Science of the Potato for the Poor

A Peruvian Experience to Remember

International Potato Center
La Molina, Lima, Peru

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"Food is the moral right of all who are born into this world." - Dr. Norman Borlaug


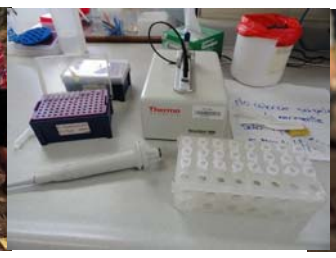


TABLE OF CONTENTS

ACKNOWLEDGMENTS

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I finally would like to thank my amazing family: my father, Dr. Venkataramana Ajjarapu, my mother Dr. Uma Ajjarapu, and my sister, Aparna Ajjarapu, for providing me unconditional support throughout my eight-week international experience. I truly appreciate their love and encouragement throughout all of my high school endeavors.

The Global Youth Institute 2008:

It was an exhilarating experience to be present amongst world renowned scientists and policymakers at the 2008 World Food Prize Conference. As a representative of the Ames Extended Learning Program, I was privileged to attend both the World Food Prize Conference and the Global Youth Institute. My eyes were opened to the realities of world hunger, as I listened to leading scientists and policymakers give inspirational lectures. I sensed the impetus for reform, as I sat in luncheons amongst leading revolutionaries in global food security. Never had I learned more about global hunger than at the conference, and I truly began to understand the urgency for global initiative. The Hunger Banquet also served as a very humble eye-opener to the depths of poverty, as I sat on the floor with other Youth Institute participants, eating meager amounts of rice while watching the "upper-class" eat lavishly.

The Global Youth Institute event proved to be equally enriching. I was extremely excited to interact with other students with the same aspirations as I; to make a difference in the world at a young age. I was thoroughly amazed by the ideas of fellow Youth Institute participants. I also gained much knowledge from the panel group discussions, during which I presented my paper regarding the prospect of transgenic crop utilization in India. The dignitaries in my panel group were very passionate and gave extremely useful commentary regarding our individual research topics.

Later in the day, I listened to the 2008 Borlaug-Ruan Interns speak with great enthusiasm regarding their international research experiences. I was amazed at the work that they had accomplished. The inspirational World Food Prize symposium and intern presentations convinced me to pick up an application. The cultural-scientific combination that the unique Borlaug-Ruan Internship offered resembled no other program that I had heard of, and I eagerly waited for two years to meet the age requirement to submit my application.

After qualifying for the interview phase of the application, subsequent months consisted of ritually checking the mailbox in anticipation of an envelope that would reveal the fate of my junior summer. The letter I had been waiting for came with good news, and to my pleasant surprise, I was selected as a 2010 Borlaug-Ruan Intern. I had never really thought that the opportunity to travel internationally would ever come. In a

couple of months, I would be headed on a once-in-a lifetime trek to South America to the International Potato Center in Lima, Peru.

The beginnings of a whirlwind adventure:

Junior year flew by very quickly, as I arduously completed my Advanced Placement and final exams. It became progressively harder to concentrate on finishing the year, as a grand internship was looming just around the corner. The last day of junior year ended with a Spanish final, and I proudly stepped out of the school having successfully completed my penultimate year at Ames High School.

I immediately began preparing for my South American journey. After conversations with Allison Zhao, the previous Intern in Peru, I gained a greater notion for what to expect during my internship. The week before my departure went by faster than I had anticipated, and before I knew, it was time to finally leave. My close friends came over to my house the night before to give their final loving send-off. It didn't hit me until I gave my last strangling hug that I was going to be flying solo to a country that I had barely an acquaintance with.

Many questions fumbled through my head as my family and I made our way to the Des Moines International Airport. Would they like me? Would I fit in? Would I get lost? The nerves startled me, but once I bid farewell and headed for my terminal, a certain wave of confidence overcame me; the confidence that I could make the journey successfully.

The layover was long, so I decided to stop by a nearby Borders bookstore at the Houston airport to read a couple of travel books about Peru. In no time, I boarded a plane for a destination out of the country. I soaked in as much of the "Americanness" from the airport as possible, as it would be the last in eight weeks that I would reunite with my homeland.

I arrived at the Jorge Chavez airport in Lima at 1 AM and repeatedly rehearsed the procedure of leaving the airport in my mind:

"Customs, Baggage Claim, Immigration. . . Customs, Baggage Claim, Immigration."

Around 2 AM, I staggered with my massive bags outside the airport, where I frantically looked for a CIP board with my name written on it. I thankfully found the sign

and the bubbly man holding it. He warmly greeted me and showed me to the car. I was finally in good hands and could relax.

The scent of the air was like no other. The musty smell of dry earth filled my lungs, as we sped through the lighted streets of Lima. I was extremely excited to have made it in one piece, and was extremely eager to meet my host family.

As the car pulled up to the Bartolini home, Ida and Jaqueline Bartolini sped towards me to give me warm hugs and kisses and welcome me to their gracious home. Was I glad to have finally made it! I thanked them for their hospitality and began to settle in. I immediately fell asleep in my new room, as I was to attend work at the International Potato Center at 6 AM that very day. I called my mother, said goodnight to my family, and closed my eyes to await an adventure that would last another eight weeks.

The International Potato Center

The International Potato Center or El Centro Internacional de la Papa (CIP) was founded in 1971. CIP's main objective is to reduce poverty and achieve food security and sustainable human development through scientific research and related activities on the potato, sweet potato, and other root and tuber crops. CIP also aims to improve management of natural resources in the Andes and other mountain areas.

CIP is located in the irrigated region of La Molina, a district just outside of Lima. CIP also has diverse experimental stations in Huancayo, San Ramón, and Quito, Ecuador. CIP is a member of the Consultative Group on International Agricultural Research (CGIAR) and has scientists from almost thirty countries.

CIP's potato and sweet potato collections are the largest in the world, comprised of 5,000 distinct types of cultivated potatoes, more than 2,000 wild relatives of the potato, and around 6,000 types of sweet potato[3]. CIP's germplasm collections preserve the vast genetic diversity of the crops and provide for a library of characteristics that may be crucial in future breeding programs. These programs aim to improve the quality of potato and sweet potato planting and breeding materials by targeting production constraints such as vulnerability to pests, diseases and climatic stresses, and enhancing taste and texture, nutritional quality, and yield[3].

CIP's Genebank is largest compillation of potato germplasm collections in the world

RESEARCH OBJECTIVE:

During my internship at CIP, I worked in Division 3 under Dr. Meredith Bonierbale and Biol. Elisa Mihovilovich. My overall research objective was to improve the efficiency of breeding potato varieties by assessing the genetic and nutritional trait diversity in native Andean potatoes. My work entailed two specific objectives: (1) Characterization of the Stenotomun groups of native potatoes with molecular makers and (2) m icronutrient analysis in the Quality and Nutrition Lab to determine the carotenoid content in potato samples.

INTRODUCTION

The world's malnutrition figures are staggering. It is known that at least 1.2 billion people, to date, are living each day without the assurance of a nutritious meal for the next. "There are people in the world so hungry, that God cannot appear to them except in the form of bread"[Mahatma Gandhi]. How can we live our day-to-day lives ignorant of these staggering figures? This pressing issue has motivated researchers worldwide to come up with a solution.

The International Potato Center (CIP) was founded on the premise of helping to eradicate global hunger by means of conducting scientific research and related activities on potato, sweet potato, and other root and tuber crops. More specifically, CIP's Germplasm Enhancement and Crop Improvement Division, aims to develop new potato and sweet potato varieties with improved nutrient concentrations and disease resistance needed to help improve global food security.

Potatoes Feeding the World:

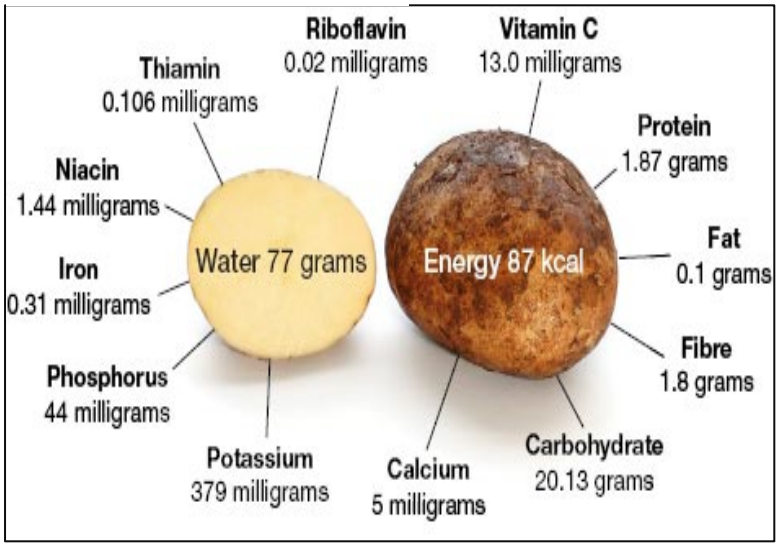
Not much is known to the general populous regarding the promise of potatoes and other roots and tubers for becoming an integral part of the global food system. For over 6000 years, the potato—or "la papa" in Spanish—has been utilized as a staple by a majority of the world's people. Moreover, the potato is becoming increasingly recognized for its diverse content of antioxidant compounds. Due to the tuber' s high starch content, the potato ranks as the world's fourth most important food crop after

maize, wheat, and rice. It is calorically rich, making it an excellent food for those who are actively engaged in laborious agricultural activities. Its energy content is also favored for its use as raw materials for animal feed, processed foods, and a range of industrial products. The potato also provides excellent sources of income and employment for farmers and communities.

The cultivated potato is thought to have originated 8,000 years ago in South America in the Andean mountain range, near the border of Peru and Bolivia. There are over 200 species of potatoes now in the Americas, but it was in the Central Andes that farmers succeeded in selecting and improving the first range of tuber crops. The potato spread to other parts of the world in the 1500s when the Spaniards took potatoes to Europe, where it eventually became an important staple crop.

Micronutrient Content in the Potato:

Courtesy of http://www.potato2008.org



Mineral micronutrients, though necessary in miniscule quantities, are nevertheless vital to human health. More than twenty mineral elements and forty nutrients essential to human health can usually be supplemented by a well balanced diet. It is almost impossible, however, for the greater majority of individuals who rely mainly on staple foods such as rice, wheat, maize, and cassava, to obtain balanced diets. Though good calorie sources, these staples supply insufficient amounts of the basic micronutrients. As a result, these persons become susceptible to micronutrient deficiencies. Over fifty percent of the world's population suffers from micronutrient malnutrition. The severe deficiency of vitamin A, for example, causes blindness and weakens the immune system.

Studies have shown that potato germplasm contains a wide-range of micronutrients that may allow the crop to be utilized in biofortification programs in effort to decrease global micronutrient malnutrition rates. Of particular significance in this

study is the carotenoid content in certain groups of potatoes. The tuber varies widely with respect to the types and concentrations of carotenoids it contains: White-fleshed types contain low levels of carotenoid, while yellow-fleshed varieties contain greater carotenoid concentrations. High carotenoid content in the potato may have particular value for human health due to its association with lowering incidences of macular degeneration and cataracts.

Beta-Carotene and Beta Carotene Hydroxylase

The identification of significant levels of carotenoid within potato germplasm has motivated scientists to optimize carotenoid levels. Beta-carotene is a provitamin that is actively converted to Vitamin A in the human body and beta-carotene hydroxylase is responsible for the synthesis of beta-carotene. The complete genomic sequence of beta-carotene hydroxylase has already been determined in potato. Variation in this structural gene has been found to be associated to differences in yellow flesh coloration and with variation in the accumulation of different levels of carotenoids. The identification of superior alleles correlated with an increase in the levels of carotenoids will allow for the development of functional markers to assist potato breeding programs in the identification of the best genotypes for use in biofortification.

Objective 1: Characterization of Stenotomun Groups of Native Potatoes with Molecular Markers

Utilization of SSR Markers

Genetic markers are utilized by scientists to study the inheritance behavior of target genes and to understand genetic diversity and relationships among species. A molecular marker is gene sequence with known chromosomal location near a target gene of interest. Markers are utilized based on the Mendelian linkage concept that genes that lie close together tend to be inherited together. Because molecular markers lie near genes of interest, they are inherited together and serve as tracking systems for scientists to study specific regions of an organism's genome.

Simple Sequence Repeat (SSR) markers are a newly developed type of marker technology. SSR markers are short fragments of DNA that repeat themselves numerous times. These repeated sequences, or core motifs, are usually only 2-5 base pairs in length. The high tendency for variation or polymorphism in the repetition of the core motif can be utilized to study inheritance patterns of target genes near the SSR markers.

The purpose of my first objective was to spend time in the Molecular Marker III Laboratory to determine if the potato samples selected for the study come from a single, two, or many distinct populations. Simple Sequence Repeat (SSR) markers of known map position in the potato genetic map were analyzed in ninety-four native accessions of the Stenotomun group of potato. The allelic variants found from SSR marker analysis of the Stenotomun group will be associated with carotenoid content through suitable statistical models that take population structure into account.

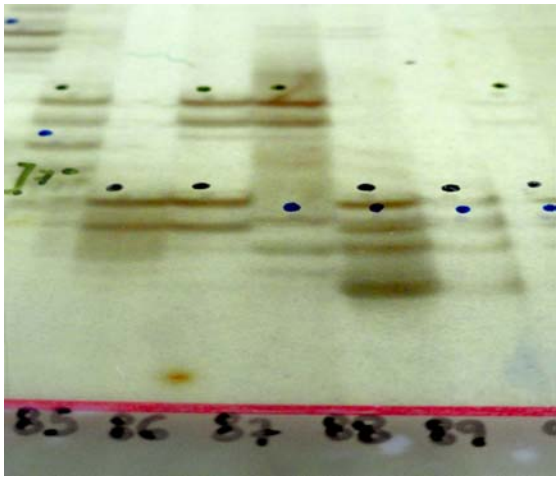
It is thought that models that do not consider population structure lead to false associations between allelic variants and phenotypic variation. Therefore, this first objective aims to utilize molecular markers to accurately consider population structure of the Stenotomun group in the association of allelic variants with phenotypic variation for beta-carotenoid production. Activities involved in realizing Objective 1 are summarized in the work-flow chart below:

Quantification of Stenotomun DNA Samples

PCR Amplification

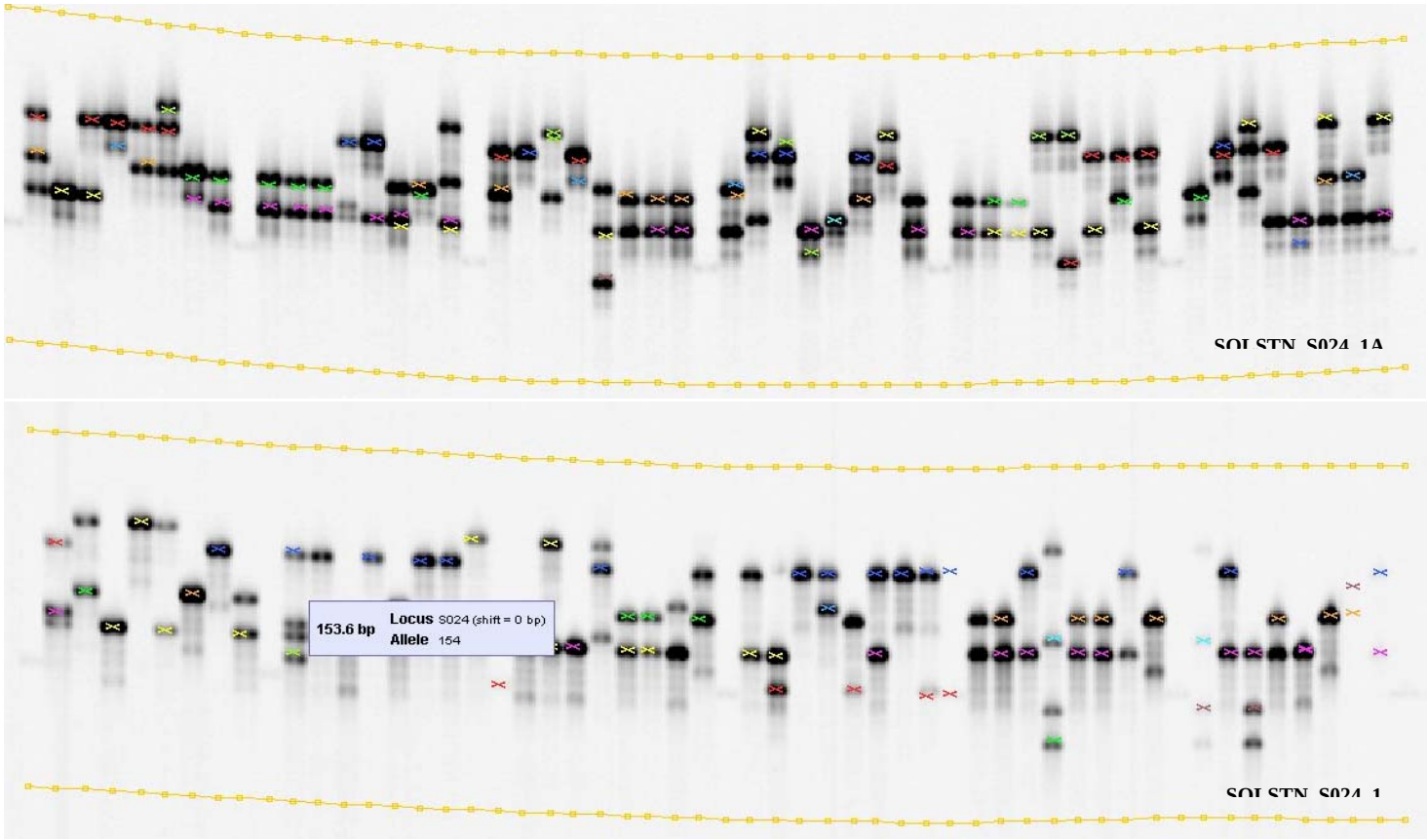
Preparation of PCR Cocktail and PCR Plates

Run Gel of PCR Products using Gel Electrophoresis



Gel Scoring and Preparation of SSR Matrix

I spent a great deal of time in screening and scoring gels produced from the PCR and Gel Electrophoresis experiments. Polymerase chain reaction (PCR) experiments were conducted to amplify the DNA samples and gel electrophoresis experiments were conducted to separate DNA fragments by base pair length. This allows one to visually observe the polymorphisms present amongst the Stenotomun DNA samples. A sample gel is presented:



The distinct bands in the gel indicate polymorphisms of the Stenotomun samples.

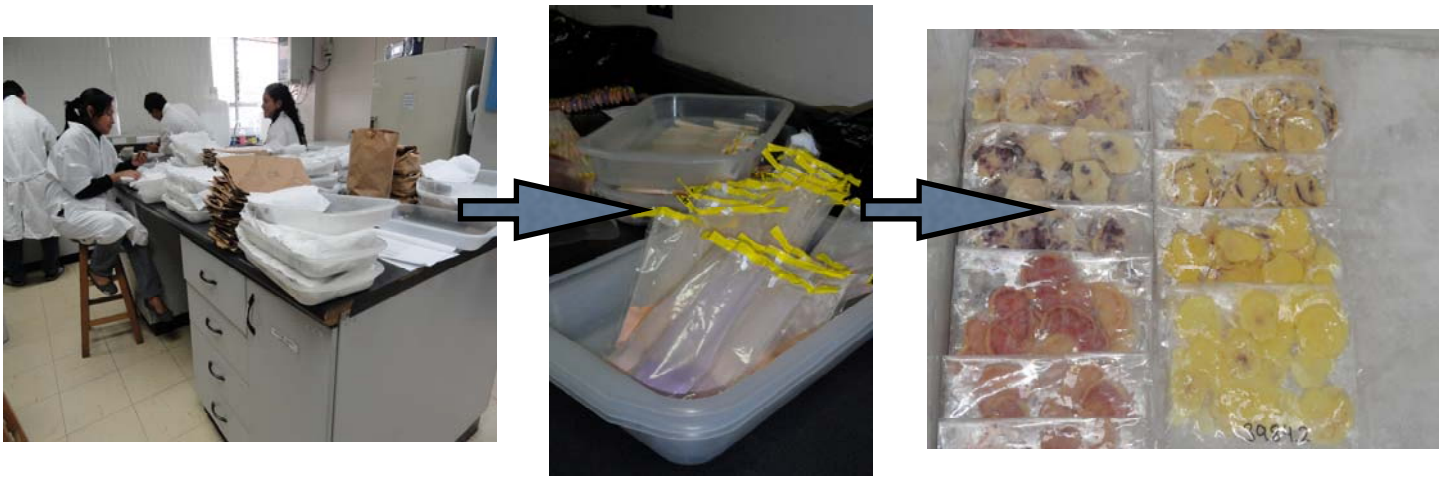
After scoring the gels for each SSR marker, data was then introduced to a matrix. A “0” was added for the absence of an allele and a “1” for the presence of an allele. The matrix that I completed with the primers assigned to me during the duration of my internship will be combined with data from other populations of Potato. The complete matrix of presence and absence of alleles at each SSR marker loci in this sample

population will be used to analyze the population structure of potato by means of suitable statistical software.

Objective 2: Micronutrient Analysis for Carotenoid Content

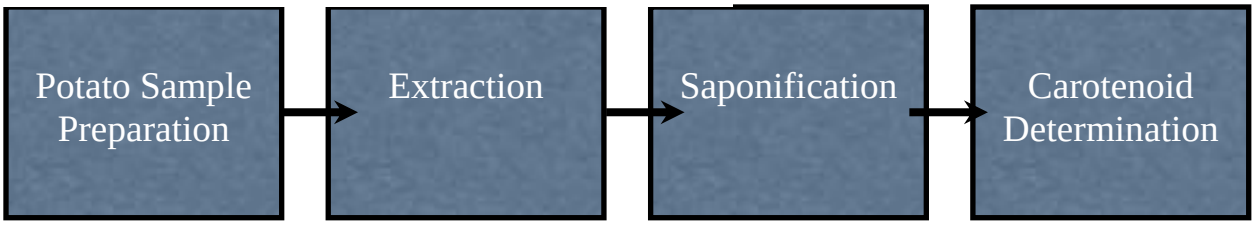
The Quality and Nutrition Laboratory (QNL) is responsible for obtaining and analyzing the phenotypic data from crop samples obtained from CIP's various field sites. QNL analyzes micronutrients and antioxidant concentrations in the potato and sweet potato using advanced technologies such as spectrophotometry, HPLC, and NIRS. QNL is the primary provider of phenotypic evidence needed to advance CIP's breeding programs related to biofortification and micronutrient enhancement and ultimately hopes to be utilized as a worldwide reference laboratory for nutrient analysis of staple food crops.

The purpose of my second research objective was to observe the workings of QNL and learn about their unique methods for micronutrient analysis. For approximately three weeks, I worked in the Quality and Nutrition Laboratory, participating in the various responsibilities of the lab. I did everything from packing and sorting potato samples to assisting in Vitamin C and zinc analysis. The most significant activity related to my research topic, however, was the observation and assistance in carotenoid extraction.



Packaging and sorting of potato samples analyzed using HPLC and NIRS technologies

Carotenoid Extraction from Potato:



**Carotenoid extraction protocol courtesy of Quality and Nutrition Laboratory.*

Sample preparation:

Potato samples were thoroughly washed using tap water, rinsed with distilled water, and dried with a paper towel. Samples were then peeled or left with skin depending on the type of analysis. Samples were then quartered longitudinally and the two opposite quarters were cut into small pieces and homogenized using a food processor. Opposite quarters of the potato were selected to obtain a representative sample of the whole potato.

Extraction:

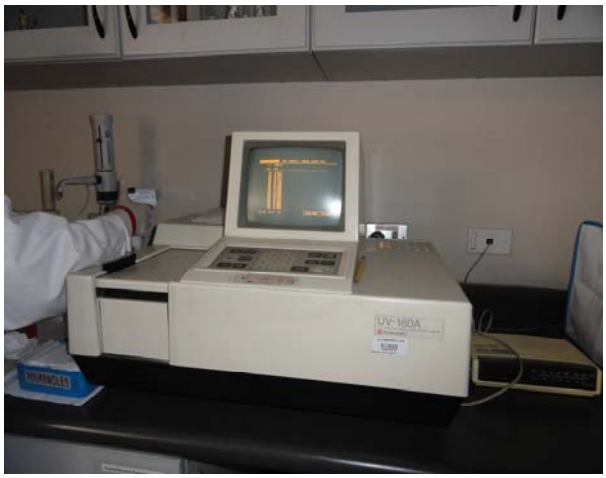
Homogeneous tissue was extracted with acetone in an Ultra Turrax at 21500 rpm and suction filtered through a glass funnel. This process was repeated three times or until the residue was colorless. The extract was then transferred to petroleum ether and washed with water to remove residual acetone.

Saponification:

An equivalent volume of 10% methanolic potassium hydrdoxide was added to the extract and left at room temperature overnight. Diethyl ether and acetone were then used for the recovery and washing of saponified carotenoids and the resulting extract was then brought to a volume of 25 ml with petroleum ether.

Data collection:

High Pressure Liquid Chromatography(HPLC) was used to determine individual carotenoid content and Spectrophotometry was used to determine total carotenoid content .



The research that I had been conducting previously in the Molecular III Laboratory was primarily concerned with understanding the genotypic characteristics of the potato. My participation in QNL research activities allowed me to understand how potato genotype manifests itself as the phenotype in the production of various micronutrients beneficial for human health. My participation in the lab also helped me to understand the need for collaborative effort of both laboratories in producing statistical models relating allelic variation in potato populations to carotenoid production. Such collaboration is also needed to achieve the overall goal of improving biofortification and breeding programs at CIP.

CONCLUSIONS

The results produced from my work are intended to be utilized by Division 3 in understanding the relationship of population structure in the production of beta-carotene and other carotenoids in various populations of potatoes. The research that I participated in both the Molecular Marker III and Quality and Nutrition Laboratory was a portion of the larger research project being pursued in micronutrient enhancement and biofortification. The work that I completed at CIP will go towards understanding the relationship between genotype and phenotypes of native Andean potatoes in the expression and manufacture of carotenoids .

2010 WORLD FOOD PRIZE: “Taking it to the Farmer”

In October of 2010, I had the wonderful opportunity to attend the Global Youth Institute and World Food Prize Conference for a second time. This time, however, as a 2010 Borlaug-Ruan Intern. It was interesting to meet all my fellow interns and share our international experiences.

Having communicated during our internships, it was a different way of viewing the person behind the Facebook profile and Skype account. I enjoyed assisting Lisa Fleming and Keegan Kautzky and escorting dignitaries to the Iowa capital building at the World Food Prize Laureate Ceremony.

My favorite part, however, was the intern presentations on Saturday. It was an exhilarating feeling to be in the same shoes as the 2009 interns, staring into the crowd of wide-eyed high school aged students, eagerly awaiting their turn to submit an application. It was truly gratifying to have come full circle. I really enjoyed presenting my work, my experiences, and my thoughts. It was a great culmination to a year’s work from the application, to the internship, and finally, to the intern presentation. I have adopted a loving BR intern family and will continue to keep in touch with each one of them as we enter college and go our separate ways with our careers.



PERSONAL REFLECTION

My participation in the movement to end world hunger manifested itself in an exhilarating 8 week internship experience in Lima, Peru. Never would I have imagined myself to be placed in such a diverse country as Peru. The sights and sounds of the country still continue to linger in my memory. The Peruvian people accepted me as one of their own, and I immediately felt at home with my newly given nickname, “Avi.”

My stay at CIP was enriching both educationally and culturally. CIP’s scientists are so dedicated to their work and are thoroughly engrossed in the goal to make their research useful in the real world. Their passion for their work is something I hope to emulate in my future endeavors. I learned that it takes dedicated people such as the staff at CIP to truly realize progress in the world. I also enjoyed the idea of working hard and having fun at the same time. There wasn’t one day that went by without a great laugh at a hilarious joke in the commons area, or just enjoying one another’s company in the cafeteria.

I would be mistaken to not acknowledge the amazing efforts of my host family, the Bartolinni’s. I was able to experience the true Peruvian lifestyle, as they graciously invited me to special family get-togethers. I can never forget the hours of conversations carried with Roxana, and Medalith, two girls that lived with the Bartolinnis. I also got to tag along with the family to Chiclayo, a province in the north of Peru. My eyes were glued to the car window, as I awed at the spectacular landscape of the Peruvian coastline.

I had never really known much about the country and was pleasantly surprised by how much an international trip would change me. I learned to become responsible, patient with the sometimes frustrating language barrier, and most of all, appreciative of the rich Peruvian culture. I have never met a people so warm and welcoming. I never felt a void between the Peruvian people and me. The Peruvians are an affectionate people and always greet you with a smile and kiss.

Something that surprised me greatly was the similarity between our American culture and the culture of the Peruvians. Though there may have been certain subtleties that vary between the countries, I was amazed to note how similar we both are. The reverence for family, friends, and self-respect are all shared by both countries. Such notice greatly spurred a thought in my mind: How are we so similar when separated by vast bodies of water with little contact? I realized that though we may identify ourselves by nationality and religious affiliations, we are ultimately part of the one human race. We share the same sacred ancestry that obligates us to take care of one another. This premise solidified my appreciation for science helping the impoverished, because it is our moral obligation, not selflessness, which requires us to provide a decent meal and home for everyone in this world. I had lived in a country for two months, experiencing the good and bad of the country. I can never thank the Peruvian people enough for the lifetime of memories and invaluable lessons learned on my trip. From learning the importance of the potato crop to a reverence for humanity, I have taken so much more from this internship than I had ever imagined. I am now a young woman with true pride and respect for science and its ability to help alleviate global hunger.

As I look at the world's current condition, I realize that there has never been a better time to utilize our science and brain power to solve the current poverty and food insecurity issues. I feel that as a fellow sister, friend, and human being, that it is my responsibility to keep the care and value instilled in these relationships and apply them to those all around the world. Food is the basis for living. Without it, nothing in society can progress. By improving agricultural biotechnologies, we are building, from the grass-roots level, a foundation for the world's impoverished. A better standard of living will empower these individuals to make their own contribution to the world.

My goal in high school has been to apply the concepts learned in the classroom, to the world beyond school gates. As a Borlaug-Ruan intern alumni, I hope to encourage others to step into the realms of science and technology. I strongly feel that it is up to my generation to take initiative in dreaming the impossible and shaping a food secure future. The poverty and hunger occurring all around the world is a concern that I hold dearly to my heart. With betterment as my motivation, perseverance as my driving force, and passion as my sense of direction, I hope to utilize my Peruvian experiences to continue to pursue my humanitarian interests in the future years.

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