100g, found in the amino acids cysteine and methionine), calcium (149 mg/100 g), potassium (927 mg/100g), phosphorus (348 mg/100 g), iron (13.2 mg/100 g), magnesium (250 mg/100g) and zinc (4.4 mg/100g), although dehulling reduces the calcium content by 36 percent (Konishi et al. 2004).

The main flavonoids in quinoa are kaempferol and quercetin. Both are strong antioxidants and free-radical scavengers (Zhu et al. 2001). Along with the saponins, the flavonoids contribute to the bitterness and astringency of quinoa, as well as to the color of the seed.

Galvez Ranilla et al. (2009) reported that quinoa shows potential for in vitro alpha-glucosidase inhibition, meaning that people who consume it may experience delayed uptake of glucose and oligosaccharides along the intestinal brush border. Conforti et al. (2005) reported in vitro alpha-amylase inhibitory activity of 51% and 28% in raw whole amaranth flour made from two seed varieties. These findings may be relevant for diabetics, since such carbohydrate utilization inhibitors have been found to slow the digestion of complex carbohydrates and the uptake of glucose in vivo, significantly reducing postprandial glycemic and insulin responses. (Godbout et al., 2007)

Saponin content in quinoa ranges from 0.01% to 4.65% of dry matter, depending on the variety and environmental conditions (Koziol 1992). Saponins are water- and methanol-soluble, detergent-like molecules that consist of hydrophilic sugar chains attached to lipophilic triterpenoid aglycones. The saponins in quinoa, termed sapogenins (phytoaccagenic acid, hederagenin and oleanolic acid), are derivatives of three main triterpenes or sterols (Mizui et al. 1988 and 1990, Ridout et al. 1991). They are concentrated in the hull of the quinoa seed, which can contain up to 6% saponins. Abrasive dehulling reduces saponin content by 85.2% to 98.8%. Washing the seeds effectively removes the remaining saponins (Improta and Kellems 2001).

Saponins taste bitter, foam in water and have been demonstrated to damage intestinal mucosal cells by altering cell membrane permeability and interfering with active transport (Gee et al. 1989). A saponin-free variety, called “sajama” or “sweet” quinoa, has been developed in Bolivia. However, sweet quinoa is only grown experimentally. It cannot be cultivated for food or feed on a massive scale currently, due to its susceptibility to pests and diseases (Lindeboom 2005).

In addition to saponins, quinoa contains the anti-nutrient phytate in quantities similar to those found in wheat, rye or lentils (Koziol 1992; Ruales and Nair 1993). The embryo contains 60% of the total phytate in quinoa. Phytates can form insoluble complexes with multivariate cations such as Fe3+, Ca2+, Mg2+, Fe2+ and Zn2+ in the gastrointestinal tract, thereby reducing the bioavailability of these minerals (Serraino et al. 1985).

As noted previously, quinoa is especially high in iron compared to other cereals; however, the phytates could markedly decrease the bioavailability of this iron. Valencia et al. (1999) reported that soaking, germination and lactic fermentation of quinoa resulted in improved iron solubility and reduced phytate content. The most effective treatment for reducing phytate was fermentation of germinated quinoa flour, whereby the phytate was almost completely hydrolyzed and the iron solubility increased five to eight times compared to its unfermented counterpart. Quinoa contains very little or no tannins (Chauhan et al. 1992, Ruales and Nair 1993) or trypsin inhibitors (Chauhan et al. 1992, Ruales and Nair 1993).

Use and potential functional benefits of quinoa

Quinoa has many potential uses as well as some potential benefits as a functional food. Schlick and Bubenheim (1993) noted that quinoa's desirable nutritional profile, and in particular its high protein and desirable amino acid composition, make it an ideal candidate for NASA's Controlled Ecological Life Support System, which is meant to provide a nutritionally balanced diet to astronauts embarking on long-term human space missions.

Quinoa can also be cooked alone and eaten in whole grain form, similar to the way rice is consumed. Berti et al. (2005) reported that quinoa has potential to assist in controlling appetite. The study compared subjects who consumed cereal controls with subjects who consumed quinoa. The authors reported that the quinoa group had stopped eating faster and reported greater fullness and satiety sensations.

Another potential benefit of eating quinoa for celiac patients and others with gluten sensitivities relates to postprandial glycemic and insulin response. While many gluten-free foods, particularly gluten-free breads and crackers, cause a high postprandial glycemic response, Berti et al. (2004) demonstrated a low glycemic response for quinoa (similar to that of pasta, which is considered a low glycemic food). They also reported that consumption of quinoa led to significantly lower levels of circulating free fatty acids (FFA) and triglycerides than consumption of regular and gluten-free bread, crackers and pasta. Insulin responses were also significantly lower in consumers of quinoa. High levels of FFA impair insulin-mediated glucose disposal and increase triglyceride levels and glucose output from the liver. Thus, frequent quinoa consumption may lead to long-term suppression of FFA, resulting in improved insulin sensitivity and lower blood glucose and triglyceride concentrations (Berti et al., 2004)

Table 5

Nutrition facts

Cooked Quinoa **vs** **Cooked White Rice**

Nutrition Facts	Cooked Quinoa	% Daily Value*	Cooked White Rice	% Daily Value*
Serving Size	1 cup 185g (185 g)		1 cup 158g (158 g)	
Amount Per Serving				
Calories	222 (Calories from Fat 32)		205 (Calories from Fat 4)	
Total Fat	4g	5%	0g	1%
Saturated Fat		0%	0g	1%
Trans Fat				
Cholesterol	0mg	0%	0mg	0%
Sodium	13mg	1%	2mg	0%
Total Carbohydrate	39g	13%	45g	15%
Dietary Fiber	5g	21%	1g	3%
Sugars			0g	
Protein	8g		4g	
Vitamin A		0%		0%
Vitamin C		0%		0%
Calcium		3%		2%
Iron		15%		11%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

©www.NutritionData.com

Source: NutritionData.com (accessed April 27, 2011)
Notes: 1 c of cooked quinoa also contains 30% DV magnesium, 28% DV phosphorus, 13% DV zinc, 18% DV copper and 56% DV manganese. Dietary fiber ratio: 2:1 insoluble to soluble

Colorado State University has been granted a patent on quinoa protein concentrate (QPC), which contains at least 50% and up to 90% protein at food and/or pharmaceutical grades (Scanlin et al. 2007). The patent publication states that the QPC is useful as a food ingredient and as a supplement in food products such as foods for infants and toddlers, meat analogs, ice creams, whipped toppings, baked products, salad dressings and the like. Functionally, the authors state that QPC can also be used for a variety of functional effects that are associated with proteins. It can serve as a gelatin aid in yogurts and puddings, as a water binder for meat and sausage, as a foaming or whipping agent in toppings and fillings, and as an emulsifier in ice cream, margarine and mayonnaise. It may be formed into protein fibers for use in meat analogs or it may be used as an egg white substitute or extender in food products where egg white is used as a binder. It can replace all or a portion of the fat or cream in food products such as ice cream, yogurt, salad dressing, mayonnaise, cream, cream cheese, other cheeses, sour cream, icings, whipped toppings, frozen confections, milk, coffee whitener and spreads. It can also be hydrolyzed to produce a variety of vegetarian flavors, similar to those currently produced from hydrolyzed soy proteins.

There is some disagreement regarding to the upper limit at which quinoa flour can be substituted for wheat or other grain flours in foods. The National Research Council (2005) found that due to its lack of gluten, quinoa flour can only be substituted for approximately 30% of wheat or other gluten-containing flours. However, Ahamed et.al. (1998) reported that quinoa flour can be substituted for wheat flour at up to 60% to make high-protein cakes, cookies and biscuits, while noodles can be made using 40% quinoa flour without affecting the appearance or other characteristics of the product.

Regardless of the ratio, mixing quinoa seeds with corn, wheat, barley or other grains improves the protein quality of foods, while slightly increasing total protein content (Ranhotra et al., 1993).

L. Nutritional composition and properties of amaranth

Over 60 species of amaranth grain are grown around the world. It is popular in many countries in Latin America, as well as in parts of Asia (India, in particular) and Africa. Like quinoa, it is a seed, and it is often referred to as a “pseudocereal” (Breene, 1981). Amaranth grain contains more protein and fat than most cereals. The grain contains 105 calories in one ounce, including of 4.0 g protein, 1.8 g fat, 2.6 g dietary fiber, and 18.5 g of total carbohydrates. Amaranth is a good source of iron (2.1 mg per ounce, or 12% or the Daily Value, DV), magnesium (74.5 mg per ounce, or 19% of the DV), phosphorus (127 mg per ounce, or 13% of the DV), copper (0.2 mg per ounce, or 11% of the DV), and manganese (0.6 mg per ounce, or 32% of the DV). The grain also contains the B vitamins (except B12), as well as vitamins C and E, calcium, potassium and zinc. (USDA, 2007)

Table 6 **Nutrition facts: cooked amaranth vs. cooked wheat berries**

Cooked Amaranth

Nutrition Facts

Serving Size 1 cup 246g (246 g)

Amount Per Serving	
Calories 251	Calories from Fat 33
	% Daily Value*
Total Fat 4g	6%
Saturated Fat	0%
Trans Fat	
Cholesterol	0%
Sodium 15mg	1%
Total Carbohydrate 46g	15%
Dietary Fiber 5g	21%
Sugars	
Protein 9g	
Vitamin A 0% • Vitamin C	0%
Calcium 12% • Iron	29%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

©www.NutritionData.com

Cooked Wheat berries

Serving size 1 cup					
Calories	300		**Total Carbohydrate**	64 g	22% DV
Total Fat	1 g	2% DV	Dietary Fiber	12 g	46% DV
Cholesterol	0 mg	0% DV	Sugars	0 g	
Sodium	6 mg	0% DV	**Protein**	12 g	
Vitamin A	0%		**Calcium**	4%	
Vitamin C	0%		**Iron**	16%	

Sources: NutritionData.com, retrieved April 27, 2011; Earthlychoice.com/wheat-berries.html, accessed Oct 4, 2011.

Perhaps the most noteworthy nutritional quality of amaranth grain is its protein composition, which is high in the essential amino acid lysine, tryptophan and threosine, in contrast to the compositions of corn, rice and wheat, which are typically low in tryptophan and lysine, in particular. Lysine is typically the limiting amino acid in most cereal grains, meaning that it is the essential amino acid that is typically present in least amount relative to the requirement for that amino acid in the composition of complete protein. The ratio between the amount of the limiting amino acid in a protein and the requirement for that amino acid provides a chemical estimation of the nutritional value (i.e. protein quality) of that protein, termed its chemical score. Unlike most cereal proteins, the protein in amaranth, quinoa and kañiwa is not limited by lysine. In fact, lysine is present in amaranth at twice the level found in most other grains. In addition, since amaranth contains all 9 essential amino acids, as well as 9 non-essential ones; thus it is considered a complete protein, again in contrast to corn, wheat and most other grains (Pedersen et al., 1987).

Even when processed (via popping at high temperatures—similar to the way popcorn is popped—toasting and grinding into flour, or extrusion, where the grain is cooked at medium-high temperatures, ground in a mill and pushed out into a final product such as flakes of cereal), the grain retained its protein quality and digestibility among humans. Protein digestibility refers to the ability of the human body to break down and effectively utilize the protein. This characteristic led the authors of one study to conclude that the protein quality of amaranth grain is as good as the protein found in animal products (Bressani et al., 1993). The only exception may be processing by popping, which reduced lysine content to 83 percent of the level found in raw seeds, according to one study. Mineral content was substantially reduced by processing, the same study reported, but this effect may be mitigated by the fact that total mineral content of amaranth seeds is significantly higher than in most grains (for example, it has 3 times the amount of calcium and between 2 and four times the amount of iron, compared to wheat) (Pedersen et al., 1987).

But another study of a particular species of amaranth—Amaranth caudatus, the variety most commonly eaten in the Andes region of South America—found that its protein digestibility is high at 87 percent and that digestibility is unaffected by processing, putting into question the conclusion of the previous study regarding the possible reduction of lysine content due to popping. The Amaranth caudatus study did point out that protein digestibility can vary somewhat among the different amaranth varieties; for example the Amaranth cruentus variety grown in Mexico and found most often in the US has slightly lower protein digestibility of 76 percent, so it could be that the previous study was done using the Mexican/US variety. However, the authors of both studies agreed that the generally high protein digestibility of amaranth is nearly comparable to that of casein (milk protein), which has a digestibility of 93 percent (Pedersen et al., 1987).

Given the high lysine content and general high protein quality, scientists generally agree that amaranth is a good candidate for blending with other cereals. In addition to amino acid composition, the scientists making this conclusion also took into account the functional properties of amaranth that contribute to water binding, gel formation, foam formation and emulsification (i.e. its ability to hold together ingredients that don't usually like to stay together, such as oil and water), among other properties (Bressani et al., 1993; Breene, 1991; Becker et al., 1981). All of those qualities, which are present in favorable amounts in amaranth, make the grain a good candidate for inclusion in many food products. Not only because the protein composition of amaranth makes it an excellent complement to the compositions of other more common grains, but because the functional properties of amaranth starch hold much promise for its use as a food thickener. Thanks to these properties, a wide variety of amaranth-containing products are already on the market (though not on a wide scale and more often in developing countries than in the developed world), including breads and other baked goods, salad dressings, sauces, soups, pilafs, tostados, dumplings, snacks, puddings, marzipan, pancakes, sweets and candies, tortillas, nut butter, mayonnaise, amaranth milk, cereals and noodles (Breene, 1991).

The high protein quality of amaranth makes it a good choice for vegetarians, for people with allergies to dairy products, and for people in developing countries who lack access to animal proteins, in that it can substitute for meat or milk proteins. The protein composition, high mineral content and fatty acid profile also make it a good main ingredient for infant formulas and for oatmeal-like porridges for toddlers (Breene, 1991). Also, unlike wheat and many other cereal products, amaranth does not contain gluten. This also makes it a good choice for people with allergies to wheat, corn and other cereals, as well as for people with celiac disease who cannot tolerate gluten (Thompson, 2000).

However, there is one other important reason to eat amaranth besides its high protein content, unusual protein composition, and high content of dietary fiber and certain minerals. Since it contains mostly unsaturated fats—ratios of saturated to unsaturated fatty acids range from 0.29 to 0.43, depending on the species—amaranth also contributes to the "good fats" that we need to include in our diets. Overall, the grain averages 7-8 % fat, of which 52% is polyunsaturated fat and 20% is monounsaturated fat. Prevalent fatty acids in amaranth include: linoleic acid (37-62 %), oleic acid (19-35 %), palmitic acid (12-25 %), stearic acid (2-5 %), and linolenic acid (0.3-2 %). In addition, amaranth oil is rich in squalene (up to 8% of oil content), a linear triterpene sterol precursor, which is also found in the livers of sharks and whales as well as in wheat germ, rice bran and olives. Amaranth oil is also a good source of tocopherols (2% of oil content), phospholipids (10% of oil content) and phytosterols (2% of oil content). In humans, squalene has been shown to be converted directly into cholesterol. When the body makes cholesterol, it tends not to absorb it from food, and the study showed evidence that cholesterol absorption was inhibited by amaranth grain and oil, based on the levels of cholesterol that were excreted from the body. In addition to its nutritional benefits, squalene is also an important ingredient in cosmetics (Berger et al., 2003).

The oil in amaranth grain is fairly high in vitamin E tocopherols, which are disease-fighting antioxidants, and tocotriniels, which have been shown to lower serum cholesterol in humans (Lehmann et al., 1994). Another study done on hamsters found that a diet of 20 percent amaranth grain or 5 percent amaranth oil lowered total and LDL (low density lipoprotein) cholesterol by 15 and 22 percent, respectively, while raising HDL cholesterol by 25 percent. The grain and oil also increased very low density lipoprotein (VLDL) cholesterol by 21-50 percent, as well (Berger et al., 2003). Other studies have found similar results in humans who consumed amaranth, including one that found that consuming amaranth decreased blood pressure, total cholesterol (by 20%), triglycerides (by 36%), and LDL and VLDL cholesterol (by 25% and 36%, respectively) in obese hypertension and coronary heart disease patients. The study also found an association between consuming amaranth oil and a decrease or disappearance of coronary deficiency symptoms, including headaches, weakness, fatigue, shortness of breath during physical activity, and edema in the legs; in addition, 40-50% of the study participants showed heart rhythm normalization and decreased coronary deficiency (Martirosyan et al., 2007). Thus, people who are seeking to lower their LDL cholesterol levels could also benefit from consuming foods containing amaranth, though this group would benefit most from consuming the least processed forms of the grain.

In terms of its glycemic value, when highly processed via milling, defatting and extrusion, a snack prepared from the grain was found to have an average glycemic index value of 107, which is similar to the index level for white bread. This suggests that highly processed amaranth is digested very quickly and while it may be a good choice for athletes due to its high starch and protein content, diabetics may want to consult with their dietitian before consuming it. However, the authors of that study noted that the intense processing to which the amaranth in the study was subjected damaged the grain's dietary fiber, made the starch more available to digestive enzymes in the human body, and was probably the main reason why the glycemic index value they reported for the amaranth snack was so high (Guerra-Matias et al., 2005).

Another study found that while the glycemic index for popped amaranth (in milk) was high (this study reported it to be 97), foods composed of a mix of amaranth and whole grain wheat in a 25:75 ratio were low glycemic at 65.6, making them comparable to the glycemic index value for 100% whole wheat, which was 65.7. The study, which was conducted on non-insulin dependent diabetics, concluded that while diabetics should not be advised to consume amaranth by itself, they would benefit from eating it in combination with other grains, particularly considering its high protein content and complementary composition as well as the high amounts of calcium and iron it contains. The study authors also suggest that amaranth grain is ideal for use in developing countries, where animal protein is often limited and iron and calcium are often deficient in the diets of low-income people (Chaturvedi et al., 1997).

Amaranth has been found to possess antioxidant activity, presumably due to its phenolic compound and phytic acid content, in both raw and extruded forms. Repo-Carrasco-Valencia et al. (2009) reported antioxidant activity of about 400 micromole trolox/g following the DPPH method, and between 670-828 micromole trolox/g following the ABTS method, with lower antioxidant content and activity in extruded form.

In addition to its nutritional benefits, amaranth has shown promise in the agricultural sense, as well. Though amaranth grain is often considered both somewhat exotic and a “health food,” the amaranth plant is actually hardier than most other grain-producing plants. Once the plant breaks the surface of the soil, it can grow with little rainwater in poor quality soils (Izquierdo et al., 1998). The amaranth plant is able to tolerate drought conditions, adapts readily to new environments, is a high-yielding, fast-growing crop, and is beautiful to look at, with its bright purple, orange, red or gold flowers (Tucker, 1986). With its nutty flavor, it is tasty enough to be accepted by even picky children (well documented in studies on children) (Morales et al., 1988), especially when baked or toasted and added to baked goods, or mixed with honey and made into a candy, such as “alegría,” which is popular in Mexico.

M. Nutritional composition and properties of kañiwa

A lesser known relative of quinoa, kañiwa (*Chenopodium pallidicaule*) is another hardy plant that flourishes in poor, rocky soil; can survive frosts, drought, snowstorms and strong winds that would even destroy quinoa; and is remarkably nutritious (National Research Council, 1989). Like quinoa and amaranth, kañiwa has a huge amount of genetic variability, allowing for cultivation from sea level to high mountains, in both cold and subtropical climates (Repo-Carrasco-Valencia et al., 2010). Since it can be grown at over 4,000 meters, it is very important for subsistence farmers living in the highlands of the Andes mountains.

Kañiwa seeds are even smaller than quinoa, with diameters of just 1.0-1.2 mm. Thus, they usually are not eaten whole; rather they are normally toasted and ground into a nutty-tasting flour called kañiwaco, which can be used in baked goods, pasta, puddings, hot and cold drinks, entrees, soups, stews and desserts, or mixed with milk and sugar to make a pasty porridge-type breakfast cereal (FAO, 1994). Like quinoa and amaranth, kañiwa is gluten-free, making it safe for consumption for people with celiac disease (Repo-Carrasco-Valencia et al., 2010). Unlike quinoa, kañiwa seeds only contain very small amounts of triterpene saponins; thus, kañiwa can be used directly in food without washing (Rastrelli, et al., 1996).

Table 7 Nutrition facts: Raw kañiwa vs. raw corn

Raw Kañiwa (brown)

Serving size 100 g					
Calories	343		**Total Carbohydrate**	58 g	19% DV
Total Fat	5 g	8% DV	Dietary Fiber	25 g	100% DV
Cholesterol	0 mg	0% DV			
Sodium	0 mg	0% DV	**Protein**	15 g	
Vitamin A	0%		**Calcium**	17 %	
Vitamin C	4 %		**Iron**	83 %	

Source: Food composition tables, Instituto nacional de salud, Peru, 2009; Repo-Carrasco-Valencia et al., 2010.

Raw Corn (Peruvian)

Serving size 100 g				
Calories	341	**Total Carbohydrate**	76 g	22% DV

Total Fat	4 g	6% DV	Dietary Fiber	2 g	8% DV
Cholesterol	0 mg	0% DV			
Sodium	0 mg	0% DV	**Protein**	6 g	
Vitamin A	0%		**Calcium**	1 %	
Vitamin C	4 %		**Iron**	8 %	

Sources: Food composition tables, Instituto nacional de salud, Peru, 2009.

Nutritionally, kañiwa is a good or excellent source of protein, carbohydrates, dietary fiber, fat, calcium, phosphorus, iron, thiamin, riboflavin, lignans and flavonoids (Centro nacional de alimentación y nutrición, 2006; FAO, 1994; Repo-Carrasco-Valencia et al., 2010). Similar to quinoa and amaranth, kañiwa provides a nutritionally balanced amino acid profile that is equivalent to milk protein in quality, and that offers high lysine content, similar to amaranth and quinoa (Gross et al., 1989; Repo-Carrasco et al., 2003). In a comparative study of quinoa, amaranth and kañiwa, Repo-Carrasco-Valencia (2010) reported that the protein content of kañiwa grains was significantly higher than that of quinoa and amaranth; while fat content of all three seeds was high, and not different. Glorio et al. (2008) reported that kañiwa has the highest content of total dietary fiber of all the Andean cereals (27.6% of total seed content), which consists of ~23% insoluble fiber and ~ 4% soluble fiber; the soluble fiber content was higher than that found in quinoa, amaranth, wheat, oats, barley and maize, and is similar to the content in rye. Kañiwa is also a very good source of good quality edible oil (Berganza et al., 2003; Repo-Carrasco et al., 2003). It is an excellent source of several minerals; 100 g of brown kañiwa provides 83% DV of iron, 17% DV of calcium and 50% DV of phosphorus. It also provides 52% of the RDA for thiamine, 68% of the RDA for riboflavin, and 11% of the RDA for niacin (Instituto nacional de salud, 2009). Repo-Carrasco-Valencia et al. (2009) reported that kañiwa consists of 6.9-8.0% lignans, as compared to 2.0% for wheat, 3.9% for rice, and 1.4% for corn. Phytate content was 8 mg/g, which is higher than amaranth (3.4-6.1 mg/g), but lower than rice (43.2 mg/g) and wheat bran (52.7 mg/g) (Repo-Carrasco-Valencia et al., 2009; Gualberto et al., 1997). Although phytate has been considered an anti-nutrient due to its chelation with minerals and trace elements, it is also a potent antioxidant in the human body (Fardet et al., 2008). Unlike in common cereals such as wheat, rye, oats and barley, flavonoid content, commonly associated with berries, of quinoa and kañiwa (but not amaranth) is very high. Depending on the variety sampled, quantities ranged from 36 – 144 mg/100 g (as compared to ~ 10 mg/100g in cranberries and lignonberries). Quercetin (highest in kañiwa), kaempferol (highest in quinoa), and isorhamnetin (highest in kañiwa) were the predominant flavonoids observed, along with a lesser amount of rhamnetin (in kañiwa only) and myricetin (Repo-Carrasco-Valencia et al., 2010). Overall, Repo-Carrasco-Valencia et al. (2009) reported antioxidant activity of 4,050-4,200 micrograms of trolox equivalents (TE)/g for kañiwa, as compared to 35 for whole wheat flakes, 27 for whole grain oat flakes, and 20 for corn flakes. Total content of phenolic acids varied from 17 to 60 mg/100g in 5 samples analyzed; and kañiwa was particularly high in ferulic and caffeic acid, while quinoa was higher in vanillic acid (Repo-Carrasco-Valencia et al., 2009). Nevertheless, all three Andean cereals contained lower levels of phenolic acids than some common cereals, such as whole wheat (137 mg/100g) and rye (134 mg/100g) flours, but was on par with levels found in oats, barley, corn, rice and millet (Mattila et al., 2005). However, using the 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) inhibition assay, a different assay instrument for determining antioxidant activity, Galvez Ranilla et al. (2009) reported that kañiwa radical scavenging activity was 75%, second to quinoa's very high 86%; thus, the authors concluded that antioxidant activity is only moderately related to total phenolic content. Plant polyphenols and flavonoids have been linked to the protective effects of plant foods against major chronic diseases including cardiovascular disease and diabetes (Arts et al., 2005).

Table 8

Mean soluble phenolic acid & flavonoid content of Andean cereals (mg/100g)

Phenolic acids	**Quinoa**	**Amaranth**	**Kañiwa**
Caffeic acid	0.7	0.9	3.0
Ferulic acid	15	6.9	23
p-Coumaric acid	8.0	0.9	1.0
p-OH-benzoic acid	2.9	3.0	1.7
Vanillic acid	11.0	5.4	4.0
Sinapic acid	--	0.2	--
Protocatechuic acid	--	5.0	--
Myricetin	0.5	--	0.04
Quercetin	36.0	--	60.0
Kaempferol	20.0	--	2.3
Isohamnetin	0.4	--	30.0
Rhamnetin	--	--	4.0

Source: Repo-Carrasco-Valencia et al., 2010

Kañiwa, amaranth and quinoa also have potential benefits for heart health. Bottazzi Alvarez (2003) reported total cholesterol, LDL, and triglyceride decreases of 26.9%, 37.2% and 24.9%, as well as a 25.4% increase in HDL, in 109 men and women suffering from hypercholesterolemia in excess of 200 mg/dl, after daily consumption of kañiwa for

72 days. Berger et al. (2003) reported that hyperlipidemic hamsters fed a high-amaranth diet achieved 15-22% lower total serum cholesterol levels, as well as 21-50% lower LDL levels and higher HDL levels. Asao and Watanabe reported high angiotensin I converting enzyme (ACE) inhibition activity in both quinoa and amaranth (Asao and Watanabe, 2009); and Ogawa et al. (2001) reported that quinoa ingestion suppresses systolic blood pressure in rats.

N. Summary

Research shows that people are less likely to get chronic diseases such as type 2 diabetes if they make healthy lifestyle choices, such as maintaining a healthy weight, eating healthfully, exercising, not smoking and limiting alcohol intake. In addition, two important findings have recently been reported regarding these factors. First, each lifestyle choice has been shown to independently influence a person's risk of getting diabetes, even among those with a family history of the disease; and second, each additional lifestyle choice lowers risk in an additive manner.

Nevertheless, maintaining a healthy body weight, defined in this study as BMI<25, is the most important factor in predicting the development of diabetes. Regardless of family history or level of adiposity, among people whose diet score (a calculation that takes into account four dietary parameters: glycemic index-values of foods, ratio of polyunsaturated fat to saturated fat, and fiber and trans fat intakes), exercise level, smoking status and alcohol use were all in the low-risk group, absence of overweight or obesity lowered the odds of developing diabetes from 61% and 43% for overweight and obese men and women, respectively, to 28% and 16% for normal weight men and women (Reis et al., 2011).

Consuming whole grains has been shown to be beneficial for maintaining normal body weight and in type 2 diabetes prevention and control. Research has been presented above that suggests benefits in both arenas may be associated with consumption of Andean grains. Recently, in vitro evidence was published indicating the potential of including quinoa, amaranth and kañiwa in the diet of type 2 diabetics as part of a strategy to manage that disease (Galvez Ranilla et al., 2009). However, there is a lack of research regarding the potential health benefits of frequently consuming traditional Andean grains as part of the regular diet.

III. Objectives

The main objective of this study was to describe observations regarding consumption of the native Peruvian grains quinoa, amaranth and kañiwa and weight status among a self-selected sample of people living in the Peruvian city of Arequipa.

A secondary objective was to report observations regarding consumption of these native Peruvian grains, as well as consumption of refined grain products and other high carbohydrate foods such as breads and pasta made with refined wheat flour, rice, potatoes, and cassava and self-reports of certain potential risk factors, symptoms, and complications of type 2 diabetes in this sample.

IV. Research Methods

A. Recruitment of study participants

Subjects were invited to participate in the study directly and in person by one of four interviewers over a period of 18 days. Time constraints did not allow for the use of advertisements, public notices or other standard recruiting techniques. Thus, the participants were directly recruited and represent a convenience sample.

Interviewers recruited subjects from a variety of sites in the city of Arequipa, including the Universidad de San Agustín, a local club of women retirees, the Altiplano street market, the District of Alto Selva Alegre, and the diabetic education program at the Hospital Regional Honorio Delgado (HRHD). The only inclusion criteria were age ≥ 40 and willingness to be interviewed and/or to complete the survey instrument. Failure to complete the food frequency section of the study survey instrument was the only criterium for exclusion. Of the 110 study subjects, 10 were excluded for failure to complete the food frequency section of the survey instrument.

Since one objective of the study was to describe observations regarding cereal consumption frequency and self-described experiences of diabetes complications or self-described experiences of diabetes risk factors, both diabetic and non-diabetic subjects were recruited. The diabetic education program at HRHD was selected as a recruitment site for the specific purpose of recruiting diabetic subjects. However, additional diabetic subjects are personal acquaintances of one of the interviewers.

Upon requesting and obtaining permission from the diabetic education program director to attend one of the group's regularly scheduled monthly education sessions at HRHD, one interviewer attended a session on August 15, 2009. After being introduced to the group by the nurse educator at the end of that session, which was attended by approximately 25 diabetics, the interviewer explained the scope and purpose of the study to the group and requested the members' participation. Fifteen diabetics from the group agreed to be interviewed and interviews were conducted immediately afterward by the interviewer in attendance, in small groups of 3 or 4 subjects per interview group.

Two interviewers were undergraduate students of nutrition in their last year of study at the Universidad de San Agustín (UNSA). They recruited 40 subjects at the University and used the survey instrument to interview those subjects, mostly non-diabetic professors and staff. Unlike the other four interviewers, they were financially compensated for their work in recruiting and interviewing subjects. The interviewers were selected based on recommendations by Dr. Sonia Quiroga Medina, Nutrition Sciences Department Chair at UNSA, who instructed them on details of the study and supervised their work.

Prior to interviewing subjects at the local women's retiree's club, one of the interviewers contacted the club organizer and obtained permission to attend a social gathering of club members, held at a local restaurant, for the purpose of conducting the interviews. Two interviewers attended said social gathering on August 17, 2009, and interviewed approximately 30 club members over a two-hour period. Interviews were conducted one-on-one or in groups of 2 or 3 using the survey instrument.

Two interviewers interviewed 10 vendors at the Altiplano street market. Interviewers recruited participants at the market by approaching them in person, explaining the scope and objective of study, ascertaining that they met the age inclusion criterion, and asking them to participate by submitting to an interview. Interviews were conducted immediately using the survey instrument with vendors who agreed to participate.

One interviewer recruited participants and conducted interviews in the Alto Selva Alegre District in Arequipa. Subjects in that District were family members, friends, or acquaintances of the interviewer. They included diabetics and non-diabetics. The Interviewer approached such subjects directly, explained the scope and objective of the study and ascertained their willingness to be interviewed. The interviewer used the survey instrument to interview 15 subjects directly either at the subjects' homes or businesses, or at the home of the interviewer. Another 15 subjects filled out the survey instrument independently at home after receiving instructions for doing so from the interviewer. Subjects who filled out the survey instrument on their own returned their completed surveys to the interviewer's home within 3-5 days of receiving them.

Participation in the study was strictly voluntary and study participants were not financially compensated for their participation. Time constraints upon the principal study author were the main factor limiting the number of participants in the study. All subjects had to be recruited and all interviews conducted within a period of 18 days, due to schedule limitations of the principal interviewer. However, the interviewers exceeded the initial goal of recruiting and interviewing a minimum of at least 100 subjects.

B. Survey instrument and data collection

A survey instrument that included a food frequency questionnaire was written in English specifically for this study and then translated into Spanish, following guidance provided in the Manual for social surveys on food habits and consumption in developing countries. (den Hartey et al., 1983) Prior to administration, the instrument was reviewed by a food scientist and a professor of nutrition, both of Peruvian origin, to ensure the use of proper terminology in Spanish.

A key feature of the survey instrument was a food frequency questionnaire that assessed the consumption of quinoa, amaranth, and kañiwa, as well as other grain- and tuber-derived carbohydrate staples including bread, rice, potatoes, cassava and pasta. In addition, the instrument addressed family health history, personal medical history and health practices, change in weight over time, certain lifestyle behaviors related to diet and physical activity, tobacco use, and self-described experiences of selected diabetes risk factors or complications. The instrument also included basic demographic questions.

The anthropometric information collected included height and weight, which were used to calculate body mass index (BMI) for each participant, and waist circumference. Participants were grouped into WHO-defined weight categories ranging from underweight to obese, according to BMI. (WHO, 2000a) Physical activity level was obtained via questions about occupation and recreational physical activity. Participants were grouped into two physical activity categories—“inactive” and “active”—according to physical activity level. “Inactive” participants included those who engaged in moderate or greater intensity exercise less than 30 minutes per day at least 3 times per week, and who indicated a profession requiring little physical activity, such as homemaker, retiree, office worker or professional. “Active” participants included those who engaged in moderate or greater intensity exercise 3 or more times per week, or who worked as a laborer or in other physically demanding jobs. “Smokers” included those who regularly smoked one or more cigarettes per week; “nonsmokers” included those who smoke occasionally (less than one cigarette per week) or never.

Health-related questions included history of weight gain and loss over the past 20 years, family history of diabetes and personal diabetes status. Participants were asked to provide the amount of weight they had gained or lost in kg over the past one, five, ten and twenty years. Family history of diabetes included participants with at least one close family member (a grandparent, parent, brother, sister or child) who had been diagnosed by a physician with any common form of diabetes (type 1, type 2 or gestational). Participants were categorized as “diabetic” if they had ever been diagnosed as having any type of diabetes (type 1, type 2 or gestational) by a physician.

Self-described diabetics completed 6 supplemental questions regarding length of time since their original diagnosis, treatment regimens they are following, adherence to prescribed treatments for diabetes, and perceived presence of complications resulting from diabetes. Subjects were asked to indicate type of treatments using a list that included eating an appropriate diet, exercising, taking insulin, taking other medications besides insulin, or indicating other treatment options not listed. The survey participants were asked to indicate (by checking a box) the frequency with which they adhered to each treatment: “every day,” “most days,” “sometimes,” “once in a while,” or “never.”

Another question requested further details regarding diet-related treatments using the same frequency categories. In this question, diabetics were asked about how often they limit their intakes of starches, fats, sweets, salt, calories, cholesterol, animal products, and alcohol, and how often they consciously eat high-fiber and whole-grain foods. Finally, they were asked to indicate which if any complications they had suffered in relation to their diabetes, from a list that included vision problems, kidney insufficiency or other problems, heart problems, recurrent infections or wounds that take a long time to heal, pain or numbness in their extremities, high blood pressure or other (specify).

The survey questions that addressed self-described perceptions of 14 diabetes risk factors and warning signs (15 for women) were used to categorize self-described non-diabetic participants according to their future risk of developing diabetes. These questions were devised based on interviews with two Peruvian physicians, Dr. Ronald Sánchez, MD and Dr. Walter Medina Rueda, MD. The physicians identified the most commonly reported diabetes warning signs and risk factors reported by pre-diabetics in Arequipa and in the medical literature.

Among the warning signs identified and included in the survey were a frequent desire to eat, drink and urinate; blurred vision; delivering a large (> 4 kg) birth-weight baby among women; contracting recurrent urinary tract, respiratory system, or vaginal infections; having significant weight gain or sudden, unexplained weight loss; and meeting the criteria for metabolic syndrome (with the exception of raised fasting blood sugar, which was omitted from the survey). Calculated BMI≥25 was also included as a risk factor.

According to the International Diabetes Federation, metabolic syndrome is characterized by the prevalence of two or more of the following: hypertension (>130/85 mmHg), abdominal obesity as measured by waist circumference ≥80 cm in women of any ethnicity and ≥90 cm in ethnic South American men, hypertriglyceridemia (≥150 mg/dL), reduced HDL cholesterol (<40 mg/dL in men and <50 mg/dL in women), and raised fasting blood sugar ≥100 mg/dL (IDF, 2006).

The food frequency section asked participants to indicate the average frequency with which they consumed the following foods over the past year: quinoa, amaranth, kañiwa, white rice, brown rice, white potatoes, chuño (freeze-dried white potatoes), cassava, white bread, whole wheat bread, baked goods, cookies, crackers or sweets made with white flour, pasta or noodles, and whole wheat pasta. For each food item, participants had the option of indicating how often they consumed each food in general, and also as a main dish or as a component of another food. For quinoa, amaranth, kañiwa and rice, the following options were listed as possible ways of eating the food: as an entrée or salad; in a soup or stew; in a drink, juice or dessert; as a hot or cold cereal; and in bread, cake, pastry or dessert made from [grain] flour. Participants were asked to indicate how often during the past year they ate each item listed on the food frequency questionnaire using the following categories: never or <once per month, about once per month, 2-3 times per month, once per week, several times per week, once per day, or two or more times per day. The food frequency section also included 8 open-ended questions that asked participants to list foods they typically eat for breakfast, lunch, dinner, and snacks, along with specific questions regarding number of rolls or pieces of bread consumed with each meal, and total number of rolls consumed each day, on average.

The questionnaire was either administered via interview or self-administered, according to the personal preference of each participant, to 110 subjects in the city of Arequipa, Peru. After obtaining informed consent from each participant, face-to-face interviews were conducted in Spanish over a period of three weeks in August 2009 by a small team of researchers including the principal study author, two Peruvian nutrition students identified by the dean of the Nutrition Department at the Universidad de San Agustín, a Peruvian food scientist. Self-administered surveys were completed during the same time period at the home of the participant (in which case, the participant received instructions on completing the survey from an interviewer prior to receiving the survey instrument), or in the presence of a survey administrator, who was available to answer questions and provide any necessary clarification. All data were self-reported. The full questionnaire is attached in the appendix.

V. Results and discussion

A. Participant characteristics

A total of 110 Peruvian adults living in Arequipa, 22 of whom had been diagnosed with type 2 diabetes mellitus by a physician, completed the survey instrument (Table 9). The study sample was 79% female and 21% male, and ranged in age from 33–95 years, with a mean age of 59 years. All except two were 40 years of age or older at the time the survey was administered. Compared to non-diabetics, the diabetic participants were older, more sedentary, and more likely to be overweight and to have a family history of diabetes.

Study participants included members of a local retired women's club, diabetics enrolled in a diabetes education program at a local hospital (Hospital Regional Honorio Delgado, or HRHD), professors and staff at the Universidad San Agustín, acquaintances of the survey administrators, and local merchants at the Altiplano outdoor market. Participants were generally middle and upper-middle class.

It should be noted that most diabetics in Peru do not attend diabetes education programs or receive nutritional support. Thus, the diabetics in our sample were unique from the majority of diabetics in Arequipa in the sense that they had more information available to them. They were also probably more interested in their health than diabetics who do not attend the HRHD program.

It should also be noted that Arequipa is a city that is known for its generous meal portions. Thus, participants in our sample probably regularly consume larger quantities of food at mealtimes than in other areas of the country. This is particularly true for the mid-day meal, when it is customary to eat a large bowl of hearty soup containing multiple, portions of carbohydrate-rich foods (typically some combination of potatoes, chuño, cassava, pasta and/or rice), as well as a serving of meat, poultry or seafood and one or more servings of vegetables (typically sweet potatoes, carrots, onion, celery, corn and/or squash) and possibly a few beans or other legumes, as well. Following the large bowl of soup, most people also eat another full plate of food, referred to as the “segundo” (literally, “second”). The segundo generally consists of a large serving of rice (often covering a third to half the plate) and a large serving of meat, poultry or fish. It will sometimes be accompanied by a side salad, as well. It is not customary to eat desserts after meals in Peru, but consuming a sugar-sweetened beverage following a meal is common. Many people keep leftovers from lunch on the stove all day long and eat a smaller portion of the same food at dinnertime. Many of the participants in our sample reported adhering to such customs. Thus, it is possible that people in Arequipa, including the participants in our sample, generally ate larger quantities of food than is customary in other parts of Peru. Such behavior would presumably affect blood sugar and insulin levels, increasing the likelihood that our participants may experience spikes and dips in these levels throughout the day.

Perhaps as a consequence of consuming large meals at mealtimes, many participants in our sample reported consuming few if any snacks between meals. This suggests that the participants in our sample may eat fewer sweet and salty snacks than the general population of Peru, which has generally increased its consumption of such foods in the past decade.

Ten participants who did not complete the food frequency section of the questionnaire were excluded from the analysis. Therefore, the data presented pertain to the remaining 100 participants.

Table 9. Selected characteristics of study participants

Characteristic	All participants (n=100)*		Non-diabetics (n=78)*		Diabetics (n=22)*	
	n	%	n	%	n	%
Ages						
33-39	4	4	3	4	1	5
40-49	25	25	21	25	4	18
50-59	24	24	20	24	4	18
60-69	29	29	23	29	6	27
70-79	12	12	7	11	5	23
>79	7	7	5	8	2	9
Gender						
Male	21	21	16	20	5	23
Female	79	79	62	80	17	77
Weight Status (BMI)						
Underweight (<18)	0	0	0	0	0	0
Normal (18-24.9)	33	33	28	36	5	27
Overweight (25-29.9)	51	51	38	47	13	55
Obese (≥30)	16	16	12	17	4	18
Waist Circumference (WC)*						
Males (WC > 90 cm)	12	86	9	82	3	100
Females (WC > 80 cm)	32	52	28	50	4	80
Smoker						
Yes	3	3	3	4	0	0
No	97	97	75	96	22	100

Sedentary Lifestyle						
Yes	70	70	51	65	19	86
No	30	30	27	35	3	14
Family History of DM2						
Yes	27	27	11	14	16	68
No	71	71	66	85	5	27
Unsure/No response	2	2	1	1	1	5
Diagnosed with DM2						
Yes	22	22	0	0	22	100
No	78	78	78	100	0	0

*Waist circumference data were collected for 75 participants (men, n=14; women, n=61; non-diabetics, n=67; diabetics, n=8)

B. Weight status measures

Using weight and height to calculate body mass index (BMI=kg/m2), we found that 0% of our sample (n=100) was underweight (BMI<18), 33% were normal weight (BMI of 18-24.9), 51% were overweight (BMI of 25-29.9), and 16% were obese (BMI≥30). We assigned weight status according to the World Health Organization standard, using the following BMI cut-offs: <18 for "underweight;" 18-24.9 as "normal weight;" 25-29.9 as "overweight;" and ≥30 for "obese." (WHO, 2000) The convenience sample in our study appeared to be representative of the general urban population of Peru in terms of weight status. Jacoby et al. (2003) reported overweight and obesity prevalence of 64% in Peru's most populous urban areas. Medina et al. (2006) reported overweight and obesity prevalence of 71% among people ages 35-80 living in the city of Arequipa.

Waist circumference (WC) measurements were taken on only 75 participants (61 women and 14 men). (Twenty-five subjects opted not to participate in waist circumference measurements.) Among all of the participants for whom valid waist circumference measurements were available, 59% (44 participants) met the criteria for abdominal obesity, which included 52% (n=32) of the women and 86% (n=12) of the men. The International Diabetes Federation (IDF) for Central and South American populations has established a WC ≥ 90 cm for men and WC ≥ 80 cm for women as the criteria for abdominal obesity (Alberti et al., 2005).

The women in our sample seemed representative of women in Peru regarding the prevalence of abdominal obesity in the population. Peruvian government data indicate that 54.5% of Peruvian women exhibit abdominal obesity, as defined by WC ≥ 80 cm. (CENAN, 2006) However, a larger percentage of the men in our sample exhibited abdominal obesity than reported elsewhere. For example, Medina et al. (2006) found that 63% of men between 35-64 years of age living in Arequipa exhibited abdominal obesity, compared to 86% in our study. The difference may be due to the small (n=12) convenience sample used in our study, and to differences in the age ranges of the men, as participants in our study included men in their 70s and older.

Generally, participants categorized as abdominally obese were also either overweight or obese according to the WHO criteria for BMI (WHO, 2000). However, 7% of the participants in our study who had a BMI in the normal range met the criteria for abdominal obesity according to the IDF WC criteria (Alberti et al., 2005).

C. Cereal and tuber consumption

The frequency of consumption of native Peruvian grains and other carbohydrate sources, stratified by BMI category and presence of diabetes, is shown in Table 10. Participants were asked how often they ate the food during the past year.

Table 10. Consumption of native Peruvian grains and other carbohydrate sources

		BMI Category						Diabetic status			
		Normal (<25) (n=37)		Overweight & Obese (≥25) (n=63)		All participants (n=100)		Non-Diabetics (n=78)		Diabetics (n =22)	
Grain	**Consumption Fqy**	**n**	**%**	**n**	**%**	**n**	**(%)**	**n**	**(%)**	**n**	**(%)**
Quinoa	High (≥1 x week)	25	67.6	32	50.8	57	57.0	44	56.4	13	59.1
	Low (<1 x week)	12	32.4	31	49.2	43	43.0	34	43.6	9	40.9
Amaranth	High (≥1 x week)	18	48.6	25	39.7	43	43.0	31	39.7	12	54.5
	Low (<1 x week)	19	51.4	38	60.3	57	57.0	47	60.3	10	45.5
Kañiwa	High (≥1 x week)	15	40.5	11	17.5	26	26.0	19	24.4	7	31.8
	Low (<1 x week)	22	59.5	52	82.5	74	74.0	59	75.6	15	68.2
Quinoa, Amaranth or Kañiwa	High (≥1 x week)	28	75.7	42	66.7	70	70.0	52	66.7	18	81.8
	Low (<1 x week)	9	24.3	21	33.3	30	30.0	26	33.3	4	18.2
Quinoa and Amaranth	High (≥1 x week)	16	43.2	18	28.6	34	34.0	26	33.3	8	36.4
	Low (<1 x week)	21	56.8	45	71.4	66	66.0	52	66.7	14	63.6
Quinoa and Kañiwa	High (≥1 x week)	14	37.8	5	7.9	19	19.0	14	17.9	5	22.7
	Low (<1 x week)	23	62.2	58	92.1	81	81.0	64	82.1	17	77.3
Amaranth and Kañiwa	High (≥1 x week)	13	35.1	8	12.7	21	21.0	15	19.2	6	27.3
	Low (<1 x week)	24	64.9	55	87.3	79	79.0	63	80.8	16	72.7
Quinoa, Amaranth and Kañiwa	High (≥1 x week)	13	35.1	5	7.9	18	18.0	13	16.7	5	22.7
	Low (<1 x week)	24	64.9	58	92.1	82	82.0	65	83.3	17	77.3
White Rice	High (≥1 x week)	37	100	62	98.4	99	99.0	78	100.0	21	95.5
	Low (<1 x week)	0	0	1	1.6	1	1.0	0	0.0	1	4.5
White Potatoes	High (≥1 x week)	36	97.3	60	95.2	96	96.0	75	96.2	21	95.5
	Low (<1 x week)	1	2.7	3	4.8	4	4.0	3	3.8	1	4.5
White Flour	High (≥1 x week)	27	73.0	62	98.4	89	89.0	71	91.0	18	81.8
	Low (<1 x week)	10	27.0	1	4.8	11	11.0	7	9.0	4	18.2
Cassava	High (≥1 x week)	16	43.2	37	58.7	53	53.0	40	51.3	13	59.1
	Low (<1 x week)	21	56.8	26	41.3	47	47.0	38	48.7	9	40.9
Pasta	High (≥1 x week)	17	45.9	46	73	63	63.0	52	66.7	11	50.0
	Low (<1 x week)	20	54.1	17	27	37	37.0	26	33.3	11	50.0
Chuño	High (≥1 x week)	19	51.4	44	70	63	63.0	46	59.0	17	77.3
	Low (<1 x week)	18	48.6	19	30	37	37.0	32	41.0	5	22.7

Participants were grouped into two BMI categories (normal weight for BMI<25 and overweight and obese for BMI≥25) to simplify comparisons between the two groups. These groups were selected due to the composition of the study sample, which contained zero underweight subjects (BMI<18.5) and too few obese subjects to allow for reliable comparisons. Thus, obese and overweight subjects were placed into a single BMI category and compared to normal weight subjects in an attempt to simplify observations of potential differences between BMI category and grain and other carbohydrate consumption.

Grain and other carbohydrate consumption frequency was likewise collapsed into two categories: high (≥ 1 x week) and low (<1 week). The decision to collapse the consumption data into two categories came about due to having too few observations (none, in some cases) in many of the original consumption categories, in relation to the small size of the sample. Since one of the main objectives of the study was to see if people who ate more Andean grains were more or less likely to be overweight or obese compared to less frequent consumers, dividing the intake frequencies into the high and low categories allowed for a clearer observation of any potential trends. Doing so was also intended to facilitate the observation of potential relationships regarding grain and carbohydrate consumption in diabetics and non-diabetics.

The frequency of consumption of foods high in carbohydrates in our sample was similar to what has been reported for other areas of Peru (CENAN, 2006). As seen in Table 2, most of the participants in our sample reported consuming Western cereals such as rice and white flour at least on a weekly basis (99% and 89%, respectively, with more than a respective 70% and 50% reporting daily or more frequent consumption). However, subjects reported consuming Andean cereals less often. This was true regardless of BMI category or diabetic status. White potatoes were also consumed at least weekly by almost all subjects (96%); almost half (48%) reported consumption at least once per day. In addition, more subjects reported consuming pasta (63%) and chuño (63%) at least once per week, than reported weekly consumption of any of the individual Andean cereals.

Most study participants (57%) reported regularly consuming quinoa. However, the majority of participants reported that they never consumed amaranth and kañiwa, although those who did report consuming amaranth tended to do so regularly—43% of the participants reported consuming amaranth at least once per week. Kañiwa was consumed less often by the participants—only 26% said that they consumed kañiwa at once per week. Relatively few participants reported weekly or greater consumption of more than one Andean cereal. Frequent consumption of both quinoa and amaranth was reported by 34% of participants, compared to just a respective 21% and 19% reporting frequent consumption of amaranth and kañiwa, or quinoa and kañiwa. Just 18% reported consuming all three Andean cereals on a weekly basis.

When comparing Andean cereal and carbohydrate consumption according to BMI category, several differences were apparent between the two groups. Normal BMI subjects were more likely to report individual frequent weekly consumption of quinoa (67.6%), amaranth (48.6%) and kañiwa (40.5%), compared to overweight and obese subjects, who reported respective weekly consumption of 50.8%, 39.7% and 17.5%. They were also more likely to report weekly consumption of more than one Andean cereal. Among normal BMI subjects, weekly consumption of quinoa and amaranth was 43.2%, compared to 28.6% for overweight and obese subjects. For amaranth and kañiwa, 35.1%

of normal BMI subjects reported weekly consumption, compared to 12.7% of overweight and obese participants. For quinoa and kañiwa, 37.8% of normal BMI subjects reported weekly consumption, compared to just 7.9% of overweight and obese participants. All of the overweight and obese subjects who reported frequent consumption of quinoa and kañiwa also consumed amaranth on a weekly basis. All of the normal BMI subjects who reported frequent consumption of amaranth and kañiwa also consumed quinoa on a weekly basis. Normal BMI subjects were also less likely to report frequent consumption of white flour (73%), cassava (43.2%), pasta (45.9%) or chuño (51.4%), compared to overweight and obese subjects (98.4%, 58.7%, 73%, and 70% of whom reported frequent consumption of these four carbohydrate sources, respectively).

It is not possible to ascertain associations in a case study such as this, since potential confounders such as socio-economic status, level of education, and differences in lifestyle between study subgroups may exist that may influence BMI and health status. However, the inverse trend we observed in our study between frequent kañiwa and amaranth consumption and lower overweight or obesity is not altogether unexpected, given the high fiber, fat and protein content of these Andean cereals. Foods rich in fiber, fat and protein, which can slow gastric emptying rate or glucose diffusion, have been associated with higher satiety and lower prevalence overweight and obesity levels among frequent consumers (Venn and Mann, 2004). Since Andean grains contain significant quantities of dietary fiber, protein and fat, we would expect slower digestion rates of their starches.

In addition, Andean cereals have been reported to inhibit the activity of digestive enzymes. Galvez Ranilla et al. (2009) reported that quinoa showed potential for in vitro alpha-glucosidase inhibition, meaning that people who consume it may experience delayed uptake of glucose and oligosaccharides along the intestinal brush border. Conforti et al. (2005) reported in vitro alpha-amylase inhibitory activity of 51% and 28% in raw whole amaranth flour made from two seed varieties. In addition, carbohydrate utilization inhibitors have been found to slow the digestion of complex carbohydrates and the uptake of glucose in vivo (Godbout et al., 2007). In addition, Berti et al. (2004) demonstrated a low glycemic response after consumption of quinoa (similar to that of pasta, which is considered a low glycemic food) in humans. They also reported that insulin responses were also significantly lower in consumers of quinoa. A meta-analysis of test meal studies reported an association between postprandial insulin response, decreased hunger, increased satiety and lower subsequent energy intake (Flint et al., 2007). The implication inherent in these findings is that slower digestion and lower postprandial insulin response and circulating blood sugar levels may occur after consumption of Andean cereals, compared with white flour-based foods. Further, Berti et al. (2005) reported that quinoa has potential to assist in controlling appetite in a study comparing subjects who consumed cereal controls with subjects who consumed quinoa. The authors reported that the quinoa group had stopped eating faster and reported greater fullness and satiety sensations. Additional research is required to confirm whether such reported associations may in part explain the trend observed in this study between regular consumption of Andean cereals and normal BMI.

Diabetics in our sample reported consuming Andean cereals—particularly amaranth—more frequently than non-diabetics; they were also less likely to consume white flour-based foods, compared to non-diabetics (82%, compared to 91% of non-diabetics). Almost 82% of diabetics reported regular consumption of at least one Andean cereal, compared to almost 67% of non-diabetics. Both groups were similarly likely to report frequent quinoa consumption. However, more than half of the diabetics (54.5%) reported weekly amaranth consumption, compared to fewer than 40% of non-diabetics. More diabetics (almost 32%) reported regular consumption of kañiwa, compared to 24% of non-diabetics.

Diabetics also reported more frequent consumption of tuber-derived carbohydrates—particularly chuño and cassava—which perhaps replaced flour in their diets. Nevertheless, the level of Andean cereal consumption reported by the subjects in this study may not be indicative of the general population of diabetics in Peru, since the majority of the diabetics in our sample were participants in a diabetes education program sponsored and implemented by the Hospital Regional Honorio Delgado, Arequipa's main hospital. The education received through the program may have influenced the dietary choices of the diabetics in our sample, perhaps leading them to eat more Andean cereals and tubers, and less white flour, compared to Peruvian diabetics who are not enrolled in such a program. This, along with the small number of diabetics included in our sample, obscured our ability to observe trends regarding cereal and tuber consumption, and self-described experiences of symptoms that may represent diabetes complications.

In addition to reporting consumption of selected individual cereals, participants were asked to estimate the average number of white-flour bread rolls they consume per day. Bread is a commonly consumed food at both breakfast and dinner among people living in Arequipa. Roll consumption varied among study participants. While 88% reported consuming at least 2 rolls per day, nearly a third (32%) reported consuming 4 or more rolls per day, and 7% said they typically consume 6 or more rolls per day. By BMI category, 55% and 35% of overweight and obese participants reported daily consumption in excess of 2 and 3 rolls per day, respectively, compared to a respective 40% and 19% of normal weight subjects.

Participants were also asked to estimate how often, measured by number of meals per day they consume 3 or more ½-cup-servings of starchy foods (i.e. potatoes, rice, chuño, cassava, pasta, bread, etc.). About half (51%) of the participants said they consume a high-starch meal just once per day, 32% said they did so twice per day, and 10% reported consuming 3 high-starch meals per day. Seven percent of the participants said they never consume high-starch meals. There was little difference in consumption frequency of high-starch meals between BMI category groups (data not shown).

Diabetics were less likely than non-diabetics to consume frequent high-starch meals, although self-described experiences of bread roll consumption differed little between the two groups. However, bread roll and high-starch meal consumption patterns may differ between diabetics in our sample and the total population of diabetics in Peru, for the reasons stated earlier. In addition, since many of the diabetics in our sample attend the HRHD's diabetes education program, it is possible that their probable familiarity with the need to control carbohydrate intake and body weight led them to under-report their consumption of bread, high-starch meals, tubers and Western cereals, or to over-report their consumption of Andean cereals.

D. Self-described experiences of diabetes risk factors and warning signs in non-diabetics

Self-described experiences of diabetes risk factors and warning signs among non-diabetics in our sample are shown in Table 11. Most non-diabetics (70%) appeared to be at low or medium risk for developing diabetes, based on the number or risk factors and warning signs they reported experiencing (low risk = 0-2 risk factors/warning signs; medium risk = 3-4; high risk $\geq$ 5). However, approximately 30% were at high risk. Relatively few normal BMI non-diabetics (13%) were at high risk for diabetes, as compared to overweight and obese non-diabetics, of whom 38% were at high risk.

Table 11

Potential Risk Factors and Warning Signs in Non-Diabetic Participants

Number of risk factors/warning signs	Number and percent of non-diabetic participants					
	All (n= 85)		Normal weight (BMI 18.5-25) (n= 30)		Overweight or obese (BMI ≥ 25) (n=55)	
	#	%	#	%	#	%
0 – 2	29	34	14	47	15	28
3 – 4	31	36	12	40	19	35
≥5	25	29	4	13	21	38

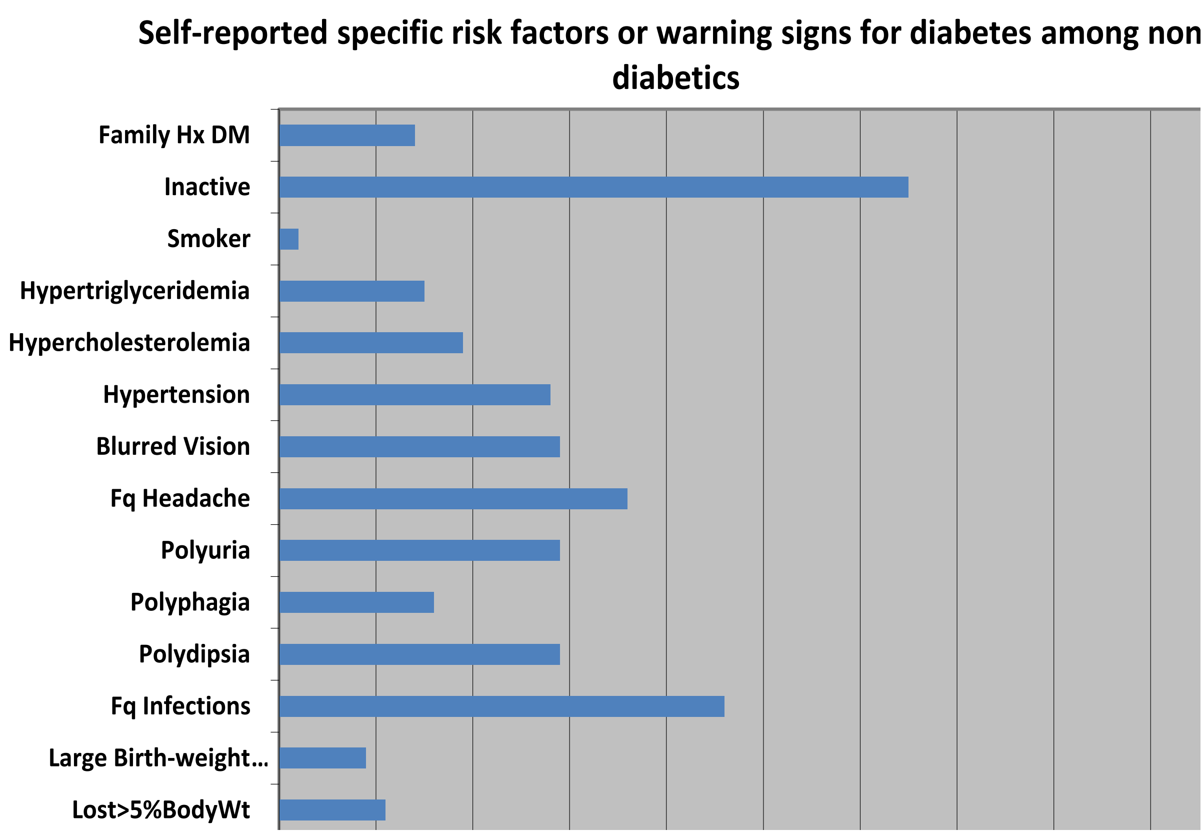
Note: "Low risk" is defined as perceiving 2 or fewer risk factors or warning signs; "medium risk" pertains to perceiving 3-4 risk factors; "high risk" is defined as perceiving 5 or more risk factors or warning signs.
Note: Total possible risk factors and warning signs: 14 for men (n=17), 15 for women (n=68)

These findings are not surprising for several reasons. First, having a BMI ≥ 25 is itself a risk factor for diabetes. In addition, overweight and obesity have been clearly associated with increased prevalence of a number of diabetes risk factors, including hypertension, hypertriglyceridemia, hypercholesterolemia, physical inactivity and birthing large babies (NIH, 1998; Kabali and Werler, 2007). Thus, we expected overweight and obese participants to report experiencing more diabetes risk factors and warning signs than normal BMI participants.

The figure below shows the distribution of diabetes risk factors and warning signs reported by non-diabetics in our sample. Among the most common risk factors reported by non-diabetics in our sample were BMI ≥ 25 (reported by 68%), having a sedentary lifestyle (35%), and hypertension (28%). Perhaps more alarming was the relatively high percentage of non-diabetic participants who reported suffering from potential warning signs including frequent infections (46%), frequent headaches (36%), polyuria (29%), polydipsia (29%) and blurred vision (29%).

Such numbers suggest that it is possible that some of the participants in the non-diabetic category may suffer from metabolic syndrome, pre-diabetes, or undiagnosed diabetes. However, it is important to note that many of these risk factors and warning signs may be indicators of a number of medical conditions; they are not specific to diabetes. In addition, individuals may have varying levels of tolerance, and thus varying perceptions regarding the presence or absence of conditions such as polyuria, polydipsia, polyphagia, and frequency of infections and headaches.

Figure 4



*Note: Large Birth-weight Baby applies to females only; n=85, females=68, males=17

E. Andean cereal consumption frequency and self-described experiences of diabetes risk factors and warning signs in non-diabetics

At the start of this study, we had expected to observe inverse relationships between Andean grain consumption and self-described experiences of diabetes risk factors and warning signs in non-diabetics, particularly in regards to hypertriglyceridemia, hypercholesterolemia, hypertension, polyphagia, large birth-weight babies, and BMI $\geq$ 25. However, with the exception of BMI $\geq$ 25 (discussed above), our observations were incongruent with our expectations. In the following paragraphs, we discuss the reasons behind our initial expectations as well as factors that may help to explain the distinct lack of relationships observed between the two (other than the observations between Andean cereal consumption and BMI).

We expected to see relationships between Andean cereal consumption and markers of hyperlipidemia, including hypertriglyceridemia, reduced HDL cholesterol level, and raised total cholesterol level due to apparent associations reported in several studies. Bottazzi Alvarez (2003) reported an association between kañiwa consumption and lower total cholesterol, LDL, and triglycerides, as well as increased HDL in hypercholesterolemic individuals. Berger et al. (2003) reported an association between amaranth consumption, lower serum cholesterol and LDL levels, and higher HDL levels in hyperlipidemic hamsters. Berti et al. (2004), reported that consumption of quinoa leads to significantly lower levels of circulating free fatty acids (FFA) and triglycerides, compared to consumption of wheat-flour-based bread, crackers and pasta. High levels of FFA increase blood triglyceride levels. Thus, we expected to find that frequent quinoa consumers would experience long-term suppression of FFA, resulting in improved triglyceride and cholesterol levels. In future studies, it will be important to obtain blood samples from participants in order to ascertain whether such relationships exist among diabetic and non-diabetic frequent consumers of Andean cereals. This is particularly important since research is lacking as to whether consuming processed cereals (i.e. cereals that no longer have intact matrices), rather than intact cereal grains, may affect such parameters. It is possible that future studies may show that food processing applications such as grinding, heat or extrusion may affect the ability of Andean grains to influence HDL cholesterol and/or triglyceride levels in consumers.

Several studies have been reported addressing potential associations between Andean grain consumption and hypertension. Ranilla et al. (2009) reported an inverse association between these two variables in an in vitro study. In addition, Martirosyan et al. (2007) reported an association between consumption of amaranth oil and reduced hypertension levels in adults. Asao and Watanabe (2009) reported high angiotensin I converting enzyme (ACE) inhibition activity in both quinoa and amaranth. Ogawa et al. (2001) reported that quinoa ingestion suppresses systolic blood pressure in rats.

Based on such studies, we surmise that frequent Andean cereal consumers may be less likely than non-consumers to report experiencing hypertension. However, it is important to note that most of the studies to date were conducted in-vitro or on animals, so such relationships may not exist in humans. In addition, the only study that has been done with humans used just one component of amaranth—the oil—rather than the whole, intact grain. Finally, hypertension has many causes and diet alone may not be sufficient to prevent this condition, particularly considering that most of the participants in our sample were largely inactive, overweight or obese, and over age 40 (all of which are among the risk factors for hypertension). Thus, it will be important in future studies to take participants' blood pressure measurements in order to ascertain whether or not a relationship exists between Andean cereal consumption and hypertension.

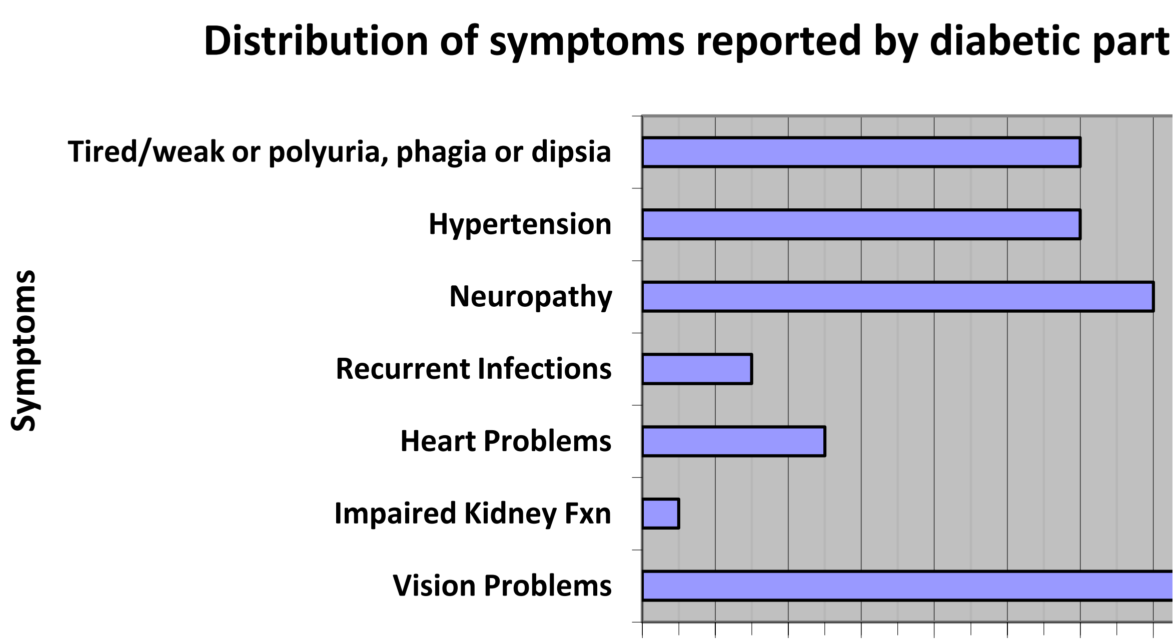
F. Self-described experiences of symptoms that may represent diabetes complications in diagnosed diabetics

Of the 22 participants in our sample who indicated they had been diagnosed with diabetes, 18 (82%) reported experiencing one or more symptoms that may be construed as potential complications from their disease. The greatest number of such symptoms experienced by any participant was 5, which was reported by 5 (23%) individuals (Table 12). Nearly half (9 subjects, 41%) reported experiencing 3 symptoms. The remaining third of the sample (8 subjects, 36%) reported 2 or fewer symptoms. Among the seven symptoms listed in the survey instrument, the one cited most often was vision problems, which was reported by 16 participants (73%), followed by neuropathy, which was reported by 14 participants (64%). As seen in Fig. 5, the symptoms which were reported least often were recurrent infections, heart problems, and impaired kidney function. However, it is important to note that given the observational nature of this case study, it cannot be assumed that any experiences of such symptoms among diabetics imply the existence of disease complications. For example, vision problems may also indicate prevalence of myopia or macular degeneration. Thus, it will be important in future research to include questions in the survey instrument aimed at determining the etiology of such symptoms in diabetics.

Table 12. Number of participants reporting symptoms that may represent complications from diabetes

Number of symptoms reported	Number (%) of participants
0	1 (4.5)
1	3 (13.6)
2	4 (18.2)
3	9 (40.9)
4	0 (0)
5	5 (22.7)
6	0 (0)
7	0 (0)

Figure 5



G. Andean cereal consumption frequency and self-described experiences of symptoms that may represent diabetes complications in diabetic participants

The size of the sub-group of diabetics in our sample (n=22) was too small to make any reliable observations regarding potential relationships between consumption of Andean grains and self-described experiences of symptoms that may represent diabetes complications. It will be important that future studies be conducted with diabetic populations to determine whether such relationships exist, and thus, whether or not diabetics should be advised to increase or moderate consumption of these cereals. It is possible that diabetics may digest, absorb and/or metabolize the nutrients found in quinoa, amaranth and kañiwa differently than non-diabetic individuals, due to altered metabolism accompanying the disease pathology (Franz et al., 2002). Thus, additional research is needed to investigate whether type 2 diabetics digest, absorb and metabolize Andean cereals differently than healthy individuals, and whether frequent consumption of these cereals may either help control or exacerbate symptoms that may represent diabetes complications.

VI. Strengths, limitations and lessons learned

One strength of this study is that although a convenience sample was used, the results seemed parallel to those obtained from the general population of Arequipa in terms of overweight and obesity prevalence as well as lifestyle factors such as physical activity level. Jacoby et al. (2003) reported overweight and obesity prevalence of 64% in Peru's most populous urban areas. Medina et al. (2006) reported overweight and obesity prevalence of 71% among people ages 35-80 living in the city of Arequipa. The study sample also reflects the sedentary lifestyle common in today's urban Peruvian areas, with 70% reporting living a sedentary lifestyle. Medina et al. (2008) found that in Arequipa, prevalence of physical inactivity is 63% in women and 52% in men ages 20-69.

Another strength of the study is that our sample consisted primarily of individuals ages 40 and above. Age is associated with weight gain and is a risk factor for the onset of symptoms of type 2 diabetes mellitus. Barceló and Rajpathak (2001) reported that age ≥ 40 is a non-modifiable risk factor for type 2 diabetes in Peru, and that signs and symptoms of undiagnosed type 2 diabetes are more likely to appear after age 40 in individuals with a chronically unhealthy lifestyle (e.g., poor diet and exercise habits). Also, the Peruvian government's most recent population health survey concluded that middle-aged women and urban residents have the greatest risk of developing non-communicable chronic diseases (CENAN 2006). As such, we chose to include a disproportionate number of subjects meeting these criteria in our sample population and we targeted individuals ages 40 and above when drawing up our convenience sample. Limiting the study sample to middle-age and older adults increased the likelihood of observing potential relationships between consumption of Andean grains and self-described experiences of potential diabetes warning signs and symptoms, given that such symptoms occur more frequently in older age-groups.

Although it was not our intention, smokers were under-represented in the study sample. Only 3% of the participants were self-described smokers. The absence of smokers from our sample group strengthens the study in the sense that it eliminates any potential influence smoking may have on self-described experiences of potential diabetes risk factors, warning signs, and symptoms that may represent complications.

A limitation of our study was that our questionnaire failed to gather several items of data that have potential relationships to BMI and diabetes risk factors, warning signs and complications. For example, the study would have been strengthened by including questions aimed at gathering information on participants' educational level (a proxy for socioeconomic status), socioeconomic status (SES), and alcohol consumption. SES has been associated with overweight and obesity in the literature (Medina et al., 2006), and alcohol consumption has been associated with chronic disease prevalence (Soderberg, 1999). Nevertheless, a comparison between the distribution of normal weight, overweight and obese individuals in our sample to national averages indicates that our sample is reasonably similar to the population. Medina-Lezama et al. (2008) reported that in Arequipa, while almost 60% of men ages 35-49 report drinking alcohol, only 22% of women in that age group are current drinkers. At age 50 and older, the percentage of current drinkers drops to 49% of men and less than 10% of women. Given that our sample was 78% female, it is unlikely that alcohol consumption was a significant factor in our study. However, future studies would benefit from accounting for such factors in the analysis.

For the purpose of this case study, we relied on a convenience sample. Many of the participants were members of either the local hospital's diabetes patient education program, a local retired women's club, or affiliated with the local university. Such membership and affiliations may have influenced the results observed in the study in a number of ways.

The diabetics in our sample may have enjoyed better health (and suffered from fewer diabetes complications) than those who may have been identified in a random sample of diabetics, considering that they were sufficiently health-conscious to have made efforts to attend diabetes control education classes. The inclusion of health-conscious diabetics may have lessened the likelihood of our observing relationships between grain consumption frequency, weight status and symptoms that may represent complications in our diabetes cohort.

The inclusion of participants from the local women's club lead to a sample comprised of 78% females of similar socioeconomic status (upper-middle class). This also may have inadvertently influenced the study results, given that women tend to be less physically active and have higher BMIs than men, particularly after retirement (Medina-Lezama et al., 2008).

The food frequency questionnaire we used was developed specifically for this study due to the absence of a culturally appropriate, validated questionnaire that would provide accurate measures of food intake and other data points in this population. Consultation with Dr. Mary Penney of the Institute of Nutrition Research in the Peruvian

Ministry of Health on December 8, 2011, ascertained that the country lacks a validated food frequency questionnaire that measures intake of Andean cereals (Ministry officials instead rely on 24-hour recalls to estimate cereal consumption in the Peruvian population). Although we followed the guidelines provided in den Hartog and van Staveren's Manual for social surveys on food habits and consumption in developing countries to create a questionnaire suitable for Peru, lack of funding and time constraints made it infeasible to conduct a pre-test or otherwise validate our questionnaire prior to administration.

In addition, the collected survey responses were based on interviews and self-reports, and were not verifiable. This introduces the potential for inaccuracies in the data that may have obscured or overstated the relationships observed between Andean cereal consumption, BMI and self-described experiences of potential diabetes risk factors, warning signs and complications. However, in a review article examining future directions in the development of food frequency questionnaires, Willett (1994) reported that such questionnaires are capable of obtaining correlations in the range of 0.6 to 0.7, compared with multiple diet records, whether they are self-administered or given via interview. Nevertheless, future studies would benefit from making use of the Peruvian government's pre-validated 24-hour recall survey instrument, asking participants to record or photograph daily food intake over a pre-determined period in a food journal, or conducting a pre-test to validate the survey instrument employed to increase the robustness of cereal consumption data.

Research indicates that due to the limited availability of medical services in Peru, many people do not have access to health care providers and services (Huynen et al., 2005). Consequently, many Peruvians do not seek out medical services except in emergency circumstances. The tendency to forego health services may have led to an underreporting of family history of diabetes as well as experiences of potential diabetes risk factors and warning signs, such as hypertension, hypercholesterolemia, hypertriglyceridemia, and birth of a baby weighing more than 4 kg. In reference to the latter, home childbirth is common in Peru, and babies are not routinely weighed at birth. Consequently, many women in the sample indicated uncertainty regarding their children's birth weight. Underreporting in any of those categories may have artificially lowered reports of self-described experiences of potential diabetes risk factors and warning signs among our sample participants.

An additional potential consequence of inadequate availability of medical services is that prevalence of diabetes may have been underreported in our sample. In other words, it is possible that some of our "healthy" participants may have been falsely categorized as such. Since facilities and funds were unavailable for drawing blood samples and conducting biochemical analyses to determine diabetes prevalence, the responses to questions regarding diabetes prevalence as well as experiences of potential diabetes risk factors, warning signs and symptoms that may represent complications were based on self-report, and thus were subjective, unverifiable and vulnerable to recall bias. Future researchers should secure funding and access to laboratory facilities and personnel. Such resources are necessary to obtain participants' blood samples to secure accurate blood lipid and glucose measures, both to improve data accuracy and to ensure the accuracy of disease and health cohorts.

One study suggested that risk functions based on prevalence of diabetes risk factors and warning signs may be almost as accurate as biochemical analysis of blood samples. Schmidt et al. reported that a risk function based on BMI, hypertension, family history, ethnicity and age performed similarly to one based on fasting glucose (AUC 0.71 and 0.74, respectively) in predicting glucose tolerance capabilities, and thus risk for development of type 2 diabetes. (Schmidt et al., 2005) AUC, or area under the receiver operating characteristic curve, is a measure of comparison that is used to select optimal models. It is a graphical plot of sensitivity (the true positive rate) versus [1-specificity] (the false positive rate). However, given the importance of distinguishing the diabetics from the non-diabetics in this study, as well as the high reliability of glucose tolerance tests in diagnosing pre-diabetes and diabetes, we believe that the study would have been strengthened significantly by asking the participants to undergo a glucose tolerance test. In addition, we would very much like to see clinical trials held in the future to measure postprandial blood glucose and insulin responses in both diabetics and non-diabetics after consuming Andean cereals.

Conducting such clinical trials would fill the current gap in the literature regarding these measures, and would provide much-needed evidence regarding the advisability of recommending consumption of these cereals in both diabetics and non-diabetics for the purposes of weight management, as well as for pre-diabetes and diabetes management. Our suggestions in this regard are based on findings reported in the literature, discussed below, of factors that may influence digestion and absorption of nutrients in the Andean cereals in diabetics and non-diabetics alike.

Andean cereals have significant quantities of dietary fiber, protein and fat, which would slow digestion rates when the grains are consumed in their whole, intact forms (Venn and Mann, 2004). As such, we would expect slower digestion rates of the starches in Andean cereals, compared to the starches in rice and wheat flour, which may translate into lower blood glucose and insulin levels after consumption.

However, digestion depends not only on nutrient composition, but also on the form and structure of the food matrix. Thus, the effects of processing are also relevant to determining rates of digestion and absorption. In Peru, Kañiwa, amaranth and quinoa are often processed via grinding, extrusion or popping prior to consumption. Such processing techniques disrupt cell structures and render starches more readily digestible. This would occur because processing produces very small starch particles which are highly bioavailable and thus easily digested.

Venn and Mann (2004) and Chaturvedi et al. (1997) found that the physical composition, form and properties of starches influence their digestion and absorption speed. Compared to the starch in most other cereals, the starch granules in quinoa, amaranth and kañiwa are smaller (<1 - 2.5 micrometers in diameter), lower in amylose, and higher in amylopectin. In addition, the starch in Andean grains is characterized by having a low gelatinization temperature, a low viscosity value (which increases absorption), and a lack of resistant starch.

Amylose is a linear glucose polymer that has a high gelatinization temperature (gelatinization speeds digestion). Amylose retrogrades faster than amylopectin after cooling, and forms an amylase-resistant crystal structure (resistant starch) that slows digestion. In contrast, amylopectin is a highly branched glucose polymer that is quickly gelatinized during cooking and rapidly digested.

Gelatinization refers to the process that takes place when starch molecules are mixed with water and heated, causing the starch molecules to swell and then dissolve irreversibly into a gel. Gelatinization temperature is inversely correlated with glycemic response. Viscosity value refers to the ability of the starch to form a paste when mixed with water. Starches with low viscosity values absorb more water and form pastes more readily than those with high viscosity values. Resistant starch is starch that has formed a crystalline structure that resists digestion in humans and passes through to the large intestine, where it acts like dietary fiber. Although resistant starch occurs naturally in some foods (seeds, legumes, raw potatoes), it can also be formed through retrogradation, a process that occurs when starch—particularly high-amylose starch—is cooked and later cooled. A complex association exists between starch size, degree of branching, digestion and absorption, with smaller starch particles (such as those present in Andean cereals) producing a more rapid glycemic response than larger ones (Venn and Mann, 2004). The combination of these factors would be expected to favor the rapid absorption of the starch in Andean cereals and a high glycemic response, though the presence of significant quantities of dietary fiber, protein and fat may mediate such a response.

In their meta-analysis of the literature, Schultze and Hu (2005) reported that in both healthy individuals and diabetics, glucose metabolism depends on both the presence of dietary fiber and the physical structure of grain. In addition, an in vitro study by Heaton et al. (1988) showed a progressive increase in insulin response as the amount of processing of whole grains was increased (i.e., insulin response to fine flours > coarse flours > cracked grains > whole grains). Similarly, Venn and Mann (2004) reported that while intact whole grains improved insulin sensitivity and glycemic response and control (possibly due to entrapment of starch in fibrous thick-celled walls), foods made from whole grain flours or popped whole grains did not have this effect, even when high levels of dietary fiber were present in the food matrix. Chaturvedi et al. (1997) reported a rapid rise in blood glucose levels in women who consumed popped amaranth, which further supports the notion that the structure of grains may be a more important determinant of glycemic response than the fiber content of the grain. Even though popped amaranth is a whole grain product and is high in fiber, the popping process disrupts the seed structure and makes the starch readily available to digestive enzymes, leading to an elevated level of blood glucose. High postprandial insulin and blood glucose responses have been tied to lower satiety and subsequent increased energy intake in the literature (Flint et al., 2007).

Although the participants in our study generally consumed whole grain Andean cereals, food processing applications that altered the physical structure of these cereals may help explain the lack of relationships observed with self-described experiences of diabetes risk factors and warning signs. In future observational studies, in addition to consumption frequency, it will be important to obtain detailed information regarding portion sizes and forms of Andean grains consumed. Similarly, clinical trials would be of benefit in clarifying the relative influence of structure/form and nutrient composition upon rates of digestion of Andean cereals in diabetics and non-diabetics.

Another reason that we believe it is important to determine postprandial blood glucose levels after consumption of Andean cereals is that the literature suggests that these cereals may have the potential to inhibit the activity of digestive enzymes. Galvez Ranilla et al. (2009) reported that quinoa shows potential for in vitro alpha-glucosidase inhibition, meaning that people who consume it may experience delayed uptake of glucose and oligosaccharides along the intestinal brush border. Conforti et al. (2005) reported in vitro alpha-amylase inhibitory activity of 51% and 28% in raw whole amaranth flour made from two seed varieties. In addition, carbohydrate utilization inhibitors have been found to slow the digestion of complex carbohydrates and the uptake of glucose in vivo (Godbout et al., 2007). Obtaining blood samples from diabetics and non-diabetics post-consumption would help to clarify whether such inhibition may occur in vivo after consumption of Andean cereals.

Berti et al. (2004) demonstrated a low glycemic response after consumption of quinoa (similar to that of pasta, which is considered a low glycemic food) in humans. They also reported that insulin responses were significantly lower in consumers of quinoa. In a different study, Berti et al. (2005) reported that consuming quinoa assists in controlling appetite, reducing energy intake and increasing sensations of satiety. A meta-analysis of test meal studies reported an association between postprandial insulin response, decreased hunger, increased satiety and lower subsequent energy intake (Flint et al., 2007). The implication inherent in these findings is that slower digestion and lower postprandial insulin response and circulating blood sugar levels may occur after consumption of Andean cereals, compared with white flour-based foods. Again, a clinical trial would help to confirm this relationship with quinoa consumers, as well as determine whether similar relationships exist with regard to amaranth and kañiwa.

Finally, the food frequency section of the questionnaire asked participants to estimate their consumption frequency of Andean cereals, other cereals, tubers and other foods of interest during the past year, but it was not possible to verify whether such estimates were accurate measures of actual consumption. In addition, since participants were asked about their consumption of each food over the course of one year, ascertaining detailed information such as exact portion sizes, food structure and degree of processing was not feasible. The use of open-ended questions regarding average daily consumption of bread rolls and high-starch meals (defined in the survey as meals at which ≥1.5 cups of starch-rich foods were consumed in one sitting), as well as typical foods consumed for breakfast, lunch, dinner and snacks, were included in our questionnaire for the purpose of double-checking the precision of participants' responses to food frequency questions and thus, improving their accuracy. However, we recommend that future studies also use one or more 24-hour dietary intake recalls to further improve data accuracy. In addition, accuracy may be improved in future studies via other verification methods, such as asking participants to photograph plates of food prior to consumption. Although Willett reported that gathering detailed information on portion size typically provides only modest gains in food frequency questionnaire validity, (Willett, 1994) it is possible that the absence of information about the quantity or degree of processing of the food products typically consumed may have hindered our ability to observe relationships. Thus, including questions regarding typical portion sizes and food structures should be considered for future studies.

If we were to repeat the study, there are several changes we would implement arising from our previous experience in Peru. First, we would use traditional recruitment methods to obtain participants, such as posting flyers or advertising via radio. We would also calculate the sample size required to ensure sufficient power for the study, and aim to obtain a sample size of 125% of that number in order to allow for dropouts and experimental error.

Second, we would aim to reduce the potential for confounding by controlling for factors that cannot be mediated by diet, such as use of medications for weight control, cardiovascular function, diabetes, hypertension, or hyperlipidemia; smoking; alcohol consumption; physical activity; and family history of diabetes. We would develop a screening survey for this purpose, separate from the food intake survey. Only participants that met the inclusion criteria that we'd set out in advance (i.e. non-smokers, moderate drinkers, aged 40 and older who do not use diabetes, weight control, blood pressure or blood lipid control medications, with no family history of diabetes) would be included in the study sample.

Third, we would seek funding prior to conducting the survey and enlist the support of a university, hospital, health center or laboratory in order to weigh and measure waist circumference, and take blood samples and obtain clinical measures of blood lipids, blood pressure and blood glucose. Trained health workers or students of medicine would take and record these measures on participants' charts. We would use clinical blood measures in order to obtain more reliable groups of diabetics and non-diabetics. In addition, we would compensate participants with a two-part stipend for their participation, due to the invasiveness of these clinical procedures. Participants would receive the first payment after submitting to these measurements, and the second payment after completing the food intake survey.

Fourth, we would eliminate survey questions that do not contribute to the study, including questions regarding occupation type and residence. Instead, we would include a question regarding level of education as a proxy for socioeconomic status. We would also simplify the question regarding weight change, asking participants to simply estimate weight change over the past year as well as whether the weight change was deliberate or unplanned. We would simplify the family history section to ask only about history of diabetes.

Fifth, we would pre-test and ideally validate our food frequency questionnaire prior to commencing our study. Participants would be provided with detailed instructions and food models to help them estimate the size of the portions they typically consume. They would also be required to record their physical activity during the same time period. To verify the data collected in the food frequency questionnaire, we would also create a separate food intake and activity survey (or ideally, use the validated survey developed by the Peruvian Ministry of Health, if adequate for our purposes) that would consist of three 24-hour recalls, to be completed on three consecutive days, comprising one weekend day and two weekdays. Participants would be instructed to record their entire food and drink intake on those days, including portion sizes and recipes, if possible. Finally, they would be asked if their intake and activity deviated from the norm in any way on those days, and if so, in what way. This combined survey instrument would replace the food frequency questionnaire used in the current study.

We believe that repeating the study implementing the changes outlined above would likely uncover additional relationships between Andean cereal consumption, weight status and diabetes that were obscured due to the limitations inherent in this case study.

VII. Conclusions

This case study investigation described the usual dietary intake of native Andean grains, as well as other foods that are major sources of carbohydrates, among a sample of people living in Arequipa, Peru. The purpose of the study was to describe observations regarding the consumption of grains and other carbohydrate sources, weight status as assessed by BMI, and participants' self-described experiences or perceptions of certain potential diabetes risk factors, warning signs and symptoms that may represent complications.

We found that most of the participants in our sample reported consuming Western cereals such as rice and white flour more frequently than traditional Andean cereals, which is reflective of recent general cereal consumption trends in urban areas of Peru. This was true regardless of BMI category or diabetic status. Overall, a respective 99% and 89% of participants consumed white rice and flour at least on a weekly basis, compared with a respective 57%, 43% and 26% who consumed quinoa, amaranth and kañiwa at least once per week.

In addition, we observed a relationship between Andean cereal consumption frequency and weight status. Normal BMI participants were more likely to report individual frequent weekly consumption of quinoa (67.6%), amaranth (48.6%) and kañiwa (40.5%), compared to overweight and obese subjects, who reported respective weekly consumption of 50.8%, 39.7% and 17.5%. Normal BMI participants also were more likely to report weekly consumption of more than one Andean cereal. Conversely, normal BMI subjects were less likely to report frequent consumption of white flour, cassava, pasta or chuño, compared to overweight and obese subjects. Diabetics in our sample reported more frequent consumption of Andean cereals—particularly amaranth—and tubers such as cassava and chuño, compared to non-diabetics. They were also less likely to report consuming white flour-based foods compared to their non-diabetic counterparts.

Among non-diabetics, approximately 30% were potentially at high risk for developing diabetes, based on the number of potential risk factors or warning signs they reported experiencing. We observed that a lower BMI seemed to be related to a lower risk of diabetes: while 38% of overweight and obese non-diabetics were potentially at high risk for diabetes, only 13% of normal BMI non-diabetics were potentially at high risk. Other than BMI, we did not observe any trends in non-diabetics regarding Andean grain consumption and self-described experiences of potential diabetes risk factors and warning signs, or symptoms that may represent diabetes complications in diabetics.

VIII. Future Research

Very little research exists describing observations regarding Andean cereal consumption, weight status and diabetes. Given the small size and non-random nature of our sample, the lack of access to objective data such as that which may be obtained from medical records or laboratory tests, and the self-reported nature of our data, there is much need for additional research to verify and expand upon our results. In this section, we offer suggestions for future research in this regard:

1. Conducting similar research with a larger sample and include a larger percentage of diabetics in the sample. Also, using random sampling techniques to recruit participants for the study, possibly from hospital records, doctors' records or other reliable sources. This would result in a more heterogeneous sample and increase the statistical power of the results. It would also allow for the determination of associations between reports of potential diabetes complications and cereal and starch consumption frequency, after verifying the presence of such complications with a physician.
2. Providing pictures or food models to participants to help them estimate their portion sizes when administering the food frequency questionnaire section of the survey would help improve data accuracy. Alternatively, asking participants to keep written or photographic food records would also improve data accuracy for a future observational study.

3. Laboratory measurements of participants' blood cholesterol and triglyceride levels, and response to glucose loads, would provide a more accurate assessment of certain diabetes risk factors, warning signs and complications. Additionally, clinical assessment methods should be used to obtain more accurate measures of weight, height, waist circumference and blood pressure. Use of such methods would improve the accuracy of the data beyond what is possible by relying on self-reports.
4. Future research should make use of a validated food frequency questionnaire and include pilot testing and cognitive testing of the questionnaire among the target population prior to administering the instrument to the study participants. This should increase the reliability and validity of the responses.
5. Future research should be conducted to identify associations between overweight or obesity, potential diabetes warning signs, and frequency of grain consumption, after taking into account the structure of the cereal (ground meal or flour, popped cereal, extruded food products, or intact whole grain) that is consumed by study participants as well as the amount (i.e., portion size) consumed at each meal. This could be accomplished through the use of a more detailed questionnaire, although the ideal situation would be to provide participants with food prepared specifically for a study in this regard, and record the amount consumed at each meal. This would provide insights regarding differences in glycemic and insulinemic responses that occur when Andean grains are consumed in specific forms, with varying structures; it would also allow for the determination of the degree of influence upon such responses that can be attributed to factors such as

cooking method, temperature, and use of other ingredients that may influence such responses and confound results.

6. Given the findings by previous researchers (Bottazzi Alvarez, 2003; Asao and Watanabe, 2009; Ogawa et al., 2001) further studies should be conducted in hyperlipidemic Peruvians using laboratory facilities to obtain accurate measures of blood lipid levels, to verify whether frequent consumption of quinoa, amaranth and kañiwa may be inversely associated with hyperlipidemia.
7. Future research is required to determine whether type 2 diabetics digest, absorb and metabolize Andean cereals differently than healthy individuals, and whether frequent consumption of these cereals may trigger abnormal metabolic processes in individuals with type 2 diabetics that cause them to develop heart conditions.
8. There is a need for more robust observational studies to ascertain associations between Andean cereal consumption, weight status and diabetes, as well as prospective studies which can provide information about these associations over time.
9. The large percentage (66%) of diabetics in our sample who report experiencing symptoms that may represent complications suggests that diagnosed diabetics may not be taking appropriate steps to monitor and control their disease. Many participants reported that they do not follow a modified diet, get regular exercise, or receive ongoing nutrition support or education. As such, research that can be used to inform the creation of diabetes care interventions in Peru is warranted.
10. Almost all the participants in our sample—diabetics and non-diabetics alike—reported eating a very high-carbohydrate diet and leading a sedentary lifestyle.

The combination of these two factors almost certainly contributes to the high prevalence of overweight and obesity in Peru. It may also help explain why approximately 64% of the sample is considered to be at medium or high risk for developing diabetes (according to the previously defined criteria of perceiving 3 or more risk factors or warning signs).

11. Peru would benefit from research aimed at identifying the specific contributions of physical activity and diet in weight control and chronic disease risk reduction, and at encouraging moderation in caloric intake among Peruvians.
12. The observations reported in this study regarding average BMI and diabetes risk suggest that there is a great need in Peru to develop and disseminate public health campaigns that encourage regular physical activity and consumption of a varied diet that emphasizes intact whole grains rather than refined wheat flour-based foods.

XI. Appendix

English Translation
Questionnaire for Nutrition Masters Thesis
Studying the Effect of Consumption of Quinoa, Cañihua and Kiwicha on Type 2 Diabetes Mellitus Incidence
Katherine Sanchez
University of Maryland, College Park

Code: _____________ Today´s date: _____________________________

(Assigned by the interviewer, consisting of 3 digits and the initials of the interviewer: i.e. KS001, KS002, KS003, etc.).

General personal information

1) Date of birth: ____

2) Gender (circle one): ↑ Male ↑ Female

3) Height: ________ m

4) Weight: __________ kg

5) Waist circumference: __________cm

6) Occupation type:
↑ Homemaker ↑ Sedentary work (mostly seated) ↑ Active work (most of day standing/walking) ↑ Heavy labor (lifting, carrying, etc.)
↑ Other (specify) ______________________

7) History of smoking:
↑ Regular daily smoker ↑ Casual smoker (several times per week) ↑ Occasional smoker (once per week or less) ↑ Non-smoker

8) Average weekly physical activity (not work-related): Check here if you do **NOT** exercise regularly ______. Otherwise, please fill in the table below.

Intensity of activity	**Days per week**	**Minutes per day**
None		
Light (i.e. walking)		
Moderate (i.e. jogging, volleyball, weight-lifting)		
Vigorous (i.e. playing soccer, racing, circuit training)		

9) Name of town/community where you live: _______________________________

10) How long have you lived in (town/community)?
   ↑ 0-5 years   ↑ 6-10 years   ↑ 11-20 years   ↑ > 20 years

   a. If less than 20 years, where did you live before and for how long?
   ____

11) Compared to one year ago, would you say your weight has gone up, stayed about the same, or gone down? (Repeat question for 5 years ago, 10 years ago, 20 years ago. If subjects say their weight has gone up or down for any of these time periods, ask by about how much).

# Years Ago	**Weighed more (check if yes)**	**Weighed same (check if yes)**	**Weighed less (check if yes)**	**Amount of difference from current wt (+/- kg)**
1 year ago				
5 years ago				
10 years ago				
20 years ago				

Family History

12) As far as you know, have any of your immediate relatives, including parents, grandparents, brothers, sisters or children, ever been diagnosed by a health professional with any of these conditions:

Condition	Yes	No	Not sure
Type 1 diabetes			
Type 2 diabetes			
Gestational diabetes			
High blood pressure			
Coronary heart disease			
Abnormal cholesterol level			
Obesity			

Personal Medical History

13) Have you ever been told by a doctor or health professional that you have diabetes?
   ↑ Yes   ↑ No (**if no, please proceed to question 19)**

If yes, check the type of diabetes you were diagnosed with, when you were diagnosed, and indicate the current treatment you are receiving (i.e. dietary modification, exercise, insulin, other drugs or medicines)

	✓	When diagnosed? (year)	Describe current treatment
Type I diabetes			
Type II diabetes			
Gestational diabetes			

14) How often do you follow your prescribed treatments for diabetes? Would you say you do it every day, most days, sometimes, hardly ever, or never?

	Every day	Most days	Some-times	Hardly ever	Never
Eat a proper diet					
Get exercise					
Take insulin					
Take other medicines besides insulin					
Follow other treatments (describe_____________________________ ___________________________)					

15) Do you currently see a nutritionist or dietitian (or someone who specializes in dietary advice?)
   ⭡ Yes ⭡ No

   If Yes, how about often do you see this person?
   ⭡ Only once ⭡ Once a year or less ⭡ 2-4 times per year
   ⭡ More than 4 times per year

16) Since your diabetes diagnosis, have you changed your diet according to one or more of the following treatments in order to control your disease? Please indicate with a ¨✓¨ the

frequency with which you adhere to the following dietary treatments: Every day, most days, some days, once in a while, or never?

	Every day	Most days	Some-times	Once in a while	Never
Count carbohydrates					
Limit/modify starch intake					
Limit/modify fat intake					
Eat fiber					
Eat whole grains					
Limit sweets/sugars					
Limit salt					
Limit calories					
Limit cholesterol					
Eat recommended protein/animal products					
Limit alcohol					
Eat or refrain from eating specific foods (describe)__________________________ ______________________________					
Other (describe)___________________					

17) Do you think your dietary treatments have been effective in controlling your diabetes?
↑ No ↑ A little effective ↑ Somewhat effective ↑ Very effective

18) Have you suffered any complications from your diabetes?
↑ Yes ↑ No ↑ Not sure

If Yes, check the conditions below:

Condition	✓
Vision problems	
Impaired kidney function	
Heart problems	
Recurrent infections/wounds	
Numbness/pain in limbs	
High blood pressure	

(Diabetic respondents may proceed to question 23)

19) (For women only) Did any of your children weigh more than 4 kg at birth?
↑ Yes ↑ No

20) Have you suffered from recurrent infections in the past few years (i.e. respiratory, vaginal/yeast, urinary tract, etc.)?

↑ Yes ↑ No

21) Do you often feel an excessive or frequent need to:

↑ drink water
↑ eat
↑ urinate?

22) Do you suffer from any of the following?

↑ frequent headaches (mild to severe)
↑ episodes of blurred vision
↑ high blood pressure
↑ high cholesterol
↑ high triglycerides

Diet history questions

23) What do you typically eat for breakfast most days?

____
____

24) How many rolls do you usually eat with your coffee/tea at breakfast?

____

25) What do you typically eat for lunch?

____
____
____

26) What do you typically eat for dinner?

____
____
____

27) How many rolls do you usually eat with your coffee/tea at dinner?

____

28) How often do you eat more than three portions (> 1.5 c— show measuring cup or picture) of starchy foods (i.e. potatoes, rice, chuño, yuca, pasta, bread, instant oatmeal) together at the same meal per day? ________

29) What foods do you eat as snacks between meals?

____

30) In general, over the past 10 years, would you say your usual diet has:

↑ Stayed about the same
↑ Changed a little
↑ Changed a lot (describe ____
____)

Food frequency questions

1) This section asks about some of the foods you ate in the past year. Listen carefully as I read the list, and tell me how often you ate the food. Persons diagnosed with diabetes should answer according to how they ate **PRIOR** to their diagnosis.

Food	Never or <1/mo	About 1/mo	2-3/mo	1/wk	Several times/ wk	1/day	2+ times/day
Do you eat quinoa? Please indicate how you consume it below.							
Main dish or quinoa salad							
Soup or stew with quinoa							
Juice/drink or dessert with quinoa							
Oatmeal, granola or cold cereal with quinoa or quinoa pop							
Bread or baked good with quinoa flour (cookies, crackers, cake, etc.)							
other food with quinoa (specify)							
Do you eat amaranth? Please indicate how you consume it below.							
Main dish or amaranth salad							
Soup or stew with amaranth							
Juice/drink or dessert with amaranth							
Oatmeal, granola or cold cereal with amaranth or amaranth pop or Kiwigen							
Bread or baked good with amaranth flour (cookies, crackers, cake, etc.)							
other food with amaranth (specify)							
Do you eat cañihua?							

Please indicate how you consume it below.							
Main dish or cañihua salad							
Soup or stew with cañihua							
Juice/drink or dessert with cañihua							
Oatmeal, granola or cold cereal with cañihua or cañihua pop							
Bread or baked good with cañihua flour (cookies, crackers, cake, etc.) or cañihuaco							
other food with cañihua (specify)							
Do you eat tarwi? Please indicate how you consume it below.							
Main dish or tarwi salad							
Soup or stew with tarwi							
Juice/drink or dessert with tarwi							
Bread or baked good with tarwi flour (cookies, crackers, cake, etc.)							
other food with tarwi (specify)							
Do you eat rice? Please indicate how you consume it below.							
Main dish with white rice							
Soup or stew with white rice							
Juice/drink or dessert with white rice							
Oatmeal, granola or cold or hot cereal with white rice							
Bread or baked good with rice flour (cookies, crackers, cake, etc.)							
other food with white rice (specify)							
Brown rice or main dish with brown rice							
Do you eat white potatoes? Please indicate how you consume them							

below.							
Main dish with white potatoes							
Side dish of fried, boiled or baked potatoes							
Soup or stew with white potatoes							
Bread or baked good with potato flour (cookies, crackers, cake, etc.)							
Potato chips or snack food made from potatoes							
Do you eat freeze-dried potatoes (chuño)? Please indicate how you consume them below.							
Main dish with freeze-dried potatoes							
Soup or stew with freeze-dried potatoes							
Bread or baked good with freeze-dried potato flour (cookies, crackers, cake, etc.)							
Chips or snack food made from freeze-dried potatoes							
Do you eat yucca? Please indicate how you consume it below.							
Main dish with yucca							
Soup or stew with yucca							
Bread or baked good with yucca flour (cookies, crackers, cake, etc.)							
Chips or snack food made from yucca							
Do you eat bread or foods made from wheat flour? Please indicate how you consume them below.							
Bread made with refined White flour							
Bread made with 100% whole wheat flour							
Dessert or pudding made with refined white flour							
Baked goods made with							

refined white flour (cookies, crackers, cake, etc.)							
Main dish of white pasta							
Main dish of whole wheat pasta							
Soup or stew with white pasta							
Soup or stew with whole wheat pasta							

Thank you very much for your time and honest responses. The information that you have provided for this study is very important in the effort to prevent diabetes in Peru and improve the lives of those who already have it. We very much appreciate your willingness to share your personal information with us for the purpose of this study.

Name of interviewer ____.

X. References

Adom KK, Sorrells ME, and Liu RH. (2005). “Phytochemicals and antioxidant activity of milled fractions of different wheat varieties.” J Agric Food Chem. 53: 2297-306.

Agri-food Trade Service. (2010). The Peruvian consumer: behaviour, attitudes and perceptions toward food products. International Markets Bureau. Market Analysis Report. Government of Canada. Retrieved on August 18, 2011, from http://www.ats-sea.agr.gc.ca/lat/5516-eng.pdf

Ahamed N,Thoufeek S, Rekha S, Kulkarni PR, and Pal, M. (1998). “A lesser-known grain, Chenopodium quinoa: Review of the chemical composition of its edible parts.” Food and Nutrition Bulletin. United Nations University. 19(1).

Alberti KG, Zimmet P, and Shaw J. (2005). “The metabolic syndrome – a new worldwide definition.” IDF epidemiology: task force consensus group. Lancet 366:1059-62.

American Diabetes Association. (2008). “Nutrition recommendations and interventions for diabetes.” Diabetes Care. 31(Supp.1):S61-S78.

American Heart Association. (2010). “Frequently asked questions about fats.” Website accessed on February 13, 2012 at http://www.heart.org/HEARTORG/GettingHealthy/NutritionCenter/HealthyDietGoals/Frequently-Asked-Questions-About-Fats_UCM_306069_Article.jsp#.Tzlptlymjgc.

Ando H, Chen Y, Tang H, Shimizu M, Watanabe, K, and Mitsunaga, T. (2002). “Food Components in Fractions of Quinoa Seeds.” Food Sci Technol Res. 8(1): 80-4.

Arts ICW and Hollman PCH. (2005). “Polyphenols and disease risk in epidemiologic studies.” Am J Clin Nutr. 81(Supp 1): 317S-325S.

Asao M and Watanabe K. (2009). “Functional and bioactive properties of quinoa and amaranth.” Food Sci. Technol. Res. 16(2): 163 – 168.

Ayala Macedo, G. (2003). “Consumption of quinoa in Peru.” Food Rev Intl. 19(1&2):221-227.

Baiocchi, N. and Marin C. (2000). Perfil nutricional del Perú. United Nations Food and Agriculture Organization. Rome, Italy.

Baldwin PM. (2001).“Starch granule-associated proteins and polypeptides: A review.” Starch. 53: 475-503.

Bao JS, Cai YZ, and Corke H. (2001). “Prediction of rice starch quality parameters by near infrared reflectance spectroscopy.” J Food Sci. 66: 936-9.

Barceló A and Rajpathak S. (2001). “Incidence and prevalence of diabetes mellitus in the Americas.” Rev Panam Salud Pública. 10(5): 300-8.

Barracco R, Mohanna S and Seclén S. (2007). “A comparison of the prevalence of metabolic syndrome and its components in high and low altitude populations in Peru.” Metabolic Syndrome and Related Disorders. 5: 55-62.

Bastien, JW; (1998). “Andean nutrition, exchange and ritual.” Regligiologiques, nourriture et sacré. 17: 123-37.

Becker R, and Hanners GD. (1990). “Compositional and nutritional evaluation of quinoa whole grain flour and mill fractions.” Lebensm Wiss Technol. 23: 441-4.

Becker R, Wheeler EL, Lorenz K, Stafford AE, Grosjean OK, Betschart AA, and Saunders RM. (1981). “A Compositional Study of Amaranth Grain.” Journal of Food Science. 46: 1175-1180.

Berganza B, Alvaro L, Moran W, Rodriguez G, Coto N, Santamaria M, et al. (2003). “Effect of variety and location on the total body fat, fatty acids and squalene content of amaranth.” Plant Foods Hum Nutr. 58: 1-6.

Berger A, Gremaud G, Baumgartner M, Rein D, Monnard I, Kratky E, Geiger W, Burri J, Dionisi F, Allan M, and Lambelet P. (2003). “Cholesterol-lowering properties of amaranth grain and oil in hamsters.” Int J Vitam Nutr Res. 73 (1): 39-47.

Bermudez OI and Tucker KL. (2003). “Trends in dietary patterns of Latin American populations.” Cad. Saude Publica. 19(supp. 1):S87-S99.

Berti C, Riso P, Brusamolino A, and Porrini M. (2005). “Effect on Appetite Control of Minor Cereal and Pseudocereal Products.” British Journal of Nutrition. 94: 850-8.

Berti C, Ballabio C, Restani P, Porrini M, Bonomi F, and Iametti S. (2004) “Immunochemical and molecular properties of proteins in Chenopodium quinoa.” Cereal Chem. 81: 275-7.

Berti C, Riso P, Monti LD and Porrini M. (2004). “In vitro starch digestibility and in vivo glucose response of gluten-free foods and their gluten counterparts.” Eur J Nutr. 43: 198-204.

Berti, C. et.al. (2002) International Workshop on Food Supplementation in Food Allergy and Immunity. Olsztyn.

Bhathena SJ and Velasquez MT. (2002). “Beneficial role of dietary phytoestrogen in obesity and diabetes.” Am J Clin Nutr. 76: 1191-1201.

Bottazzi Alvarez R. (2003). “Influencia de la ingestion de la cañihua (chenopodium pallidicaule aellen) sobre el perfil lipídico y riesgo cardiovascular en pacientes hipercolesterolémicos primarios 1994 - 2001 Hospital Regional Honorio Delgado Arequipa.” Rev peru cardiol. 29(1): 31-70

Breene WM, (1991). “Food Uses of Amaranth Grain.” Cereal Foods World. 36(5): 426-430

Bressani R, De Martell ECM, De Godínez CM. (1993). “Protein Quality Evaluation of Amaranth in Adult Humans.” Plant Foods for Human Nutrition. 43: 123-143.

Cárdenas H, Bello C, Feijoo M and Huallpa E. (2004). “Evaluación nutricional de un grupo de adultos mayores residentes en Perú.” Rev Cubana de Salud Pública. 30(3).

Cardoso AP, Mirione E, Ernesto M, Massaza F, Cliff J, Haque MR, Bradbury JH. (2005). “Processing of cassava roots to remove cyanogens.” J Food Comp Anal. 18(5): 451-60.

Carey VJ, Walters EE, Colditz GA, Solomon CG, Willett WC, et al. (1997). Body fat distribution and risk of non-insulin-dependent diabetes mellitus in women. The Nurses’ Health Study.” Am J Epidemiol. 145:614-19.

Centro Nacional de Alimentación y Nutrición (CENAN). (2009). Perfil nutricional y pobreza en Perú: Encuesta nacional de hogares (ENAHO) 1 trimestre 2008. Instituto Nacional de Salud, Ministerio de Salud. Lima, Peru.

Centro Nacional de Alimentación y Nutrición (CENAN). (2006). Encuesta nacional de indicadores nutricionales, bioquímicos socioeconómicos y culturales relacionados con las enfermedades crónicas degenerativas. Instituto Nacional de Salud, Ministerio de Salud. Lima, Peru.

Chaturvedi A, Sarojini G, Nirmala G, Nirmalamma N, and Satyaranayana D. (1997). “Glycemic response of grain amaranth, wheat and rice in NIDDM subjects.” Plant Foods Hum Nutr. 50(2): 171-8.

Chauhan GS, Eskin NAM, and Tkachuk R. (1992). "Nutrients and antinutrients in quinoa seed." Cereal Chem. 69: 85-8.

Colditz GA, Willett WC, Rotnitzky A, Manson JE. (1995). "Weight gain as a risk factor for clinical diabetes mellitus in women." Ann Intern Med. 122:481-6.

Conforti F, Statti G, Loizzo MR, Sacchetti G, Poli F and Menichini F. (2005). "In vitro antioxidant effect and inhibition of alpha-amylasse of two varieties of Amaranthus caudatus seeds." Biol Pharm Bull. 28: 1098-1102..

Cortez R, Jacoby E and Alarcón G., (2002). "Determinantes de la obesidad y el sobrepeso en el Perú." Salúd, equidad y pobreza en el Perú: teoría y nuevas evidencias. Lima: Peru. 339-75.

Coulter L, and Lorenz K. (1990). "Quinoa- composition, nutritional value, food applications." Lebensm Wiss Techn. 23: 203-7.

Craig CI, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE, et al. (2003). "International physical activity questionnaire (IPAQ): 12-country reliability and validity." Med Sci Sport Exerc. 35(8):1381-95.

den Hartog AP, van Staveren WA, and Wageningen P. (1983). Manual for social surveys on food habits and consumption in developing countries. Center for Agricultural Publishing and Documentation. Wageningen, Netherlands.

Esmaillzadeh A, Mirmiran P, Azizi F. (2005). "Whole-grain consumption and the metabolic syndrome: A favorable association in Tehranian adults." Eur J Clin Nutr. 59:353-62.

Ettinger S. (2000) Krause's Food, Nutrition and Diet Therapy. 10th ed. Philadephia, PA. pp. 54-61.

Euromonitor International. (2009). Consumer Lifestyles: Peru.

Fairbanks DJ, Burgener KW, Robison LR, Andersen WR, and Ballon E. (1990). "Electrophoretic characterization of quinoa seed proteins." Plant Breeding 104: 190-5.

Fardot A, Rock E, and Remesy C. (2008). "Is the in vitro antioxidant potential of whole-grain cereals and cereal products well reflected in vivo?" J Cer Sci. 48(2): 258-76.

Flint A, Gregersen NT, Gluud LL, Moller BK, Raben A, Tetens I, Verdich C, and Astrup A. (2007). "Associations between postprandial insulin and blood glucose responses, appetite sensations and energy intake in normal weight and overweight individuals: a meta-analysis of test meal studies." British J Nutr. 98:17-25.

Food and Agriculture Organization of the United Nations. (2001). FAO's statistical databases. Country food balance sheets, 1964-1996. Retrieved on August 16, 2011, from http://apps.fao.org/page/collections?subset=agriculture)

Food and Agriculture Organization of the United Nations. (1989). Utilization of Tropical Foods: Cereals, Food and Nutrition Paper 47/1. pp. 1-114.

Food by Country. (2009). Food in Peru. Retrieved on August 10, 2011 from http://www.foodbycountry.com

Ford ES and Mokdad AH. (2001). "Fruit and vegetable consumption and diabetes mellitus incidence among US adults." Prev Med. 32: 33-39.

Franz MJ, Bantle JP, Beebe CA, Brunzell JD, Chiasoon JL, Garg A, Holzmeister LA, Hoogwerf B, Mayer-Davis E, Mooradian AD, Purnell JQ, and Wheeler M. (2002).

“Evidence-based nutrition principles and recommendations for the treatment and prevention of diabetes and related complications.” Diabetes Care. 25:148-98.

Gaesser, GA. (2007). “Carbohydrate quantity and quality in relation to body mass index.” J Am Diet Assoc. 107(10): 1768-80.

Galvez Ranilla L, Apostolidis E, Genovese MI, Lajolo FM, and Shetty K. (2009). “Evaluation of indigenous grains from the Peruvian Andean region for antidiabetes and antihypertension potential using in vitro methods.” J Med Food. 12(4): 704-13.

Galwey NW. (1993). “The potential of quinoa as a multi-purpose crop for agricultural diversification: a review.” Ind Crops Prod. 1: 101-6.

Gannon MC, Nuttall JA, Dumberg G, Gupta V, and Nuttall FQ. (2001). “Effect of protein ingestion on the glucose appearance rate in people with type 2 diabetes.” J Clin Endocrinol Metab.86:1040-47.

Gee JM, Price KR, Ridout CL, Johnson IT, and Fenwick GR. (1989). “Effect of some purified saponins on the transmural potential difference in the mammalian small intestine.” Tox In-Vitro 3: 85-90.

Glorio P, Repo-Carrasco R, Velezmoro C, Anticona S, Huaranga R, Martinez P, Melgarejo S, et al. (2008). “Dietary fiber in fruits, roots, tubers, cereals and pulses from Peruvian cultivars.” Rev Soc Quím Perú. 74(1): 46-56.

Godbout A and Chiason JL. (2007). “Who should benefit from the use of alpha-glucosidase inhibitors?” Curr Diabetes Rep. 7: 333-9.

Goldstein J, Jacoby E, Del Aguila R and Lopez A. (2005). “Poverty is a predictor of non-communicable disease among adults in Peruvian cities.” Preventive Medicine. 41(3-4): 800-806.

González JA, Roldán A, Gallardo M, Escudero T, and Prado FE. (1989). "Quantitative determination of chemical compounds with nutritional value from Inca crops: Chenopodium quinoa ('quinoa')." Plant Foods Hum Nutr. 39: 331-7.

Grant LA, Vignaux N, Doehlert DC, McMullen MS, Elias EM, and Kianian S. (2001). "Starch characteristics of waxy and nonwaxy tetraploid (Triticum turgidum L. var. durum) wheat." Cereal Chem. 78: 590-5.

Gross R, Koch F, Malaga I, de Miranda A, Schoneberger H, and Trugo L. (1989). "Chemical composition and protein quality of some local Andean food sources." Food Chem. 34: 25-34.

Gross LS, Li L, Ford ES, and Liu S. (2004). "Increased consumption of refined carbohydrates and the epidemic of type 2 diabetes in the United States: an ecologic assessment." Am J Clin Nutr. 79: 774-9.

Grupo de Opinión Público de la Universidad de Lima. (2009). Barómetro social: V encuesta sobre la situación de la salud en el Perú. Paper 454, Lima and Callao, Peru.

Gualberto D, Bergman C, Kazemzadeh M, and Weber C. (1997). "Effect of extrusion, processing on the soluble and insoluble fiber and phytic acid contents of cereal brans." Plant Foods Hum Nutr. 51: 187-98.

Guerra-Matias AC, and Areas JAG. (2005). "Gylcemic and insulemic responses in women consuming extruded amaranth." Nutrition Research. 25: 815-22.

Halton TL, Willett WC, Liu S, Manson JE, Stampfer MJ, and Hu FB. (2006). "Potato and french fry consumption and risk of type 2 diabetes in women." Am J Clin Nutr. 83(2): 284-90.

Harrison and Isselbacher. (2005). Principios de medicina interna. 16th edition. Bogotá, Colombia.

He M, van Dam R, Rimm E, Hu F, and Qi L. (2010). “Whole-grain, cereal fiber, bran, and germ intake and the risks of all-cause and cardiovascular disease—specific mortality among women with type 2 diabetes mellitus.” Ciruclation. 121(20): 2162-8.

Heaton KW, Marcus SN, Emmett PM, and Bolton CH. (1988). “Particle size of wheat, maize, and oat test meals: effects on plasma glucose and insulin responses and on the rate of starch digestion in vitro.” Am J Clin Nutr. 47: 675-82.

Hernandez M. (2004). “Recomendaciones nutricionales para el ser humano: actualización”. Invest. Biomed. 23(4): 266-92.

Hu FB, Manson JE, Stampfer MJ, Colditz G, Liu S, Solomon CG, and Willett WC. (2001). “Diet, lifestyle and the risk of type 2 diabetes mellitus in women.” N Engl J Med. 345(11):790-7.

Hu FB, Li TY, Colditz GA, Willett WC, Manson JE. (2003). “Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women.” JAMA. 289: 1785-91.

Huicho L, Trelles M, Gonzales F, Mendoza W and Miranda J. (2009). “Mortality profiles in a country facing epidemiological transition: an analysis of registered data.” BMC Public Health. 9(47). Retrieved on July 15, 2011 from http://www.biomedcentral.com/147-2458/9/47.

Hurtado Fuertes, C. (2000). La alimentación en el Tahuantinsuyo. Editorial San Marcos. Lima, Peru.

Huynen MMTE, Vollebregt L., Martens P., and Benavides BM. (2005). “The epidemiological transition in Peru.” Pan Am J Public Health. 17(1):51-9.

Improta F, and Kellems RO. (2001). “Comparisons of raw, washed and polished quinoa to wheat, sorghum or maize based diets on growth and survival of broiler chicks.” Livestock Research for Rural Devt. 13(1).

Inouchi N, Nishi K, Tanaka S, Asai M, Kawase Y, Hata Y, Konishi Y, Shaoxian Y, and Fuwa H. (1999). “Characterization of amaranth and quinoa starches.” J Appl Glycosci. 46: 233-40.

Instituto Nacional de Estadística e Información (INEI). (2007). La transición nutricional en el Perú. Centro de Investigación y Desarrollo. Lima, Peru. Retrieved on August 9, 2011 from http://www.inei.gob.pe/.

Instituto Nacional de Estadística e Información (INEI). (2011). Perú en cifras. Lima, Peru. Retrieved on August 9, 2011 from http://www.inei.gob.pe/.

Instituto Nacional de Salud, Centro Nacional de Alimentación y Nutrición. (2009). Tablas peruanas de composición de alimentos. Lima, Peru. Accessed on August 3, 2011 from http://www.ins.gob.pe/insvirtual/images/otrpubs/pdf/Tabla%20de%20Alimentos.pdf.

International Diabetes Federation (IDF). (2006). The IDF Consensus Worldwide Definition of the Metabolic Syndrome. IDF Communications. Brussels, Belgium. Accessed on April 2, 2012 from http://www.idf.org/webdata/docs/IDF_Meta_def_final.pdf.

Izquierdo J, and Roca W. (1998). “Under-utilized Andean Food Crops: Status and Prospects of Plant Biotechnology for the Conservation and Sustainable Agriculture Use of Genetic Research.” Acta Hort (ISHS). 457: 157-72.

Jacobsen EE, Skadhauge B, and Jacobsen, SE. (1997). “Effects of Dietary Inclusion of Quinoa on Broiler Growth Performance.” Animal Feed Science Tech. 65: 5-14.

Jacoby E, Goldstein J, López A, Núñez E and López T. (2003). “Social class, family and life-style factors associated with overweight and obesity among adults in Peruvian cities.” J Prev Med. 37: 396-405.

Javaid MS. (1997). “Functional Properties of Buckwheat and Quinoa Starches.” MSc Thesis Food Science and Technology. University of Nebraska. Lincoln, NE.

Jenkins DJA, Kendall CWC, McKeown-Eyssen G, Josse RG, Silverberg J, et al. (2008). “Effect of a low-glycemic index or a high-cereal fiber diet on type 2 diabetes.” JAMA. 300(23): 2742-53.

Johnson R, and Aguilera R. (1980). “Processing Varieties of Oilseeds (Lupine and Quinoa).” Report to Natural Fibers and Food Protein Commission of Texas. Texas A&M University.

Jonnalagadda SS, Harnack L, Liu RH, McKeown N, Seal C, Liu S and Fahey GC. (2011). “Putting the whole-grain puzzle together: health benefits associated with whole grains—summary of the American Society for Nutrition 2010 Satellite Symposium.” J Nutr. 141(5): 1011S-22S.

Kabali C and Werler MM. (2007). “Pre-pregnant body mass index, weight gain and the risk of delivering large babies among non-diabetic mothers.” Int J Gyn & Obs. 97(2): 100-4.

Koh-Banerjee P, Franz M, Sampson L, Liu S, Jacobs DR, et al. (2004). “Changes in whole-grain, bran and cereal fiber consumption in relation to 8-yr. weight gain in men.” Am J Clin Nutr. 80:1237-45.

Konishi Y, Hirano S, Tsuboi H, and Wada M. (2004). “Distribution of Minerals in Quinoa (Chenopodium quinoa Willd.) Seeds,” Biosci Biotechnol Biochem. 68(1): 231-4.

Koziol MJ. (1992). “Chemical composition and nutritional evaluation of quinoa (Chenopodium quinoa Willd.).” J Food Compos Anal. 5: 35-68.

Krishnan S, Rosenberg L, Singer M, Hu F, Djoussé L, Cupples A, and Palmer J. (2007). “Glycemic index, glycemic load, and cereal fiber intake and risk of type 2 diabetes in US black women.” Arch Intern Med. 167(21): 2304-9.

Lee YM, Haarstert B, Scherbaum W, and Hauner H. (2003). “A phytoesterol-enriched spread improves the lipid profile of subjects with type 2 diabetes mellitus: a randomized controlled trial under free-living conditions.” Eur J Nutr. 42:111-17.

Lehmann JW, Putnam DH, and Qureshi AA. (1994). “Vitamin E isomers in grain amaranths.” Lipids. 29(3): 177-81.

Li J, Berke TG, and Glover DV. (1994). “Variation for thermal properties of starch in tropical maize germ plasm.” Cereal Chem. 71: 87-90.

Liese AD, Roach AK, Sparks KC, Marquart L, D’Agostino RB Jr and Mayer-Davis EJ. (2003). “Whole-grain intake and insulin sensitivity: the Insulin Resistance Atheroschlerosis Study.” Am J Clin Nutr. 78:965-71.

Lindeboom N. (2005).“Studies on the Characterization, Biosynthesis and Isolation of Starch and Protein from Quinoa (Chenopodium Quinoa Willd.).” Doctoral Thesis. University of Saskatchewan, Saskatoon, Canada.

Lindegarde F, Benavente Ercilla M, Retamozo Correa L, and Ahrens B. (2004). “Body adiposity, insulin and leptin in subgroups of Peruvian Amerindians.” High Altitude Medicine & Biology. 5(1): 27-31.

Liu RH. (2004). “Potential synergy of phytochemicals in cancer prevention: mechanism of action.” J Nutr. 134: S3479-85.

Liu S, Willett WC, Manson JE, Hu FB, Rosner B, et al. (2003). “Relation between changes in intakes of dietary fiber and grain products and changes in weight and development of obesity among middle-aged women.” Am J Clin Nutr. 78:920-7.

Loaiza Callata C, Negra Merel V and Samicento Calisaya L. (2006). “Efecto hipoglicemiante del Smallanthus sonchifolius (yacón) en pacientes con diabetes mellitus 2 de la asociación diabetica HRHD de Arequipa, 2005.” Thesis paper, School of Nursing, Universidad Nacional de San Augustín. Arequipa, Peru.

Lorenz K. (1990). “Quinoa (Chenopodium quinoa) starch: physico-chemical properties and functional characteristics.” Starch 42: 81-6.

Mahan KL and Escott-Stump S. (2008). Krause’s Food & Nutrition Therapy, 12th ed. St. Louis, MO. Saunders El Sevier.

Maltsoglou, Irini. (2007). Household expenditure on food of animal origen> a comparison of Uganda, Viet Nam and Peru. PPLPI. A living from lifestock, por-poor livestock policy initiative, Working Paper No. 43. Food and Agriculture Organization. Retrieved October 2009 from http://www.fao.org/ag/againfo/projects/en/pplpi/docarc/wp43.pdf

Marshall JA, Hamman RF and Baxter J. (1991). “High-fat, low-carbohydrate diet and the etiology of non-insulin dependent diabetes mellitus: the San Luis Valley Diabetes Study.” Amer J Epidemiol. 134: 590-603.

Martínez-Zuñiga, S.M. (2007). Cultural factors affecting food preference: the case of tarwi in three Quechua speaking areas of Peru. (Masters Thesis, Vanderbilt University.) Retrieved on August 4, 2011, from http://etd.library.vanderbilt.edu/available/etd-03292007-093659/unrestricted/Thesis.1.pdf.

Mattila P, Pihlava JM, and Hellstrom J. (2005). “Contents of phenolic acids, alkyl- and alkenylresorcinols, and avenanthramides in commercial grain products.” J Ag and Food Chem. 53: 8290-9295.

Medina Lezama J, Morey-Vargas OL, Zea-Díaz H, Bolaños-Salazar JF, Corrales-Medina F., Cuba-Bustinza C, Valdivia Ascuña Z, Postigo MacDowell M, Chirinos Pacheco J, Muñoz Atahualpa E, and Chirinos Medina J (2006). “Prevalencia de sobrepeso y obesidad en la población adulta de Arequipa metropolitan: Resultados del estudio PREVENCION.” Rev Peruana Cardiol.32(2):194-209.

Medina Lezama J, Morey-Vargas OL, Zea-Díaz H, Bolaños-Salazar JF, Corrales-Medina F, Cuba-Bustinza C, Chirinos-Medina DA, and Chirinos JA (2008). “Prevalence and lifestyle-related cardiovascular risk factors in Peru: the PREVENCION study.” Pan Am J Public Health. 24(3):169-78.

Mejía Acosta, A. (2011). Analyzing success in the fight against malnutrition in Peru. Institute of Development Studies Working Paper 367, University of Sussex. Brighton, UK. Retrieved on August 18, 2011 from http://onlinelibrary.wiley.com/doi/10.1111/j.2040-0209.2011.00367.x/pdf

Meyer KA, Kushi LH, Jacobs DR Jr, Slavin J, Sellers TA, and Folsom AR. (2000). “Carbohydrates, dietary fiber, and incident type 2 diabetes in older women.” Am J Clin Nutr. 71: 921-30.

Miller HE, Rigelhof F, Marquart L, Prakash A, Kanter M. (2000). “Antioxidant content of whole grain breakfast cereals, fruits and vegetables.” J Am Coll Nutr. 19: S312-9.

Ministerio de Salud, Perú. (1996). El desafío del cambio de milenio: un sector salud con equidad, eficiencia y calidad. Lima: Ministerio de Salud. Lima, Peru.

Mipireta, ML, Rosas, AM, Velasquez, JE, et al. (2007). “Transición nutricional en el Perú, 1991 – 2005”. Rev perú med exp salud pública. 24(2):129-135.

Mizui F, Kasai R, Ohtani K, and Tanaka O. (1990). “ Saponins from bran of quinoa, Chenopodium quinoa Willd. II.” Chem. Pharm. Bull . 38: 375-7.

Mizui F, Kasai R, Ohtani K, and Tanaka O. (1988).“Saponins from bran of quinoa Chenopodium quinoa Willd. I” Chem Pharm Bull. 36: 1415-8.

Morales E, Lembcke J and Graham. (1988). “Nutritional Value for Young Children of Grain Amaranth and Maize-Amaranth Mixtures: Effects of Processing.” J Nutrition 118: 78-85.

Morita N, Hirata C, Park SH, and Mitsunaga T. (2001). “Quinoa flour as a new foodstuff for improving dough and bread.” J Appl Glycosci. 48: 263-70.

National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK). (2001). “Diet and exercise drastically delay type 2 diabetes.” Press release issued by the NIDDK, US National Institutes of Health, Bethesda, MD. Retrieved on August 8, 2011 from http://www2.niddk.nih.gov/News/SearchNews/08_08_2001.htm

National Institutes of Health. (1998). Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. NIH Publication No. 98-4083. Accessed on April 6, 2012 from http://www.nhlbi.nih.gov/guidelines/obesity/ob_gdlns.pdf.

National Research Council. (2005). Lost Crops of the Incas: Little-Known Plants of the Andes with Promise for Worldwide Cultivation. National Academy Press, Washington, DC. pp. 149-161.

National Research Council. (1989). Lost Crops of the Incas: Little-Known Plants of the Andes with Promise for Worldwide Cultivation. National Academy Press, Washington, DC.

Ng SC, and Anderson AK. (2005). “Lipid Oxidation in Quinoa (Chenopodium Quinoa) as Determined through Accelerated Aging.” Electronic Journal of Environmental, Agricultural and Food Chemistry. 4(4): 1010-20.

Nordmann AJ, Nordmann A, Briel M, Keller U, Yancy WS Jr. Brehm BJ, and Bucher HC. (2006). ”Effects of low-carbohydrate vs low-fat diets on weight loss and cardiovascular risk factors: a meta-analysis of randomized control trials.” Arch Intern Med. 166:285-293.

Norris SL, Zhang X, Avenell A, Gregg E, Bowman B, Schmid CH, and Lau J. (2005). “Long-term effectiveness of weight-loss interventions in adults with pre-diabetes: a review.” Am J Prev Med. 28:126-139.

Ogawa H, Watanabe K, Mitsunaga T, and Meguro, T. (2001). “Effect of quinoa on blood pressure and lipid metabolism in diet-induced hyperlipidemic spontaneously hypertensive rats (SHR).” J Jpn Soc Nutr Food Sci. 54: 221-227.

Ohara T, Doi Y, Ninomiya T, Hirakawa Y, Hata J, et al. (2011). “Glucose tolerance status and the risk of dementia in the community.” Neurology. 77(12): 1126-34.

Ohio State University Medical Center. (2011). “Statistics about diabetes.” Retrieved on 9/14/2011 from http://medicalcenter.osu.edu/patientcare/healthcare_services/diabetes_endocrine/about_diabetes/statistics_about_diabetes/Pages/index.aspx.

Okarter N and Liu RH. (2010). “Health benefits of whole grain phytochemicals.” Crit Rev Food Sci Nutr. 50: 193-208.

Oki OI. (1980). “Toxicity of cyanogenic glycosides.” Food Chem. 6(2): 97-109.

Omran, A.R. (1971). “The epidemiologic transition: a theory of the epidemiology of population change.” Millbank Meml Fund Q. 49(4):509-38.

Ono, T., Guthold, R., Strong, K.. (2005). WHO Global Comparative Estimates. World Health Organization. Retrieved on August 4, 2011, from https://apps.who.int/infobase/Comparisons.aspx.

Oporto Salas MP and Rojas Salas H. (2008). Frequencia de syndrome metabolico en pacientes con diabetes mellitus tipo 2 del Hospital III Yanahuara ESSalud de Arequipa. Thesis paper, School of Medicine, Universidad Nacional de San Augustín. Arequipa, Peru.

Oshodi AA, Ogungbenie HN, and Oladimeji MO. (1999). “Chemical composition, nutritional valuable minerals and functional properties of benniseed (Sesamum radiatum), pearl millet (Pennisetum typhoides) and quinoa (Chenopodium quinoa) flours.” Int. J. Food Sci. Nutr. 50: 325-31.

Pan American Health Organization. (2010) Health Information and Analysis Project. Regional Core Health Data Initiative. Washington, DC.

Pan XR, Li GW, Wang JX, et al. (1997). Éffects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance: the Di Qing IGT and diabetes study.” Diabetes Care. 20:537-44.

Pate RN, Johnston P, Rico E, Bonifacio A, Kellems RO, and Kooyman DL. (2006). "The Palatability of Sweet (Surumi, Patacamaya, Sayana, Chucapaca) and Bitter (Real) Bolivian Quinoa Cultivars, Corn, Barley and Oats as Guinea Pig Foodstuffs." Proceeedings, Western Section, American Society of Animal Science. 57.

Pedersen B, Kalinowski LS, and Eggum BO. (1987). "The Nutritive Value of Amaranth Grain (Amaranthus caudatus)," Plant Foods for Human Nutrition, 36: 309-324.

Pereira MA, Jacobs DR Jr, Pins JJ, Raatz SK, Gross MD, et al. (2002). "Effect of whole grains on insulin sensitivity in overweight hyperinsulinemic adults." Am J Clin Nutr. 75:848-55.

Pérez, Fernando L. (2006). "Antecedentes que justifican la implementación de 5 al Día Perú para promover el consumo de verduras y frutas en Perú." Rev. Chilena de Nutrición. 33(1).

Popkin, BM. (1994). "The nutrition transition in low-income countries: an emerging crisis." Nutr Rev 52(9): 285-98.

Popkin, B, Richards, M and Monteiro, C. (1996). "Stunting is associated with overweight in children in four nations that are undergoing the nutrition transition." J Nutr 126: 3009-16.

Popkin, BM. (2001). "The nutrition transition and obesity in the developing world." J Nutr 131(3): 871S-3S.

Popkin, BM. (2002). "The shift in stages of the nutrition transition in the developing world differs from past experiences!" Public Health Nutr 5(1A): 205-14.

Praznik W, Mundigler N, Kogler A, Pelzl B, and Huber A. (1999).“Molecular background of technological properties of selected starches.” Starch 51: 197-211.

Radio Programas Peruanos. (2010). “La obesidad infantil y el riesgo de diabetes en la niñez.” Interview of Dr. Dr. Herald Manrique Hurtado, Director médico del Centro de Investigación en diabetes, obesidad y nutrición, and Endocrinólogo del Hospital Loayza on October 7, 2010. Accessed on November 21, 2010 at http://radio.rpp.com.pe/saludenrpp/la-obesidad-infantil-y-el-riesgo-de-diabetes-en-la-ninez/.

Ramírez Angulo, EG. (2009). Gastronomía Arequipeña. Retrieved on August 17, 2011 from http://historiaygastronomia.blogspot.es/.

Ramos, J and Faviola, S. (2006). “Alimentación saludable: una utopia en Perú?” Red peruana de alimentación y nutrición. Retrieved on December 12, 2009 from http://www.rpan.org/publicaciones.asp.

Ranhotra GS, Gelroth JA, Glaser BK, Lorenz KJ and Johnson DL. (1993). “Composition and Protein Nutritional Quality of Quinoa,” Cereal Chem. 70(3): 303-5.

Rastrelli L, De Simone F, Schettino O, and Dini A. (1996). “Constituents of Chenopodium pallidicaule (cañihua) seeds: isolation and characterization of new triterpene saponins.” Food Rev Int. 19: 179-89

Ruales J, and Nair BM. (1994). “Effect of Processing on In Vitro Digestibility of Proteins and Starch in Quinoa Seeds.” Int J Food Sci Tech. 29: 449-56.

Ruales J, and Nair BM. (1993). “Saponins, phytic acid, tannins and protease inhibitors in quinoa (Chenopodium quinoa Willd.).” J. Sci. Food Agric. 54: 211-9.

Raules J, and Nair BM, (1992). “Nutritional Quality of the Proteins in Quinoa,” Plant Foods Hum Nutr. 42: 1-11.

Reis JP, Loria CM, Sorlie PD, Park Y, Hollenbeck A, and Schatzin A. (2011). “Lifestyle factors and risk for new-onset diabetes.” Ann Intern Med. 155(5): 292-299.

Repo-Carrasco R, Espinoza C, and Jacobsen SE. (2003). “Nutritional value and use of the Andean crops quinoa (Chenopodium quinoa) and kañiwa (Chenopodium pallidicaule).” Food Rev Int. 19: 179-89.

Repo-Carrasco-Valencia R, Acevedo de la Cruz A, Icochea Alvarez JC, and Kallio H. (2009). “Chemical and functional characterization of kañiwa (Chenopodium pallidicaule) grain, extrudate and bran.” Plant Foods Hum Nutr. 64: 94-101.

Repo-Carrasco-Valencia R, Hellstrom JK, Pihlava JM, and Mattila PH. (2010). “Flavonoids and other phenolic compounds in Andean indigenous grains: Quinoa (Chenopodium quinoa), kañiwa (Chenopodium pallidicaule), and kiwicha (Amaranthus caudatus).” Food Chem. 120: 128-33.

Reyna Liria M, Mispireta M, Lanata CF, Creed-Kanashiro HM. (2009). “Nutritional profile of primary school children in Lima and Callao, Peru.” FASEB J. 23 (Meeting Abstract Supplement) 914.5

Ridout CL, Price KR, DuPont MS, Parker ML, and Fenwick GR. (1991). “Quinoa saponins- analysis and preliminary investigations into effects of reduction by processing.” J. Sci. Food Agric. 54: 165-76.

Rose D, et al. (2009). “Understanding the role of potatoes in the Peruvian diet: an approach that combines food composition with household expenditure data.” J Food Composition and Analysis. 22: 525-532.

Scanlin L, and Stone M. (2007). Colorado State University Research Foundation, Fort Collins, CO (US), Patent Application Publication No.: US 2007/0092629 AI, Apr. 26, 2007.

Schlick G, and Bubenheim DL. (1993). "Quinoa: An Emerging "New" Crop with Potential for CELSS." Commissioned by National Aeronautics and Space Administration. Ames Research Center. Moffett Field, CA 94035-1000.

Schmidt MI, Duncan BB, Bang H, Pankow JS, Ballantyne CM, Golden SH, Folsom AR, Chambless LE and the Athersclerosis Risk in Communities Investigators. (2005). "Identifying individuals at high risk for diabetes." Diabetes Care. 28(8):2013-18.

Schoenlechner R, Jurackova K, and Berghofer E. (2004). "Pasta Production from the Pseudocereals Amaranth, Quinoa and Buckwheat." Using Cereal Science and Technology for the Benefit of Consumers: Proceedings of the 12th International ICC Cereal and Bread Congress, Harrogate, UK, May 24-26, 2004.

Schultze MB and Hu F. (2005). "Primary prevention of diabetes: What can be done and how much can be prevented?" Annu Rev Public Health. 26: 445-67.

Schulze MB, Schulz M, Heidemann C, Schienkiewitz A, Hoffmann K, et al. (2007). "Fiber and magnesium intake and incidence of type 2 diabetes: A prospective study and meta-analysis." Arch Intern Med. 167:956-65.

Seligson FH and Mackey LN. (1984). "Variable predictions of protein quality by chemical score due to amino acid analysis and reference pattern." J Nutr. 114: 682-91.

Serraino MR, Thompson LU, Savoie L, and Parent G. (1985). "Effect of phytic acid on the in vitro rate digestibility of rapeseed protein and amino-acid." J Food Sci. 50: 1689-92.

Shah N, Atallah MT, Mahoney RR and Pellett PL. (1982). "Effect of dietary fiber components on fecal nitrogen excretion and protein utilization in growing rats." J Nutr. 112: 658-66.

Shamsuddin AM. (1995). "Inositol phosphates have novel anti-cancer function." J Nutr. 125: 725S-732S.
Sharma AM. (2002). "Adipose tissue: a mediator of cardiovascular risk." Intl J Obesity. 26(4): S5-S7.

Slavin J. (2004). "Whole grains and human health." Nutr Res Rev. 17: 99-110.

Slavin JL, Jacobs D, Marquart L and Wiemer K. (2001). "The role of whole grains in disease prevention." J Am Diet Assoc. 101: 780-5.

Slavin JL, Martini MC, Jacobs DR Jr, and Marquet L. (1999). "Plausible mechanisms for the protectiveness of whole grains." Am J Clin Nutr. 70: 459S-463S.

Snijder MB, van Dam RM, Visser M, and Seidell J. (2006). "What aspects of body fat are particularly hazardous and how do we measure them?" Int J Epidemiol. 35: 83-92.

Soderberg S, Ahrén B, Jansson JH, Johnson O, Hallmans G, Asplund K, and Olsson T. (1999). "Leptin is associated with increased risk of myocardial infarction." J Int Med. 246: 409-418.

Stern I, Iqbal N, Seshadri P, Chicano KL, Daily DA, McGrory J, Williams M, Gracely EJ, and Samaha FF. (2004) "The effects of low-carbohydrate versus conventional weight loss diets in severely obese adults: one-year follow-up of a randomized trial." Ann Intern Med. 140: 778-85.

Sun Q, Spiegelman D, van Dam RM, Holmes MD, Malik VS, Willett WC, and Hu FB. (2010). "White Rice, Brown Rice, and Risk of Type 2 Diabetes in US Men and Women." Arch Intern Med. 170: 961-9.

Svegmark K, Helmersson K, Nilsson G, Nilsson PO, Andersson R, and Svensson E. (2002). "Comparison of potato amylopectin starches and potato starches. Influence of year and variety." Carbohydr. Polym. 47: 331-40.

Tang H, Watanabe K, and Mitsunaga T. (2002). "Characterization of storage starches from quinoa, barley and adzuki seeds." Carbohydr. Polym. 49: 13-21.

Taylor AJ, Wong H, Wish K, Carrow J, Bell D, Bindeman J, et al. (2003). "Validation of the MEDFICTS dietary questionnaire: a clinical tool to assess adherence to American Heart Association dietary fat intake guidelines." Nutr J. 2(1): 4.

Theurer-Wood R. (2001). "Tale of food survivor: Quinoa." East West Journal: 63-8.

Thompson T. (2000)."Folate, Iron, and Dietary Fiber Contents of the Gluten-Free Diet." Journal of the American Dietetic Association. 100(11): 1389-96.

Timar, D. (2009). Comparing obesity trends in rural versus urban Peru from 1991 to 2005. (Masters Thesis, Georgia State University.) Retrieved on August 11, 2011 from http://digitalarchive.gsu.edu/iph_theses/119/.

Tosiello L. (1996). "Hypomagnesemia and diabetes mellitus. A review of clinical implications." Arch Intern Med. 156: 1143-8.

Toumilelito J, Lindstrom J, Eriksson JG, et al., (2001). "Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance." N Engl J Med. 344:1343-50.

Tucker, JB. (1986). “Amaranth: the once and future crop.” BioScience 36: 9-13.

US Department of Agriculture (USDA). (2007). National Nutrient Database for Standard Reference. Release 20. Accessed on April 4, 2009 from http://www.nal.usda.gov/fnic/foodcomp/Data//SR20/reports/sr20fg20.pdf

US Department of Health and Human Services and US Department of Agriculture. (2005). Dietary guidelines for Americans, 2005. 6th edition. Washington, DC.

US Department of Health and Human Services and US Department of Agriculture. (2010). Dietary guidelines for Americans, 2010. 7th edition. Washington, DC.

US Department of State. (2010). Perú Background Note. Bureau of Western Hemisphere Affairs, US Department of State. Washington, DC. Retrieved on August 9, 2011 from http://www.state.gov/r/pa/ei/bgn/35762.htm.

Valencia S, Svanberg U, Sandberg AS, and Ruales J. (1999). “Processing of quinoa (Chenopodium quinoa Willd.): effects on in vitro iron availability and phytate hydrolysis.” Int. J. Food Sci. Nutr. 50: 203-11.

van Dam RM, Rimm EB, Willett WC, Stampfer MJ, and Hu FB. (2002). “Dietary patterns and risk for type 2 diabetes mellitus in US men.” Ann Intern Med. 136: 201-9.

van Dam RM, Willett WC, Rimm EB, Stampfer MJ, and Hu FB. (2002). “Dietary fat and meat intake in relation to risk of type 2 diabetes in men.” Diabetes Care. 25: 417-25.

Venn BJ and Mann JI. (2004). “Cereal grains, legumes and diabetes.” Eur J Clin Nutr. 58(11): 1443-61.

Vessby B, Unsitupa M, Hermansen K, Riccardi G, Rivellese AA, Tapsell LC, Nalsen C, Berglund L, Louheranta A, Rasmussen BM, Calvert GD, Malletone A, Pedersen E, Gustafsson IB, and Storlien LH. (2001). “Substituting dietary saturated fat for monounsaturated fat impairs insulin sensitivity in healthy men and women: the KANWU study.” Diabetologia. 44:312-19.

Wanden-Berghe, C. (2010). “Superposición epidemiológica nutricional en Latinoamérica,” Revista española de nutrición comunitaria, 16(1):5-8.

Watanabe K, Ng LP, Hanjun T, and Mitsunaga T. (2007). “Molecular Structural Characteristics of Quinoa Starch.” Food Sci. Technol. Res. 13(1): 73-6.

Weickert MO, Mohlig M, Koebnick C, Holst JJ, Namsolleck P, et al., (2005). “Impact of cereal fibre on glucose-regulating factors.” Diabetologia. 8:2343-53.

Weickert MO, Mohlig M, Scholl C, Arafat AM, Otto B, et al. (2006). “Cereal fiber improves whole-body insulin sensitivity in overweight and obese women.” Diabetes Care. 29:775-80.

White PL, Alvistur E, Dias C, Vinas E, White NS., and Collazos C. (1955). “Nutrient Content and Protein Quality of Quinoa and Canihua, edible seed products of the Andes mountains.” J. Agric. Food Chem. 3: 531-4.

Willett WC and Leibel RL. (2002). “Dietary fat is not a major determinant of body fat.” Am J Med. 113(Suppl.9B):47-59.

Willett WC, Manson J, and Liu S. (2002). ”Glycemic index, glycemic load and risk of type 2 diabetes.” Am J Clin Nutr. 76(1): 274S-80S.

Williams DE, Wareham NJ, Cox BD, Byrne CD, Hales CN and Day NE. (1999). “Frequent salad vegetable consumption is associated with a reduction in the risk of diabetes mellitus.” J Clin Epidemiol. 52: 329-335.

Wolf MJ, MacMasters MM, and Rist CE. (1950). "Some characteristics of the starches of three South American seeds used in food." Cereal Chem. 27: 219-22.

Wood SG, Lawson LD, Fairbanks DJ, Robinson LR, and Andersen WR. (1990). "Seed lipid content and fatty acid composition of three quinoa cultivars." J. Food Comp. Anal. 6: 41-4.

Wootton M, and Panozzo JF. (1998). "Differences in gelatinization behavior between starches from Australian wheat cultivars." Starch 50: 154-8.

World Bank. (2011). World Development Indicators. Retrieved on August 8, 2011 from http://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD/countries/1W-PE?display=graph

World Health Organization (WHO). (2000a). Obesity: preventing and managing the global epidemic. Report of a WHO consultation on obesity. Geneva, Switzerland.

World Health Organization (WHO). (2000b). World health report. Geneva, Switzerland.

World Health Organization (WHO). (2002). The world health report: reducing risks and promoting a healthy life. Geneva, Switzerland.

World Health Organization (WHO) and Food and Agriculture Organization of the United Nations (FAO). (2003). Diet, nutrition and the prevention of chronic diseases. Report of a Joint WHO/FAO Expert Consultation. WHO Technical Report Series 916. Geneva, Switzerland.

World Health Organization (WHO), (2011). Fact sheet No. 312. Geneva, Switzerland. Retrieved on September 22, 2011 from http://www.who.int/mediacentre/factsheets/fs312/en/index.html.

Zhu N, Sheng S, Li D, Lavoie ED, Karwe MV, Rosen RT, and Ho CT. (2001). "Antioxidative flavonoid glycosides from quinoa seeds (Chenopodium quinoa Willd.)." J. Food Lipids 8: 37-44.

Zorn E, and Lieberman LS. (2004). "Freeze-dried but always peeled: anthropological approaches to food processing, preparation and consumption of the Andean potato." Presentation at the 2004 Indigenous Knowledge Conference, Interinstitutional Consortium of Indigenous Knowledge, Penn State University, Pennsylvania. Retrieved on 3/12/2011 from http://www.ed.psu.edu/ICIK/2004Proceedings/section2-zorn-lieberman-withpics.pdf.