Finding Value in Unsuspected Places

Investigating the effects of growing location on micronutrient content in Native Andean Potatoes

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Acknowledgements

Reflection

The final weeks of May 2018 were filled with a myriad of lasts. It was the end of an era. The start of new beginnings. I attended my last day of high school, walked across the graduation stage with my childhood best friends, packed up my belongings, and settled into a new, albeit temporary, home nearly 4,000 miles and a continent away from everything I had ever known within twenty days time.

To say I experienced culture shock during my stay would not be wrong, per say, but I do not think that would be the best way to describe the spectrum of emotions I experienced throughout my time in Peru. Some days would elicit feelings of elation and others utter defeat. Some days left me feeling incompetent and others as if I was truly contributing to the project with which I was assisting. My time as a Borlaug-Ruan Intern would not have been the phenomenal, transformative experience it was without the struggles in addition to the triumphs.

When we stand to face new, exciting, and sometimes intimidating adventures, there may not be much within our immediate control. As an intern, I did have some influence over what I was learning about and working on day to day. However, much of that was out of my control. What I did have control over, nonetheless, was how I reacted when faced with adversity.

Whether I was in the lab, observing at the test plots, or exploring the city of Lima, I always had the power to choose how I viewed a certain assignment or task I was given. Even on the hardest, most tedious days of sample preparation those surrounding me were always ready and willing to contribute whatever it took to get the work done. Their commitment and compassion for the people whose lives they are working to improve was unsurpassed and utterly inspiring. No task was too small for any individual, from Laboratory Technician to Lead Researcher, because all were working for one common goal.

Some of the most sage advice I received during my time in Peru was not anything I will forget anytime soon. The months of June, July, and August are particularly grey and dreary in Lima because of the fog along the coast. One afternoon in early July I commented that I had not seen the sun for some time and I was missing the expansive, blue skies Iowa's summers are so very well known for. Martha, my host, then turned to me and said, "The color of the sky does not matter, my dear. What matters is the eyes with which you look at it."

What I came to understand, most importantly, is that it is not the places you visit but the people you visit with. Beyond my research, learning, and day-to-day activities at CIP, I truly fell in love with the people of Peru. In addition to those working at CIP, my host, Martha, and her family were some of the most gracious people I have ever encountered. Lima is a wonderful city, yet the people are what make it magnificent. I never felt anything but welcomed and accepted wherever I went and will not hesitate to return in the future. The beautiful people of Peru are what made my summer as a Borlaug-Ruan Intern my best summer, yet.

Credits

I would like to extend my deepest gratitudes to Dr. Norman Borlaug, Mr. John Ruan, Ambassador Kenneth M. Quinn, and the staff of the World Food Prize Foundation for their unwavering dedication in the fight against hunger and for making the Borlaug-Ruan International Internship a reality. Furthermore, I would like to thank Ms. Crystal Harris for all of her hard work and dedication to the safety and success of each Borlaug-Ruan Intern this summer. Your hard work does not go unnoticed.

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This internship would not have been possible without the cooperation of the International Potato Center and their enthusiastic dedication to improving the lives of the poor through their work. The dedication and vision for a brighter tomorrow for the peoples that CIP serves is contagious and truly inspiring. Thank you to all of the staff at CIP for your warm smiles and welcoming attitudes throughout my internship. Additionally, I would like to thank the Human Resources team, especially Ana Paula Gonzalez, for their efforts to ensure I had an enjoyable and meaningful internship at CIP.

I would like to extend a great thank you to Martha Huanes and her family for making my time in Lima enjoyable and meaningful. Thank you for showing me the real Peru and sharing your home so graciously with me. You welcomed me with open arms and with no hesitation; for that I am deeply grateful.

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Lastly, I would like to thank all of my friends, family, and supporters in Iowa. Your enduring support and encouragement proved to be nothing less than outstanding throughout my time in Peru. Thank you for always encouraging me to strive for greatness and never allowing me to settle for anything less than extraordinary.

Abstract

Native potatoes are a staple crop in the highlands of Peru where the intake or consumption levels of potato can reach up to 200g in children approximately two years of age and 800g in women of fertile age per day (Burgos, 2007). The topic of this study was to evaluate the micronutrient composition of native Andean potatoes as affected by growing location. Evaluating the effects of growing location on the concentration of micronutrients in potatoes will further allow a recommendation of which growing locality is found to be the most beneficial in positively contributing to the nutrient levels in potatoes grown there. Analysis of the vitamin C content, total anthocyanin levels, and iron and zinc mineral levels of 12 different potato varieties grown in three distinct localities were performed. It was demonstrated each growing locality produced potatoes with different elevated micronutrient levels for each independent micronutrient analyzed. However, one locality did not produce elevated micronutrient levels overall.

Introduction

Potato (*Solanum tuberosum* sp.) is one of the world's most important crops, ranking fifth in terms of human consumption and fourth in worldwide production (Horton, 1992). In some regions such as the high Andes of South America, potatoes constitute as the main staple food crop (Andre, et al. 2015). Native potatoes are a staple crop in the highlands of Peru where the intake or consumption levels of potato can reach up to 200g in children approximately two years of age and 800g in women of fertile age per day (Burgos, et al. 2007).

In the developing world, undernutrition is particularly prevalent among rural farm households (Rose, et al. 2008). Over three billion people are currently malnourished, with the highest rates in developing countries where iron (Fe) and zinc (Zn) are the most critical micronutrient deficiencies (Burgos, et al. 2007). It has been estimated that approximately 40% of the world's population is deficient in Fe. In Peru, anemia, a condition caused in part by inadequate levels of iron in the blood, affects nearly 34% of children from 6 to 59 months of age (Instituto Nacional de Estadística e Informática. 2014). Children with anemia experience irrevocable cognitive and developmental delays and exhibit decreased worker productivity as adults (Walker, et al. 2007).

Iron and zinc deficiencies are among the principal causes of malnutrition worldwide (Bonierbale, et al. 2010). Weight for weight, concentrations of Fe and Zn in potato are lower than those in cereals and legumes; but the contribution of a given food to the diet depends on the bioavailability in the source and on the amount that is consumed. The bioavailability of iron in potato can be even greater than in cereals and vegetables due to the presence of ascorbic acid, a vitamin C precursor which promotes the absorption of iron (Fairweather-Tait, 1983). Potatoes have significant quantities of vitamin C (ascorbic and dehydroascorbic acid). Vitamin C plays an important role in

protection against oxidative stress (Bonierbale et al. 2010). Anthocyanins are flavonoids, a class of antioxidants characterized as the pink, red, or purple flesh colors found in potatoes.

A previous study conducted revealed the evaluation of 37 potato varieties grown in two highland locations in Peru revealed significant variation in mineral concentration due to environment and genotype x environment interaction (Bonierbale, et al. 2010). Evaluating the effect of growing location on the concentration of micronutrients in potatoes will further allow a recommendation of which growing locality is found to be the most beneficial in contributing to the nutrient levels found in the potatoes grown there.

The objective for the completion of this project was two-fold. The first objective of the project was to characterize the potatoes consumed by Huancavelica farmers in order to communicate the nutritional composition of the potatoes already consumed with farmers on the value of the products to identify potential attributes that can add to the value chain. The second objective is to use the data collected to establish a baseline for the micronutrient content of the native potatoes currently consumed in Huancavelica, which indeed will be used as a reference to develop potato material with higher levels of micronutrients.

Method

The experimental design was a randomized complete block design, where 12 varieties were grown in 3 locations with three replications in each location. Data collected included iron, zinc, vitamin C and total anthocyanin concentration expressed in milligrams per 100 grams of potato in fresh and dry weight. The design allowed the assessment of the variability of Fe, Zn, vitamin C and total anthocyanin concentrations among native varieties and the effect of environment and the genotype × environment interaction (G × E) considering ‘genotypes’ as fixed and ‘sites’ as random effects (Burgos, G., et al. 2007).

Plant Material

Twelve native varieties of potato, each with three replications, were cultivated and harvested using traditional farming practices of the native Andean farmers in three different localities of the Huancavelica department of Peru. The three different field localities include the areas of Pumaranra, Quilcas, and Castillapata. Fields were planted in a randomized complete block design.

Sample preparation of potato tubers

Preparations of the sample materials was completed using the preparation procedures found in Porras, E., et al. Harvested potato tubers were processed as follows: raw tubers were washed thoroughly with tap water to remove soil residue, rinsed with deionized, distilled water, and patted dry with paper towel. Tubers intended for vitamin C and anthocyanin analysis remain with peel intact, while tubers for mineral analysis (XRF) were peeled. Tubers were then cut longitudinally from stem to bud end into four sections and sliced to form a representative sample. Samples intended for vitamin C

analysis were then tested immediately. Additional samples intended for anthocyanin and mineral analysis were then freeze dried and milled according to specific procedures found in Porras, E., et al.

Vitamin C Analysis

Vitamin C, or ascorbic acid (AA), analysis was completed according to procedures found in Burgos, G., et al. A representative sample of unpeeled, fresh potato, an extracting solution of oxalic acid 0.4% and acetone 20%, and 2.6 dichloroindophenol (DCIP) stock solution are used in the analysis. The final solution was read in a spectrophotometer and compared against a standard curve created with ascorbic acid to determine the AA concentration in each sample.

Total Anthocyanin Analysis

Analysis of total anthocyanin concentration in freeze dried and milled potato samples was completed according to the procedure described in Burgos, G., et al. The weight of freeze dried and milled potato sample used in the analysis is dependent on the color of the sample. The extraction is done using an 80:20 solution with 95% ethanol and 1.5 M hydrochloric acid. The extract is then quantified using a spectrophotometer while referencing the extinction coefficient and the molecular weight of malvidin-3-pcumarilglucoside and pelargonidin-3-glucoside for purple and red samples, respectively.

X-ray Fluorescence

X-Ray Fluorescence (XRF) testing of freeze dried and milled potato samples was completed according to the procedure described in Sosa, P., et al. Freeze dried and milled potato samples were scanned by XRF using an X-Supreme 8000 spectrometer. Data collected includes the concentration of iron (Fe) and zinc (Zn) in mg/kg or parts per million (ppm) dry weight in each sample. The results could be transformed to fresh weight based values by using their respective dry matter percentage.

Results

The mean concentration of vitamin C in fresh potato tubers in three repetitions of 12 native varieties of potato is shown in Figure 1. Overall, the potatoes grown in the locality of Quilcas exhibited the highest average concentration of vitamin C with 14.37 mg/100g FW and the highest concentration reported overall with 19.02 mg/100g FW in the variety "Amarilla del Centro." The localities of Pumaranra and Castillapata reported a mean average concentration of 13.61 and 11.00 mg/100g, respectively. The lowest mean concentration reported was from the locality Castillapata in the variety "Añil" with 6.25 mg/100g FW of vitamin C.

The average content of the minerals Fe and Zn in peeled, freeze dried, and milled potatoes is shown in Figure 2 and Figure 3. Quilcas reported the lowest average content of Fe and Zn with 15.89 and 9.04 mg/kg dry weight (DW), respectively. The locality of Pumaranra reported the highest overall mean content of Fe with 20.76 mg/kg DW, while Castillapata reported the highest overall mean content of Zn with 14.81 mg/kg DW. The highest individual reported average Zn content was in the variety "Camotillo" grown in the Castillapata locality with 19.49 mg/kg DW. Additionally, the variety "Yawar Manto" exhibited the highest individual Fe content grown in the Pumaranra locality with 25.82 mg/kg DW.

The mean total anthocyanin content of four potato accessions each with three repetitions, respectively, with red or purple flesh color previously known to contain anthocyanins are shown in Figure 4. The locality of Quilcas reported the highest average total anthocyanin content, producing 795.51 mg/100g DW. Pumaranra reported a slightly lower average with 718.77 mg/100g DW. Additionally, Castillapata reported a significantly lower average content with only 594.70 mg/100g DW. The variety “Añil” reported the highest average anthocyanin content overall when grown in the Quilcas locality, reporting 1393.67 mg/100g DW. Further, the variety “Alcaraz” produced the lowest average anthocyanin content when grown in the Castillapata locality reporting 343.69 mg/100g DW.

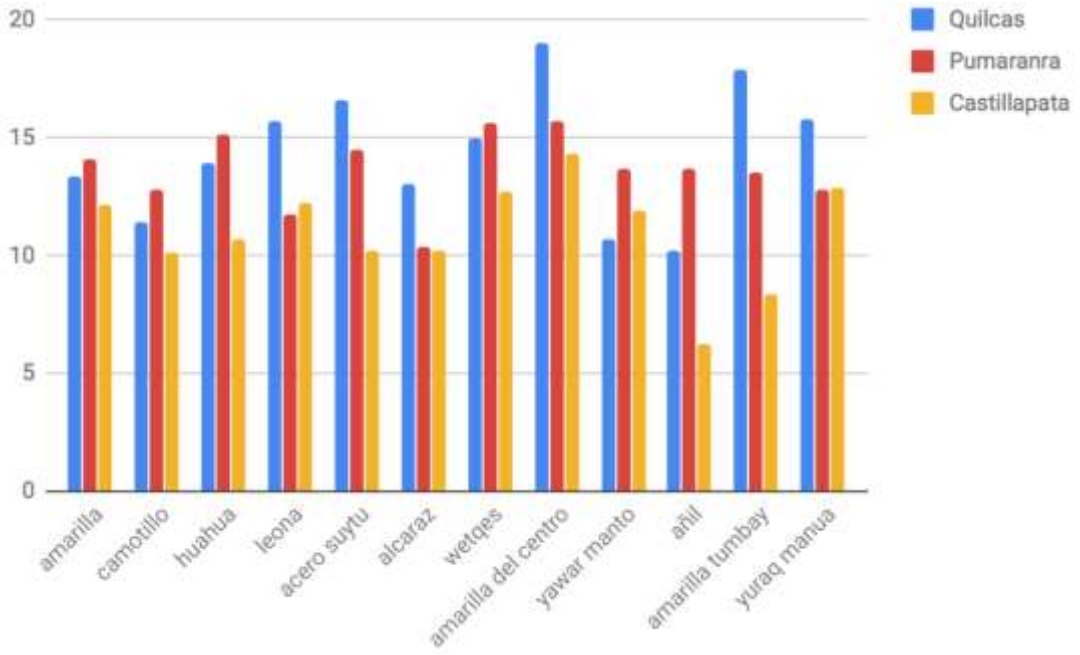

Figure 1. Average total vitamin C levels by growing locality in each variety in mg/100g fresh weight.

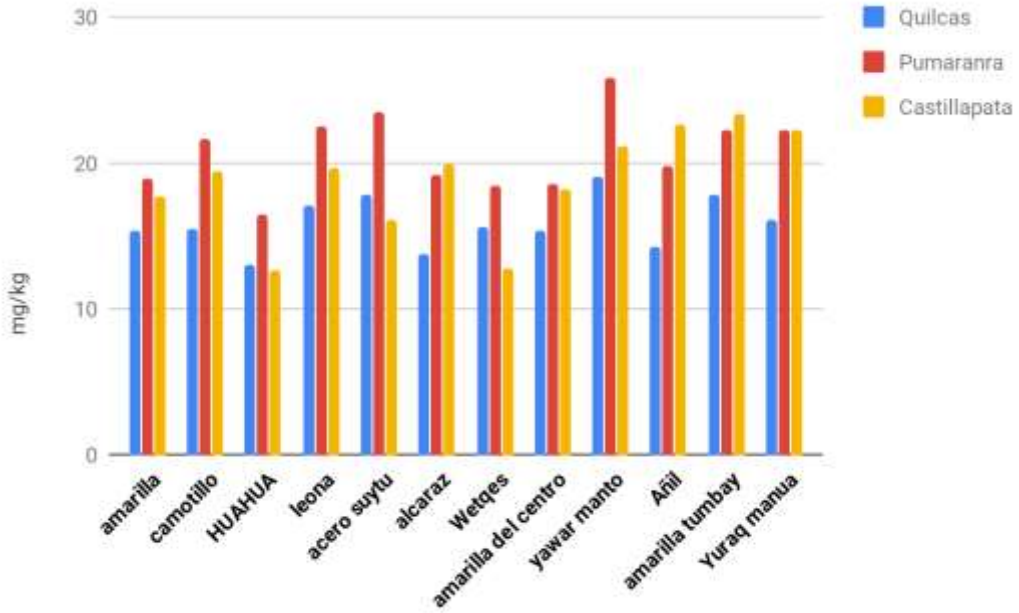

Figure 2. Average iron (Fe) content by growing locality in each variety in mg/kg dry weight.

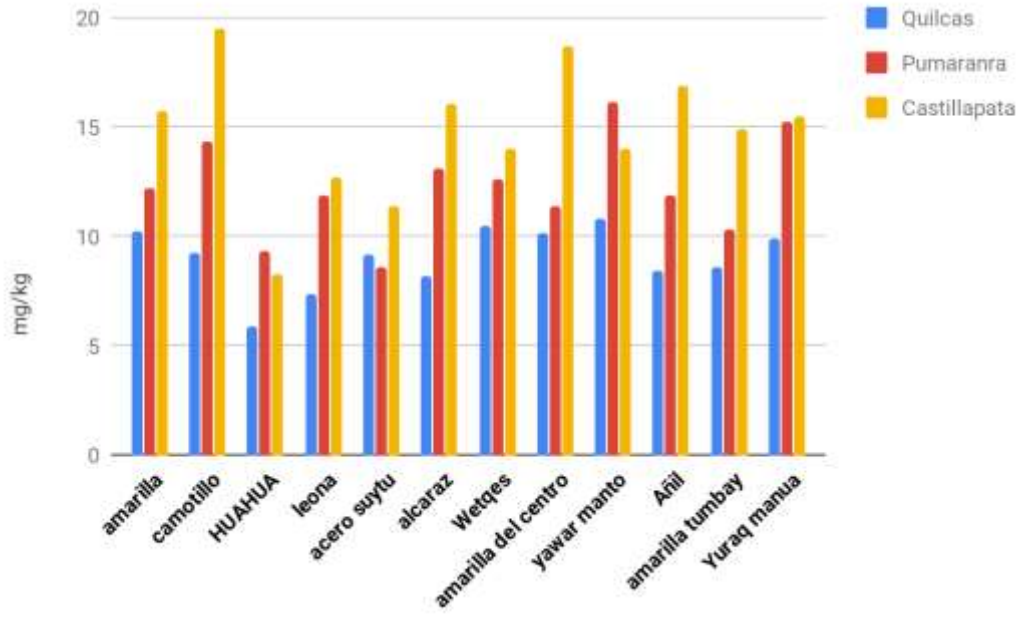

Figure 3. Average zinc (Zn) content by growing locality in each variety in mg/kg dry weight.

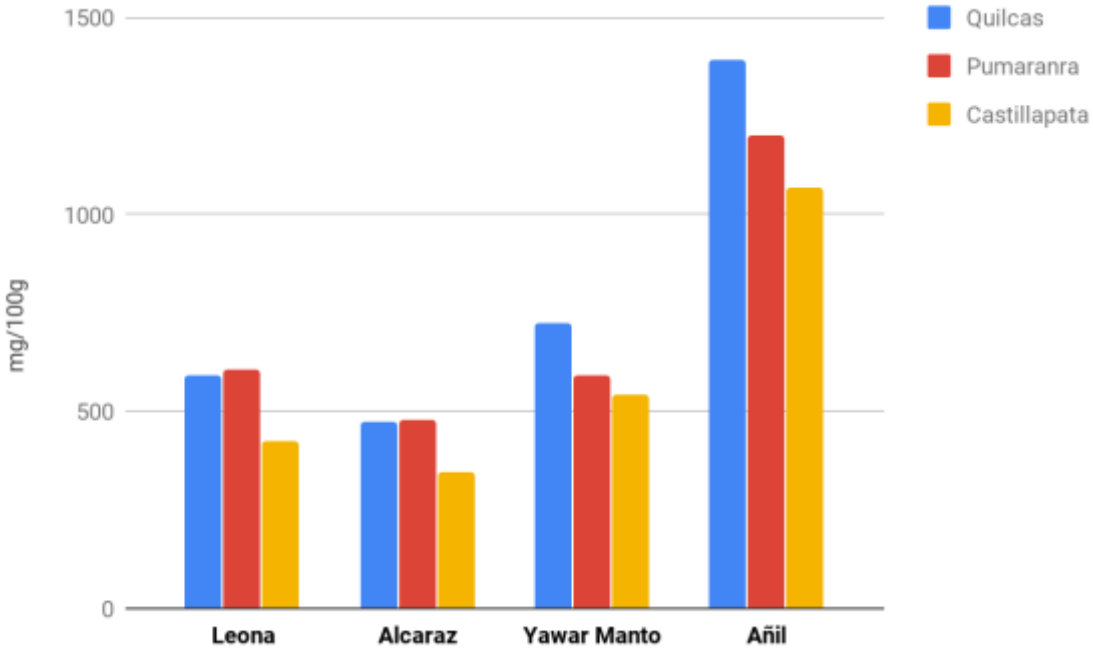

Figure 4. Average total anthocyanin content by growing locality in each variety in mg/100g dry weight.

Discussion

It is well known and discussed in literature that in the instance of poor nutrition, poor health often follows (Gwatkin, 2000). For the 40% of the world's population who are anemic, consumption and proper absorption of the minerals Fe and Zn are crucial to proper body function. Further, vitamin C is essential to the absorption of Fe in the body in addition to protecting against oxidative stress. The presence of anthocyanins in potatoes contributes to the body resisting oxidative stress. The instance of potatoes with low nutrient levels are even more detrimental to the health of those living in the Peruvian highlands where the principal food consumed is potatoes.

The discovery that growing locality can have an influence on micronutrient levels of potatoes is be an integral component in improving the overall health of those living in the Peruvian highlands. While it was not discovered any one locality was able to produce potatoes with elevated levels of all four micronutrients analyzed, the knowledge discovered will allow farmers to tailor their agricultural practices to provide crops with the most beneficial nutrients for the populations who consume them.

Limitations

While the scope of this experiment was inclusive on the large scale, the smaller experiment ran by myself did not account for the expansive variety of nearly 142 varieties of native potatoes cultivated and consumed in the department of Huancavelica. While it was demonstrated that growing location does impact total vitamin C, anthocyanin, iron, and zinc levels independently in native potatoes, storage and preparation methods of potatoes have also have been proven to impact overall micronutrient levels at the time of consumption.

Conclusion

In conclusion, when comparing recorded micronutrient levels as they correlate to growing location, there is no one locality which produced high levels overall. However, there are correlations between individual micronutrient levels and growing locality. There exists a strong correlation between elevated vitamin C levels as well as total anthocyanin content in the varieties grown in the Quilcas locality. Moreover, the locality which produced the highest overall Zn levels was Castillapata. The highest recorded Fe levels were found in the Pumaranra locality.

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Appendix

The included maps show the region and locality where each field was located in the Huancavelica district of Peru. The three localities utilized for growing locations include Quilcas, Pumaranra, and Castillapata.