

Peru: People and Potatoes

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“The Potato Eaters”
Vincent Van Gogh, 1885

Introduction:

*Beloved be
the one who thirsts or hungers, but who doesn't have
hunger to satiate all his thirst,
nor thirst to satiate all his hungers!*

--Cesar Vallejo

In the late weeks of August, one peers out on an Iowan horizon and sees a thriving civilization of green, towering stalks planted firmly in the soil. Perfect rows, life upon life, growing from broken soil bring security and happiness to individuals around the world. However, the earth exhibits many contrasts. What is fertile and lush in Iowa, one finds barren and sandy on the slopes of the majestic Andes. In the American Midwest, ample rain from overhanging clouds ensure a bountiful harvest, while in the sun-scorched deserts of Peru thousands starve and kill over meager food supplies, and water trickles intermittently from a dirty pipe. The world offers a vast array of landscapes and climates to which humanity has adapted. However, the vast array of humanity has burgeoned too quickly and has now found itself struggling to feed its hungry and provide for its poor.

What should be done for the suffering and poverty stricken masses? This is a troublesome contemplation. Some organizations and individuals, however, have devoted their lives toward improving the standard of living for those less fortunate. Two such organizations that I have had the extreme privilege of working with have been the World Food Prize Foundation headquartered in Des Moines and the International Potato Center in Lima Peru.

I was first introduced to the World Food Prize Foundation in 2002 by my father, Michael Carey, who was working with the Foundation to present the work and accomplishments of Norman Borlaug in a language other than raw data and statistics. He convinced me to participate in the 2002 World Food Prize Youth Symposium which dealt with water quality and sanitation. My paper focused not only on the region I had chosen to discuss, South America, but on the water distribution problems found around the world. It was through my research and attendance at the symposium that I found myself face to face with the harsh reality of poverty throughout the world. This is also where I found about the unique opportunity offered through the World Food Prize Youth Symposium to travel abroad and work for a summer at a world-renowned research institute.

In 2003, I attended the symposium once more and found myself holistically absorbed in the thrilling reports of my high school peers who had traveled abroad to study food security issues. I applied for such an opportunity and found myself headed for distant lands soon to enjoy the experience of a life-time.

Peru

The Republic of Peru:

On June 7, 2004, my unforgettable summer began as my departing Delta tires ascended from the tarmac of the Des Moines airport. My destination: the over-populated and over-polluted capital city of Lima, Peru.

I had spent the past few months reading up on Peruvian history and culture but, despite this “head start,” there was no way I could have fully appreciated the richness of Peruvian life had I not gone and experienced it for myself.

The Republic of Peru is situated along the western coast of South America. Its terrain is terrifically diverse and provides the country with almost every form of weather imaginable. The western desert/coastal area comprises ten percent of Peru’s total land area. As a result of the perpetual oceanic air currents that sweep the western coast, there is almost no “weather.” The temperature is an average sixty-five degrees throughout the year. A complete lack of wind and rain has not only given this area its desert-like qualities but is responsible for the stunning archeological sites that have remained exposed and intact for centuries.

The center of Peru is traversed by the majestic Andes Mountains, which comprise twenty-seven percent of the country’s land area. The Sierra, or mountainous region, is the seat of the majority of Peru’s mineral wealth, and its sky-scraping elevations make it possible for spring, summer, and winter to take place simultaneously at different elevations throughout the region. These diverse climactic locales will be important to remember when discussing specific tuber varieties that have evolved in these areas and exhibit desirable resistance traits not found in other species.

Some of the world’s first civilizations began to appear in Peru about five thousand years ago. In the intervening years, the area has been subject to multiple ruling parties. The most notable of these was the Inca Empire that is presumed to have arisen in the southern city of

Cusco through the 12th-14th Centuries. Incan civilization was able to expand its borders throughout all of present-day Peru and into its neighboring present day countries. Smaller, less militaristically advanced cultures were soon assimilated into the expanding Incan culture and the lines of distinction that had existed began to fade.

The Inca developed remarkable roads and transportation systems, elaborate social divisions, rituals, and some of the world's finest fortresses and religious centers that litter the ground as ruins in present-day Peru. The Inca civilization came to a screeching halt with the arrival of Francisco Pizarro and the Spanish crown in 1533. 170 strong, wielding the West's superior instruments of warfare, the Spanish defeated some 15,000 Incan warriors in their first confrontation. It was only a matter of time before the Spanish expanded their culture and religion throughout the area.

With liberation in 1821, the Spaniard's tyrannical rule changed hands to the wealthy, coastal elite. The whip of domination changed from the grasp of one rider to another, but the beaten horse remained. Social divisions between the wealthy and the poor, the coastal residents and the highlanders, and those of varying Spanish descent ravaged the country for centuries and still plague its lands today. It has been less than a decade since the "Shining Path" terrorist movement began to disappear from the news headlines. Those legally elected in the past few years have been exposed for scandalous acts, and Peru's current president has only been able to garner a meager seven percent approval rating.

Naturally, I was a bit apprehensive about living in a metropolis of 8 million after leaving a town of barely 500 back in Iowa. None the less, into the heart of the capital city of this diverse country of 28,409,899 residents, I was thrown. But I jumped into my adventure with full "On

the Road” enthusiasm. I kissed my mamma goodbye, grabbed my camera and journal, and headed south.

Famalia Nuestra:

I couldn't have asked for a better place to stay. The Bartolini's, with whom I lived throughout the summer, resided in San Isidro, one of the nicest neighborhoods of Lima, and was within walking distance or a short cab ride away from the major attractions of the city. I was fairly sure, before leaving, that I would be living with at least two other people. When I arrived I found out that the house was actually a large complex of about three separate houses with approximately twenty family members. I was given my own room and the attendance of a maid. Such a luxury is quite a pleasant experience and I heartily recommend it. I immediately felt at home in this house with family members ranging from 2 to 90. It almost impossible to feel lonely in a place where all you had to do was mention the word “Twister” and the children had the mat and spinner ready.



My new Peruvian friends are what really made the stay enjoyable. They introduced me not only to the sights and life of Lima, but to the pulse of Peruvian culture which emanated from them all. Some of my best memories of Peru are not the immense cathedrals, the soaring Andes, or even Machu Pichu but the Saturday nights I went out with my Peruvian pals.

Travel

Lima:

The first and foremost objective of my trip was to complete my research at the International Potato Center. After working all week, however, I was ready to shed the lab coat and explore the city. I tried to make an effort to see everything that I possibly could and completely absorb Peruvian culture.



In Lima, I toured *Plaza de Armas* numerous times and stood in awe at the colonial architecture and baroque designs that festooned its elaborate churches and balconies. I traveled to the cliffs overlooking the beaches of *Mira Flores*. I saw a play in the artistic center of *Baranco*, visited multiple museums and shops, the enormous *Cruz de San Martin* overlooking the city, and into the slums of *Rimac*. I experienced the haunting catacombs of *Iglesia de San Fansisco*, I heard a live concert of Peruvian music on the campus of *La Molina Agrarian University*, I explored the crumbling, but breathtaking ruins of Pachacamac, and perused more artisan stands than I care to remember.

I spent a day at a Peruvian high-school and got to talk with many its students. It wasn't your average Peruvian school as it was based on the American education system and was meant to prepare well-to-do Peruvian or foreign students for college here in the United States. I had a wonderful time sitting in on lectures and talking to the kids about their plans for life or the coming weekend.



During my stay in Lima, I had the opportunity to go to my first professional *futbol* game. The *Copa de America*, which is a *futbol* tournament

encompassing all of South America and much of Central America and the Caribbean, this year just happened to be held in Peru. I went to the quarterfinals featuring Colombia vs. Argentina and had a great time screaming “*Gol!!!!!!!!!!!!*” every time Argentina scored a goal.

I came to find, however, that it really isn’t the *places* you visit but the *people* you visit with that make a great experience. Lima, itself, is pretty worn out; the sky is constantly smog-gray, everything is dirty, and at every street corner you find the homeless begging. However, the people are what endear one to a place. Not only was I immediately accepted into my new Peruvian family, but by everyone at the International Potato Center as well. It was through them and their generosity that I had the best summer of my life.

Outside of Lima:

My travels outside of Lima were an experience all in themselves and to truly do them justice I would need to write another paper completely devoted to the places I visited. For our purposes, however, I will only briefly describe my adventures to the four corners of Peru.

My first trip was to the eastern highland *pueblitos* tucked away in the folds of the Andes Mountains collectively referred to as *Yauyos*. Yauyos was not on the top of my “to see” tourists sights, but Gabriela, my supervisor, had been asked to judge a



traditional food festival being held in the region and I was more than happy to accompany her.

The trip to Yauyos consisted of a three-hour car ride along the Peruvian coast and a five-hour ride up the bumpiest, most tortuous road I have ever traveled. To say it was a road marred by pot holes would be a gross understatement; a giant pothole interspersed with bits and pieces

of road seems more apt to describe this winding path. Gabriela and I didn't mind, however, as we shouted at the driver to stop for pictures every kilometer or so.

It was along this climbing path that I first caught a glimpse of Peruvian poverty. A few kilometers outside of the commercial districts of Lima, sand dunes began to rise in the distance with small huts of bamboo and cardboard plastering every exploitable inch. This continues, mile after mile, until one can't help but consider the cardboard and tin ceilings a common sight and simply sit back and allow them to slip by into the distance.

The highland *pueblitos* might be said to be more developed than that of the squatter towns on the outside of Lima, but they were little more developed than one might expect for a dog house in Iowa. The cold, dilapidated cement structures were bereft of all contemporary luxuries save electricity that might flow to a flickering, solitary bulb. The poverty and the struggles these people endured might have been overly depressing if it weren't for the bubbling *Rio Cañete* and the towering Andean peaks that smothered every *pueblito* in beautiful isolation and made for a breathtaking sight.

Upon arriving in the highland *pueblito* of *Llapay* in the district of *Yauyos*, I foolishly indulged in a freshly prepared fish and potato dinner. It only took a few hours for the altitude and food to take a toll on my fragile American stomach; the rest of my trip to *Yauyos* was not a pleasant experience. I did, however, manage to make it out to the festivities and watch the highland dancers and musicians play and dance to the cheering of the crowds. The brightly-colored shawls and hats were a sight to see along with the individual designated to supply the dancers with hard liquor when needed.

My next adventure took me south to the city of *Ica* and neighboring *Nazca* to visit the mysterious *Nazca* lines. I traveled with one of my closest Peruvian friends, Kelly Moron, to her family's house in the in the bustling city of *Ica* before catching an early morning bus to *Nazca*.



I had purchased tickets for an aerial tour of the *Nazca* lines while I was still in Lima and was surprised to find out that my tour included a trip to one of the eeriest cemeteries that I have ever visited: the *Cemetario de Chauchila*. This cemetery was located about twenty miles outside of *Nazca* and had been looted and robbed for the last one thousand years. In each of the twelve open graves lay mummies, some with hair and skin still sagging from their skeletal structure that had been preserved because of a lack of moisture and wind. The human remains and ancient cloth were hardly restrained to the confines of the pits. Shards of skeletal bone were crumbled underfoot with each step. At one point, as I bent down to tie my shoe a thousand-year-old tooth jutting out from the sand caught my eye and led me to realize how completely this place had been ransacked.

The *Nazca* Lines awaited me as I returned to the city of *Nazca* and caught a ride in a Cessna to view the stunning array of figures perfectly drawn in the sands of the *Pampas de San Jose*. The unique figures ranged from a monkey to an “astronaut” and were thought to date back some 2,000 years. The 1,000 foot long sketches were discovered in 1929. Their significance and creators have remained a mystery.

My final stop in the south was at the desert oasis of *Huacachina*. This small lake lies in the middle of some of the world's largest sand dunes and is surrounded on all sides by colonial structures and multiple street vendors. I walked to the sight and had the stereotypical experience portrayed in films of climbing through the desert to stumble across a palm-studded lake lying in wait at the bottom of the dunes. I wandered the lakeside for awhile and took in the sights of the locals attempting to snowboard down the precipitous dunes.



One of my last and most memorable trips was to *Cusco*, the Sacred Valley, and, of course, *Machu Pichu*. I can honestly say that I met some of the nicest people and had some of the most fun in my life while in *Cusco* and owe most of that to my friend/tour guide/supervisor Lucho Rivera.

From the moment I stepped off the plane at the *Cusco* airport, I was on the go. Lucho and I had an incredible amount of ground to cover in a limited amount of time and we got right to it.

Cusco is located further south than is *Ica* or *Nazca* and stands at the entrance to the "Sacred Valley," the verdant lowlands shrouded by the snow-covered peaks of the Andes. We took in the sights of the small colonial city with its hundreds of intricately designed balconies and monumental cathedrals before heading out to the numerous cultural and archeological sights that littered the Sacred Valley. We went to *C' Corao*, the *Pisac* market and ruins, *Urubamba*, *Ollantaytambo*, *Chincheros*, *Tambomachi*, *Paka Pukara*, *Quinqos*, and *Saqsayhuaman*.

The beautiful symmetry and towering fortresses constructed by the Inca is something that I will



never forget; but some of the most interesting parts of my travels weren't with the structures of the past, but with the people of the present. Talking with rural Peruvians and listening to passionate tour guides depict the raping of their culture, I began to feel more in touch with the people of Peru. With each church and each elaborate Spanish balcony I was reminded of a subjugated people who, throughout conquests and humiliating defeats, had managed to keep their culture alive and thriving. Nowhere was this more evident than in the churches and highlands. In the 1500's, when the Inca culture was conquered, Catholicism was one of the first things to be introduced. Most of the churches in *Cusco* and throughout Peru are massive Catholic cathedrals that sit atop beautifully designed Inca walls which are all that remain of the ancient Inca temples. This construction of new religious centers sitting atop the old was an intentional demoralizing effort of the Spanish to rid the people of their pagan beliefs and break them into submission. Despite this reversal of religious paradigms, the Peruvian's effort to keep their heritage alive became strikingly evident when entering a church. With a skillful eye and the assistance of a tour guide, one can discern the hints of an ancient Andean religion kept alive under the watchful eye of the Spanish. The depictions of Mary reveal not one but two distinct versions. There is the Spanish version draped in blues and whites with clothes that flow as a European or North American Christian would imagine. Then there is the Peruvian Mary; this Mary is dressed in browns and earth colors and her dress always takes the shape of a semicircle to represent the mountainous shape of *Pachamamma* or the "Mother Earth." Whether it is the distinctly Peruvian saints painted along the walls or the dove that bears an uncanny resemblance to a condor, the Incan religion remains blurred within teachings of the present day faith.

The highlight of the entire *Cusco* trip was, of course, *Machu Pichu*. This towering city of the Inca, which is accessible only by train and foot, sits upon an Andean peak in the “eyebrow of the jungle.” By this point in my trip the dry, sand-covered terrain of northern



Peru had disappeared and the lush, verdant slopes of the Andes came to dominate. Lucho and I explored the sight for an entire day and even managed to climb neighboring *Huayna Picchu* to get a spectacular bird’s eye view of the town below. It was quite possibly the most exhilarating place I have been and will never forget trekking back down the mountain to soak in the natural hot springs in the small town of *Aguas Calientes* at the bottom of mountain.

My last trip was to the North to attend the wedding of my Peruvian Mother, Ida’s, brother. The wedding was eleven hours north of Lima in the sands of the coastal city of *Chiclayo*. From the moment I entered *Chiclayo* I was accepted as a family member and fed fresh fish and fried bananas until I was completely saturated with gills and grease. The wedding was a wonderful experience and bore many resemblances to an American wedding except for the later schedule on which everything ran; dinner wasn’t served until 12:30 AM and salsa dancing followed until six in the morning.

The remainder of my stay in *Chiclayo* I spent visiting the extensive museums filled with pre-Inca artifacts, and learning about the cultures that dominated Peruvian life before the Incan expansion.

After my summer spent abroad, I found that the quote “distance makes the heart grow fonder” is a completely valid statement; of what, however, it fails to specify. Is it that one

grows fonder of the people and land one has left behind; or, is it rather that distance from things common to oneself makes one cleave to the new in an eager and absorbing way? I have found the latter to be more to the point when describing my time in Peru. Over the duration of a single summer, I saw some of the most beautiful places and met some of the most beautiful people in a country surrounded by poverty and struggle and managed to be captivated by it all.

International Potato Center



International Potato Center: Introduction:

The world, and its six billion inhabitants, continues to burgeon at an expected rate of 100 million per year (www.cipotato.org) and the strains that tear at her resources grow more intense with each passing season. Deficiencies, pandemics, poverty, hunger, war, all grip her throat and threaten to strangle her last gasp of breath. All too often those of us who have grown up in a stable environment and never had to face the harsh reality of hunger, tend to dismiss the world's problems as a horrendous but natural occurrence. Have not these horrors prevailed on earth since the first organisms began to compete and separate the world into the "Haves" and "Have Nots?" The interminable cycle of poverty, anger, violence, and the whipping of the many to feed the few seems overwhelming and too much to bear. That may be the reason so many of us choose not to acknowledge it or give it the attention it deserves. There are, however, people and organizations who have taken a different approach. There are those who have seen the pleasures

and pains that this world has to offer and have devoted their lives to making whatever beneficial impact they can. One such organization is the International Potato Center.

Set among one of the most afflicted and socially unstable nations in the world, the International Potato Center, or CIP, has taken it upon itself to breed hope in a world of despair. Centered in the bustling capital city of Lima Peru, CIP has spent the last thirty-three years striving to meet their ambitious mission statement:

“ to reduce poverty and achieve food security on a sustained basis in developing countries through scientific research and related activities on potatoes, sweetpotato, and other root and tuber crops, and on the improved management of natural resources in the Andes and other mountain areas.” (www.cipotato.org)

CIP is a member of the Consultive Group on International Agricultural Research, CGIAR. It currently employs scientists from 25 countries around the world, and has outposts in all three geographically distinct regions of Peru and one in Ecuador. Collaborators in Asia, Africa, and Latin America are also considered members of the CIP team.

In order to supply potential breeders with the most beneficial potato varieties and supply food aid to needy countries, CIP maintains the world’s largest germplasm genebank. The genebank contains approximately 5,000 potato varieties, 6,500 sweetpotato varieties, and 1,300 other Andean roots and tubers.

CIP conducts its research through four main research departments:

1. Crop Improvement and Genetic Resources
2. Crop Protection
3. Production Systems and Natural Resource Management
4. Social Sciences

Through these varied departments, CIP is able not only to advance and engineer a stronger potato crop, but to effectively cooperate and collaborate with the farmers, consider the social impact of their work, and work to secure the health of the earth's natural resources.

Peru serves as the ideal location for the Center as it is the birthplace of the potato and has been consumed in the region for the past 8,000 years. The potato has long been the staple food commodity in Peru and, after the Spanish conquest of the 1500's, has grown to its current status as the world's fourth most important food crop with over 300 million tons produced annually (www.cipotato.org).

Though it has been cursed throughout the ages and blamed for obscure plagues over the years, the potato, or *Solanum tuberosum*, is a truly remarkable crop. Up to 85% of the crop is edible and it has the potential to “yield more nutritious food more quickly on less land and in harsher climates than any such major crops as wheat, corn, and rice” (www.cipotato.org). A single, medium-sized potato can contain half of the daily Vitamin C requirement of an average adult, has only a 5% fat content, and when boiled contains a higher protein content than maize and up to twice the calcium. (www.cipotato.org)

The Native Andean Potato, of which there are around 4,000 varieties, remains an untapped resource that CIP is trying to unleash. Native Andean Potatoes are those potatoes found in the Andes Mountains that have yet to be studied and commercialized. These varieties have been found to contain anywhere from 18% to 36% dry matter



content as compared to the maximum 20% found in most commercial varieties.

As a result of Peru's extraordinary geographical diversity of desert coast, towering mountains, and humid Amazon rain forests, the native potatoes that have evolved here have done so under some of the harshest and most varied conditions. The traits that they have acquired over the years, such as frost resistance when grown in high elevations or specific pest resistance, is just starting to be understood and stands to make significant improvements in the commercially available varieties.

Actions are currently being taken to commercialize these native varieties but, as of late, have met with little success. The main explanation appears to be humanity's resistance to change. We have become accustomed to the plain white potato that saturates today's market and have been unwilling to change even when confronted with more nutritious varieties. The world population stands to gain much in the way of pest and frost resistant varieties as well as improving the living standard for rural Andean potato producers.

Primary Experiences at CIP:

I first arrived at the International Potato Center on June 8, 2004 the day after I arrived in Peru. The first thing that made an immediate, agreeable impression was the vitality of the place. I was amazed to find that the vast majority of the scientists were in their twenty or thirties and this helped to make my adoption into the CIP family painless. Gabriela Burgos, Mariela Auqui, Kelly Moron, and Eduardo Parras couldn't have been more helpful and understanding in teaching me my way around the laboratory.

I was scheduled to begin my work with Gabriela Burgos when my specific potato samples arrived; until then, however, I had the privilege of spending the first few weeks working at various stations around the center.

Processing Laboratory

I began working with a delightful young woman named Faviolla in the processing lab. Receiving the samples, slicing, washing, frying, and packaging them, we were to check the quality of the potato varieties in terms of processing. I was not in the processing lab long enough to see results, but the potatoes would be judged on the basis of two parameters:



- Color – The lighter the color of the chip the more appealing and desirable it is to producers.
- Dry Matter Content – A potato with high dry matter content absorbs less oil during processing rendering it cheaper and more cost effective to producers and more appealing to health conscious consumers.

Within a few days I was helping Faviolla with her English homework, and she was teaching me some of her native Quechua. The job was not without its perks; at the end of the day when all of the left over samples cluttered the lab, they made for a tasty, unhealthy snack.

Genebank

I had the privilege of spending a few days working in the world-renowned germplasm genebank located at CIP headquarters. As mentioned earlier, CIP's genebank is the largest in the world with well over 12,000 varieties of



potatoes, sweet potatoes, and other Andean roots and tubers. I began by working in the In-Vitro laboratory where live samples of all of CIP's varieties are kept in test tubes in secure rooms for use at a later date. My work would involve introduction and propagation within the In-Vitro Lab.

Introduction is the process of introducing a new potato species into the comprehensive CIP genebank. Although a similar process is used for potatoes I was working with camote or sweet potato.

My first task was to cut small pieces from a full sized plant grown in CIP's greenhouses. We would be introducing ten samples for ten new varieties. The process is fairly time consuming and done under the strictest of hygienic practices.

The newly cut plants are placed in their separate test tubes in a specific nutrient-rich gel. They are sealed, labeled, and placed among the throngs of other samples that occupy the genebank.

Propagation refers to the propagation of samples that have already been introduced into the genebank. This process is used for varieties that were long ago introduced and have since grown too large for their test tubes and require new samples to be introduced. The "new" samples are not really "new" but rather clones of the old plants. This process insures that CIP will always have at least three living samples of each variety.

Evaluation of the Vitamin C Content of Potato Genotypes, as Affected by Peeling Utilizing a Spectrophotometric Method

“Now, be sure and eat your potato peels. Don’t you know it contains all of the nutrients?”

At one time or another everyone has heard this refrain pass from the mouths of one of their health-conscious guardians. However, is there any validity to the statement? When I was young, I thought it was just a game adults played to show who had authority. My only defense was to stubbornly shut my mouth and put on the biggest frown my little face could muster. Today, I have more sophisticated tools. Working through the International Potato Center, I would be able to analyze different potato varieties to get to the bottom of this problem and come to the aid of children world-wide or side with my elders on the benefits of consuming the *entire* potato.

Alright, so this story is a tad exaggerated, but it does raise the question: What parts of a potato contain the highest degree of nutrients? It struck me as odd when I arrived in Peru to find that almost every time I saw someone eating potatoes it was *without* the peel. Even among the rural highlanders, who remain among the poorest and most malnourished in the country, the potato peels remained untouched due either to custom or a sense of pride.

This was the reason I chose my project along with the fact that my supervisor, Gabriela Burgos, had been conducting native potato assays for the past year and had the knowledge and equipment to carry out the needed experiments. Gabriela is a research assistant in the

Germplasm Enhancement and Crop Improvement Division and is currently conducting her research as part of the Harvest Plus project.

“Harvest Plus is an international, interdisciplinary, research program that seeks to reduce micronutrient malnutrition by harnessing the powers of agriculture and nutrition research to breed nutrient dense staple foods. (www.harvestplus.org)”

The main tool used by Harvest Plus is a process called bio-fortification, the breeding of crops rich in bio-available micronutrients. The micronutrients that Harvest Plus focuses on are Iron, Zinc, and Vitamin A. Vitamin C, however, is an extremely beneficial and necessary micronutrient that has largely been overlooked in native Andean potatoes.

Bio-fortified foods have the possibility to provide the world's malnourished and impoverished with the vitamins and minerals they so desperately need. First, however, the research must be done to decide which crops are high in such micronutrients and are logical choices for bio-fortification.

The Potato is a Phase 2 crop. This means that very little is known concerning the nutritional concentrations in the vast array of varieties found not only in Peru, but also around the world. This is, indeed, an oddity given that the potato is the fourth most important food crop in the world. The native Andean potato varieties remain practically a mystery and are ripe for inquiry. In fact, it is not even known what constitutes a high Vitamin C or mineral concentration in native potatoes. The research that Gabriela is conducting and which I have conducted is the first of its kind and will serve as the basis for further studies.

Gabriela had chosen to study native Andean varieties from a highland potato producing community named *Huancavelica*. She has been conducting Vitamin C, mineral, and

polyphenolic determinations as a way to provide Harvest Plus and the farmers of *Huancavelica* with potentially better potato crops. In poor communities such as *Huancavelica* in Peru, the potato is the staple food commodity and can nearly provide a highlander's entire daily nutritional intake. These individuals are, therefore, at great risk of starvation should any forces culminate and destroy a potato harvest. Conversely, these same individuals stand to gain much, not only in nutritional improvement, but also socially and economically, by any advancement in the food that serves as their livelihood.

Enter Andy, and his summer internship in the Andes. The research that I came to conduct concerned not only the mineral content of native Andean potatoes, but also the Vitamin C concentration and the effects that peeling has on the Vitamin C content of the given varieties.

My Project:

I began my research with these two hypotheses:

1. *Peeling the given raw tuber samples will significantly lower the concentration of Vitamin C.*
2. *Peeling the given raw tuber samples will lower the mineral content of the samples.*

It is my hope that the given data may be useful for further studies of Native Andean potatoes and the potato in general as a tool to combat world hunger.

The Importance of Vitamin C

What is Vitamin C?:

As part of my work at CIP, I first had to become acquainted with the material with which I would be working. This meant doing research on Vitamin C and understanding its vital role in an individual's well being.

Ascorbic Acid and Ascorbate have come to be affectionately known as Vitamin C. Vitamin C is a water-soluble, "six carbon lactone" synthesized naturally by many animals (FAO/WHO). However, some organisms, including humans, guinea pigs, and Indian fruit bats, are not able to synthesize Vitamin C internally and are dependent on nutritional intake to meet their daily requirements. The Vitamin C acquired through food, drink, or supplemental use is stored in the liver of humans and excess Vitamin C is excreted through urinal waste.

In order to meet an average individual's daily requirement of Vitamin C, quantities ranging from 40 mg/day to 90mg/day are suggested. The average American consumes 72 mg/day. As with all things in life, differing amounts of Vitamin C should be consumed depending on the needs of the individual. It is a general rule, however, that pregnant, nursing, and individuals who smoke need increased amounts of Vitamin C in their daily diets.

However, there is a limit to the amount of Vitamin C an individual needs to consume. Amounts in excess of 1 gram/ day prove useless to the body and are usually excreted by way of urine. Larger excesses of 2 to 3 grams/day have been reported to cause diarrhea, gastrointestinal problems, and increase the chances of kidney stones.

Functions of Vitamin C in the Body:

Vitamin C has often been misunderstood as a “cure-all” vitamin and has been overused by some in an attempt to secure improved health. However, once understanding the functions of Vitamin C and consuming it in the appropriate doses, Vitamin C has proven to be beneficial in warding off specific diseases and is necessary for the continuation of life.

Vitamin C serves multiple purposes within the human body. However, it is best recognized for its uses as:(FAO)

- An anti-oxidant and as a catalyst within the body. This means that it prevents harmful free radicals from damaging cell tissue, which might culminate in cancer.
- A facilitator in the uptake of such vital minerals as Iron and Copper.
- The fundamental facilitator in the production of the most abundant fiber contained in connective tissues, collagen. Collagen supports and connects the majority of the human body.
- A protector of fat-soluble Vitamins A and E and fatty acids from oxidation within the body.
- A protector against Scurvy. Scurvy has been found to be present in individuals receiving less than 6.5 to 10mg/day of Vitamin C or when the whole body content of an individual falls below 300mg.

Varying Vitamin C Content:

Vitamin C is a highly degenerative substance and is, therefore, susceptible to significant losses caused by “season, transport to market, shelf life, time of storage, cooking practices, and chlorination of water.”(FAO/WHO) It is also extremely light sensitive. Exposure to all forms of light greatly reduces the various amounts of Vitamin C in food products. All of these factors needed to be accounted for when conducting my Vitamin C analyses.

As mentioned above, Vitamin C is crucial in facilitating the uptake of such minerals as Iron and Copper. As iron deficiency is the most common micronutrient deficiency in the world, reported by the World Health Organization to afflict some 66-80% of the entire population, Vitamin C is of prime importance in the fight against Iron deficiency. Therefore, it is crucial to study Vitamin C in conjuncture with any attempts to combat the deficiencies that it helps to control.

Laboratory Work

Throughout this paper I use the term “I.” While it is true that I did much solo work during my time at CIP, I was taught and aided tremendously by Gabriela Burgos, Mariella Augui, Kelly Moron, Eduardo Porras, and the rest of the CIP team. Without the help of these individuals I would never have been able to complete the following trials. I owe my tremendous experience working at CIP to these individuals.



In order to analyze the various amounts of Vitamin C in a substance, one commonly used procedure is the *spectrophotometric method*. This utilizes the color absorption properties that all substances possess and allowed me to reference the obtained results by passing light through our samples and checking them against standards with a known concentration. For my given extractions, I used a light with a wavelength 520nm, which falls within the visible light

spectrum. The Beer-Lambert Law was then applied to determine the given concentration in each substance depending on how much light was absorbed or reflected. Every substance has a wavelength at which it absorbs the maximum amount of light. This data can be processed in an absorption spectrum, which shows the maximum and minimum wavelengths at which light is absorbed. The Law is expressed as “ $A = \epsilon l C$.” I will come back to the values plugged in for each coefficient when I address the ascorbic acid standard curve.

I studied six varieties of native Andean potatoes. All of the samples were chosen from the fields at random and preparation of the samples allowed for equal representation of all of the samples as will be shown in the setup. They weren't confined to Huancavelica as were Gabriela's, but represented a wide range of varieties from Ayacucho with one, Canchan, being added to the list because of its rising popularity.

One of the best parts about working at CIP was getting to see all of the polychromatic potatoes and to hear the bizarre names they carried; my samples were no exception. They included Socco Huaccoto, Maria Cruz Gon, Cuchi Chuccan, A+/- IL Papa Stn., Morado Taruna Stn., and Canchan.



My first task was to retrieve the samples and remove any debris so the mineral analyses were representative of the samples and not, say, of the soil in which they were grown. In other words, I had to spend all day washing potatoes. This was not a fun task, but it was necessary.

After washing the samples, I had to sort out the usable ones from the damaged and sort them as to which would be used for mineral analysis and which would be used for Vitamin C determination.

My basic setup was:

- I would use six varieties of tubers in both the mineral and Vitamin C analysis.
- In the Vitamin C trials, each variety would be tested with three repetitions of three tubers per repetition. Also, each variety would need to be prepared both with and without the peel. (18 tubers per variety)
- In the mineral analysis, three repetitions, with six tubers per repetition were used. Since the tubers needed to be analyzed both with and without peel, 36 tubers were used per variety. (36 tubers per variety)
- This comes to a running total of 324 tubers to be analyzed - - 54 tubers per variety. (It should be noted that I did not have sufficient Canchan supplies and, as a result, only two repetitions were completed for both peeled and unpeeled mineral analysis and two repetitions for the Vitamin C analysis. In addition, the first Canchan repetition without the peel contained only two tubers instead of the standard three.)

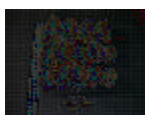
I began with sufficient samples and have recorded them below. The * represents those used for Vitamin C analysis and the “regular” are for mineral analysis.



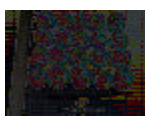
NP 09.01
 Socco Huaccoto, = *39+ tubers regular= 40+ tubers
 Ayacucho
 Weight Distribution = 74.72g – 29.42g = 45.3 grams
Total= 79 tubers



NP 01.09
 Maria Cruz Gon, =*32+ tubers regular= 40+ tubers
 Ayacucho
 Weight Distribution = $120.85 - 48.84 = 72.01$ grams
Total= 72 tubers



NP 08.04
 Cuchi Chuccan, =*40+ tubers regular=40+tubers
 Ayacucho
 Weight Distribution = $151.22g - 40.97g = 110.25$ gram
Total= 80 tubers



NP 01.07
 A+/- IL Papa Stn., =* 40+ tubers regular=40+tubers
 Ayacucho
 Weight Distribution = $52.14g - 23.15g = 28.99$ grams
Total= 80 tubers



NP 02.02
 Morado Taruna St., =*39+ tubers regular=40+tubers
 Ayacucho
 Weight Distribution = $108.89g - 53.36g = 55.53$ grams
Total= 79 tubers

After washing and sorting the samples, I was ready to begin my preparations for analysis. The mineral sample preparation would be conducted first and the Vitamin C samples were stored in the “Camara Fria” at four degrees Celsius because Vitamin C is an unstable micronutrient and degrades with exposure to heat and the passage of time.

Mineral Analysis:

The procedure I used for the mineral analysis was developed by Gabriela Burgos in collaboration with Waite Analytical Service at Adelaide University, Australia and is briefly paraphrased below by myself. The steps are as follows:

- Three repetitions of each sample. A sample containing six tubers was prepared by rinsing and peeling the tubers.
- The tubers were cut longitudinally into four sections to insure representative results. Two opposing sides were then taken for the mineral analysis and the other two for polyphenolic and chlorogenic acid analysis that Gabriela was conducting at the same time.
- The two sections were sliced with a stainless steel slicer to obtain 50g fresh weight samples to be placed in an oven to dry at 80°C for twenty-four hours. The other two samples were sliced to obtain 100g fresh weight samples and placed in polyethylene bags and stored at -20°C.
- After a period of no less than twenty-four hours, the samples were removed from the oven and weighed to determine their dry matter content. They were then milled and placed in paper bags to be sent to Adelaide University, Australia for mineral analysis.
- The preparation for the unpeeled samples is exactly the same except no peeling is required. The tubers must be rinsed in Nitric acid 0.1% for approximately ten seconds and then rinsed with distilled water in order to ensure that the peels are free of debris.

Vitamin C:

The Vitamin C analyses followed and were a complete change of pace from the mineral analyses. As opposed to the mineral analyses, the results of the Vitamin C analyses would be done entirely in the lab without the later stages carried out at another institution.

The basic procedures were developed by M.J. Egoaville; J.F. Sullivan; M.F. Kozempel,.; and W.J. Jones, in 1988. "Ascorbic acid determination in processed potatoes." American Potato Journal. Vol 65:91 – 97. Gabriela Burgos adapted them to fit our supplies and the laboratory's resources.

Before carrying out any Vitamin C analysis, I first had to prepare the extracting solution that, as its name implies, is used to extract the Vitamin C from the potato samples. The solution is prepared by dissolving 4g of oxalic acid in 100ml of distilled water. This solution is then carried to 500ml and 200ml of Acetone is added. The pH of the new solution is carried to a reading of 1.1 with concentrated sulfuric acid and carried to one liter for use in the analysis.

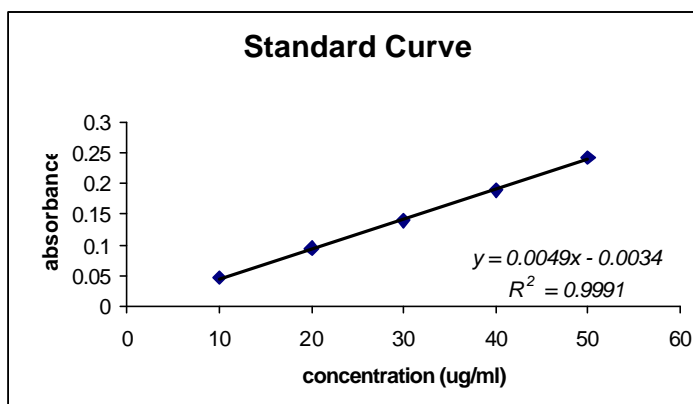
The other solution needed for the analysis was stock solution 2.6 dichloroindophenol (DCIP). This solution was referred to as "the dye." It degrades in the presence of Vitamin C. Therefore, depending on the degree of Vitamin C to which it is exposed and is thereby degraded, it will reveal a different absorption value.

This solution was prepared by dissolving 100mg of 2.6 DCIP in 100ml of warm water. 84mg of NaHCO_3 was added and the solution was transferred to a volumetric flask and carried to 500ml. The solution was then filtered with suction and stored in an amber flask to avoid degradation by the light. In order to use to the stock solution, it first had to be diluted with distilled water such that when 1 ml of the extracting solution and 9ml of the DCIP solution were reacted, an absorbance value at 520nm was obtained that fell between the range of .300 - .350 nm.

The last solution that needed preparation was the stock solution of ascorbic acid. This solution would be used to prepare the ascorbic acid standard curve against which we based our results. It was prepared by dissolving 100mg of ascorbic acid in 50ml of extracting solutions and carrying to 100ml. It also had to be stored in an amber flask because Vitamin C degenerates rapidly when exposed to light.

After finishing all of these solutions, I had to construct my Ascorbic Acid Standard Curve. To do this I took standard solutions with concentrations of ascorbic acid at 10, 20, 30, 40, and 50mg/ml and carried it to 100ml with the extracting solution. The following steps were used not only for developing the Ascorbic Acid curve, but also for the Vitamin C extractions I would soon execute.

1. Mix 1ml of the extracting solution with 9ml of the 2.6 DCPI and read the absorbance on the spectrophotometer at 520nm three times. This result is called the *Reagent Blank*.
2. Mix 1ml of the standard with 9ml of the 2.6 DCPI and read the absorbance three times to find the *Standard Absorbance*.
3. Mix 1ml of the standard with 9ml distilled water and read three times to find the *Standard blank*.
4. Subtract the Standard blank from the Standard Absorbance and subtract this value from the Reagent Blank. The result is called the Real Absorbance and is plotted against the concentration of the given sample using the Beer – Lambert Law.



I mentioned earlier that I would explain this law and it's mathematical expression: "A = ElC". Here, Gabriela set up the function to read " $y = 0.0049x - 0.0034$ " where "y" is the

absorption and “x” the concentration for which I was looking. The other numbers depend on the substance being analyzed and the Standard Blank developed earlier with the Ascorbic Acid curve.

Once I prepared the solutions and the Ascorbic Acid Curve, I was ready to carry out the extractions.

The procedure recommends that tubers weighing between 60 – 70 grams be used. My samples, however, varied greatly on both sides of this number. I weighed them again and recorded the data of each sample I used. (Results not shown)

Unlike the mineral analyses where all of the peeled trials were conducted and then the unpeeled, the Vitamin C analyses required an entire variety to be completed at one time to ensure that degradation due to the interval between trials didn't interfere with the results. Therefore, six raw tuber samples were prepared, three containing the peel and three without the peel. Three tubers were used to prepare each sample.

The tubers were rinsed once more and those designated to be peeled samples were peeled before cutting them longitudinally and taking the two opposing sides for the analysis. For the Vitamin C extractions, 15grams of the fresh weight sample was weighed and combined with 75ml of extracting solution. This solution was then homogenized in a “Sorvall Omni Mixer” for five minutes. The rest of the tubers that weren't used for the Vitamin C analysis were weighed into twenty-gram samples for dry matter determination.

The homogenized solution was then filtered with suction through “Whatman #2” filter paper. The obtained Vitamin C extract was, then, transferred to an amber volumetric flask and carried to 100ml with extracting solution.

The same steps were used as when establishing the ascorbic acid curve to find the *Reagent Blank*, the *Sample Absorbance*, and the *Sample Blank*. After each reading the *Sample Blank* was subtracted from the *Sample Absorbance* and this result was subtracted from the *Reagent Blank*. The number obtained, or the *Real Absorbance*, was used to estimate the Vitamin C concentration in each sample and had to fall between the range of .047 - .243 or the numbers established from the ascorbic acid standard curve.

For my own better understanding of the results, Gabriela went over how to convert the data into numbers that are in a more convenient form in both fresh weight and dry weight. Fresh weight values may be more pertinent when dealing with the quantities that an individual may consume. Dry weight, however, is often the data used when discussing the values scientifically and corrects for higher degrees of water retention that may alter the results.

Conclusions:

Mineral Analysis Results:

The mineral analysis determined the Iron, Manganese, Boron, Copper, Molybdenum, Cobalt, Nickel, Zinc, Calcium, Magnesium, Sodium, Potassium, Phosphorus, Sulfur, Aluminum, and Cadmium concentrations of each of the six varieties. However, I have listed only the relative concentrations for Iron and Zinc. This is due to the high priority that Harvest Plus Programs has placed on the value of these two minerals in combating nutritional deficiencies.

The results show that, in each variety, the relative concentrations of Iron and Zinc increase with retention of the peel. In some cases the difference may be insignificant, but in such samples as Socco Huaccoto and Morado Taruna the difference is plainly visible. (Results in graph form are shown below.)

Socco Huaccoto showed the highest values of Iron concentration with 2.65mg of Iron per every 100grams of non-peeled sample. Maria Cruz had the lowest non-peeled iron concentration with 1.98mg/100g. In peeled samples, Cuchi Chuccan lost only .06mg of Iron and retained the group high of 2.33mg/100g. Conversely, A +\ IL Papa Stn lost .8mg to end with just 1.66mg/100g.

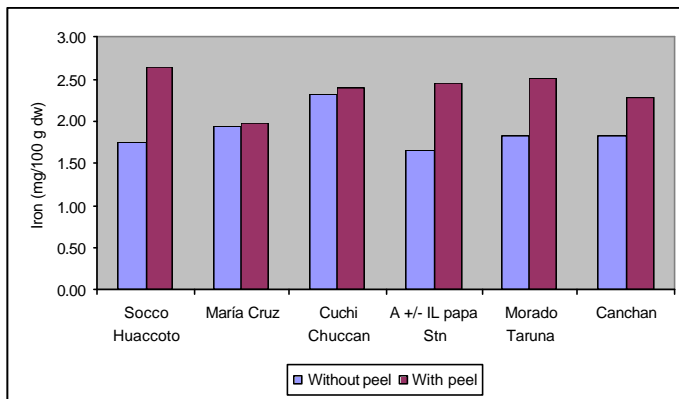
In the zinc results, Morado Taruna revealed the highest levels of concentration for non-peeled samples with 1.34mg/100g while Cuchi Chuccan had only 1.02mg/100g. For peeled samples, Maria Cruz had the highest concentration with 1.11mg/100g. Cuchi Chuccan had the lowest levels of concentration by losing .03mg and ending with .98mg/100g.

Based on these results, one hundred grams of variety Socco Huaccoto could supply approximately 25% of the average individual daily Iron requirement for males.(NIH) Also, varieties high in Zinc Concentrations, like Morado Taruna, have the ability to provide up to 12% of the daily Zinc requirement for 100 gram samples.(FNIC).

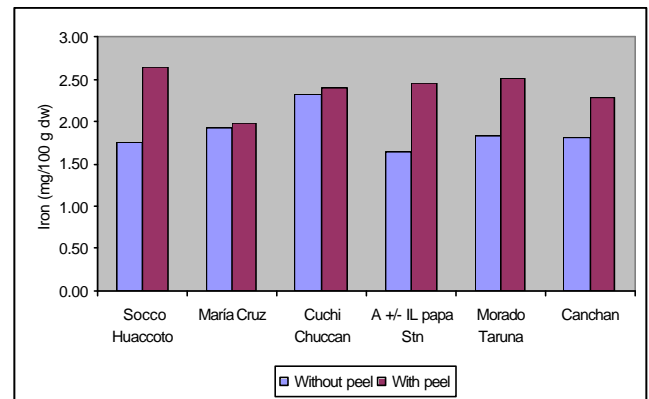
Therefore, my hypothesis that “*Peeling the given tuber samples will lower the mineral content of the samples.*” was proven valid for all but one variety with respect to the Iron and Zinc concentrations. The only exception was variety Maria Cruz whose zinc content actually lowered by .03mg/100g. However, this amount is probably due to the variations in the testing method and is not representative of the overall trend. It should, also, be noted that possible soil

contamination was possible, and multiple trials need to be conducted before stating any definite conclusions.

Fresh Weight

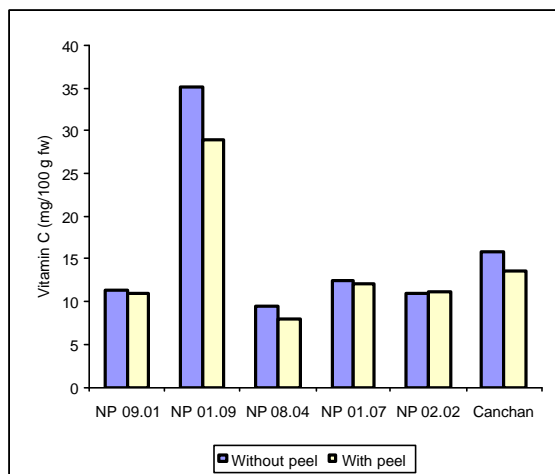


Dry Weight



Vitamin C Analysis Results:

The results from my Vitamin C extractions had a very different outcome than I had expected. It turns out that consuming the entire potato actually yields a slightly lower Vitamin C content in at least four of the varieties than if the potato was peeled. The results are close and the

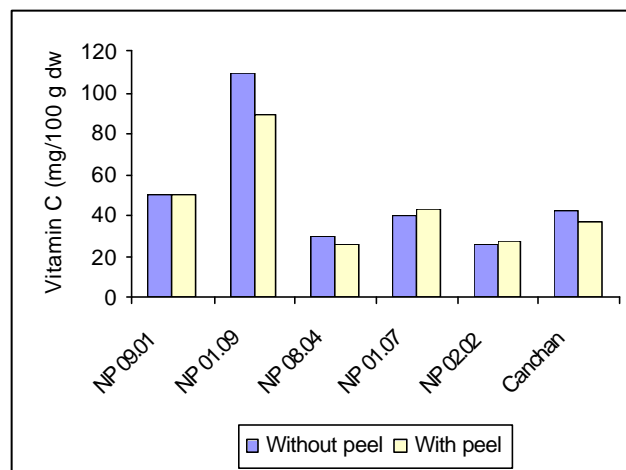


difference in varieties 09.01, 08.04, 01.07, and 02.02 are too minor to be considered significant, but they still differ from the lowered concentrations that were expected.

The Vitamin C content of the six varieties of potato ranged from NP 08.04 with 8.04mg/100g

fresh weight to NP 01.09 with 35.13mg/100g fresh weight. This means that variety NP 08.04, which yielded the lowest concentrations of 8.04mg/100g, would almost meet an average individual's daily requirement to ward off the effects of Scurvy. Also, the concentration found in 100gram samples of NP 01.09 Maria Cruz potato without the peel could supply almost 90% of an individual's daily Vitamin C requirement as compared to the less than 50% provided by some commercially available products. It should be noted, however, that when cooked, the relatively high concentrations found in Maria Cruz might be substantially lowered and would require a higher intake to meet daily requirements.

My hypothesis that peeling the potato would lower the Vitamin C content and thus degrade the nutritional value of potatoes was proven *false* in all of my samples except for NP 02.02 in the fresh weight group and both NP 02.02 and NP 01.07 in the dry weight group.



Could it possibly be true that my grandmother was wrong? Does this mean long-awaited relief from the torture of consuming an entire potato for children around the world? Most significantly, does it mean that poverty fighting agencies should advocate that potatoes be peeled before consumption?

These results are in no way indicative of all potato varieties and multiple trials need to be conducted before any conclusive argument can be made. Experiments with samples of the same variety but grown in different locations should, also, be conducted before any results are made

final. This will ensure that any advanced breeds of biofortified potatoes will provide the same yields on a farmer-to-farmer basis no matter where the new breed is introduced.

In addition, it should be taken into consideration that I did not have a sufficient time to conduct trials on both cooked and uncooked samples. Raw samples are more convenient for conducting analyses but are not necessarily the most common way to eat a potato. Should the samples have been cooked before analyses, very different results might have been obtained. Perhaps the peel acts as a shield against the heat and oxidation that occurs during cooking and would, thus, protect the Vitamin C from degradation. It might also be possible that peels analyzed separately from the whole potato would yield a higher concentration per volume than that of the center. All of these are speculations, but need to be taken into consideration before coming to any conclusions.

Final Summary of Results and Observations:

In my brief overview of Vitamin C, I found that a daily recommendation for the average adult can range anywhere from 40mg/day to 90mg/day. This means that an individual only needs to consume a little over 100g/day of such uncooked varieties high in Vitamin C, like Maria Cruz Gon, in order to meet the minimum daily requirement. Depending on the variety, this translates into about one or two average sized potatoes per day.

One hundred grams of varieties high in Iron content, like Socco Huaccoto, can supply approximately 25% of the a male's daily recommended intake for iron.(NIH) One hundred grams of varieties high in zinc, like Morado Taruna, can supply up to 12% of the average male's daily recommended intake.(FNIC)

Based on the results that I found, variety NP 01.09 Maria Cruz Gon contained the highest concentration of Vitamin C per 100grams of fresh and dry weight potato. I would, therefore, recommend that when breeding HarvestPlus Projects or any other aid agency consider the Maria Cruz variety in their trials.

In the mineral results, I found that variety NP 09.01 Socco Huaccoto had the highest Iron concentrations for unpeeled samples while NP 08.04 Cuchi Chuccan retained the highest concentrations for the peeled samples. However, NP 02.02 Morado Taruna showed the highest concentrations of zinc for unpeeled samples and NP 01.09 Maria Cruz the peeled samples. Therefore, these varieties might prove beneficial to Harvest Plus Programs in carrying out bio-fortification processes.

The custom I had noted and thought so strange beforehand, that everyone in Peru peeled their potatoes before consumption, returned to me. What had been attributed to custom or a sense of pride might actually have been the instinctive know-how of a native people pertaining to the crops that have sustained their ancestors since the first Peruvians figured out that this strange looking plant was edible. This concept seems counterintuitive, but might come naturally to those who have lived with these native potato varieties all of their lives and have come to depend on them for their livelihood.

Conclusion:

Organizations such as the World Food Prize and the International Potato Center strive everyday to improve the lives of thousands of people around the world. While I am sure that their beneficial work has reached those most in need of their services, I am also sure that they have reached me. Though I remain indebted to these organizations for different reasons than the malnourished, my gratitude is very real. I can not express how this past summer has opened my

eyes to hunger-related issues, scientific research, independent living, and a beautiful and welcoming culture personified in all of the wonderful people I met. Thank you for this life-changing opportunity.

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