The Nutritional Contribution of Potato Varietal Diversity in Andean Food Systems: a Case Study.

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The nutritional contribution of potato varietal diversity in Andean food systems: a case study

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Abstract

Potato is a mainstay of agriculture and diets in high-altitude food systems of Peru, where farmers grow diverse varietal portfolios. Here we report on the role of intraspecific diversity, specifically of diverse landraces and modern varieties, within the Andean diet. The dry matter, energy, protein, iron and zinc content of 12 floury landraces and 9 bitter landraces was determined (fresh and/or freeze-dried). The contribution of the potato intraspecific diversity to the dietary intake of energy, protein, iron and zinc was established during two contrasting periods of overall food availability. Results show that the potato and the inherent intraspecific diversity make an important contribution to nutrition. Several floury landraces contain higher concentrations of protein and iron compared to the common standard reference. Traditional freeze-drying of bitter landraces doesn't affect energy and iron concentrations, but reduces the protein and zinc content considerably. Content values for protein and iron in boiled *chuño* derived from the bitter landraces are lower compared to the standard reference. Findings clearly suggest that the nutritional content of the varietal diversity of the potato needs to be taken into account when conducting nutrition studies in the crop's Andean center of origin. The potato contributes positively to the nutritional balance and the recommended requirements for energy, protein, iron and zinc of women and children. Floury landraces and modern varieties complement each other providing valuable nutrients during contrasting periods of the year. The potato thus contributes positively to food security; yet overall dietary diversity was found to be poor, resulting in micronutrient deficiencies. The production environment and the local economy provide limited options to produce or acquire fruits, vegetables and animal products to enrich the diet.

Introduction

Food systems encompass activities and knowledge related to the production, acquisition and utilization of foods that affect human nutrition and health (HLPE 2017; Kataki and Babu 2002). The Andean food system typically makes use of numerous indigenous plant and animal species which are little known outside their centre of origin (FAO 1994, 1992; NRC 1989). The high-altitude food system in central Peru is further characterized by mixed crop-livestock production systems (Morlon 1996), the use of traditional processing technologies (De Haan et al. 2010a; Werge 1979), an indigenous food culture, cuisine and related collective knowledge (PRATEC 2001), frequent rural household involvement in off-farm employment and consequent ability to purchase basic foodstuffs (Antezana et al. 2005; Mayer 2002), and the presence of external food assistance programs addressing food insecurity and undernutrition (Aguiar et al. 2007; Stifel and Alderman 2003). Furthermore, the Andean food system is continuously evolving in response to global environmental and socioeconomic change (Vallejo-Rojas et al. 2016).

Links drawn between biodiversity, dietary diversity and possible nutrition outcomes frequently focus on species diversity (Berti and Jones 2013; Jones 2017; Toledo and Burlingame 2006). Relatively little attention has been given to the potential role of intraspecific diversity and its contribution to dietary and nutrition security (Thrupp 2000). Diets characterized by nutritional diversity with food intake from a variety of sources, including different crop species and cultivars, are likely to be more balanced compared to monotonous diets (Johns 2002). It is well established that the cultivated potato is both genetically diverse and a mainstay of the rural diet in the Andean highlands (Brush 2004). Contemporary taxonomic treatments recognize four cultivated species: *Solanum tuberosum*, *S. ajanhuiri, S. juzepczukii*, *S. curtilobum* (Gravrilenko et al. 2013; Ovchinnikova et al. 2011). One of the most striking features, however, of Andean potatoes is the immense varietal diversity that farmers have selected and still cultivate and consume (Ochoa 1999; Zimmerer 1996). Recent baseline studies of landrace variability in Peru confirm high levels of on-farm conserved landrace diversity and inherent variability in nutritional content (Figure 1) (CIP 2015; MINAGRI 2017). Farmers in Peru's central highlands typically consume diverse potato species and varieties boiled from fresh tubers or processed into dried potato (*papa seca*), freeze-dried potato (*chuño)* and anaerobically fermented *tokosh*. However, also in the Andes there tends to be a decline in the use of traditional food processing techniques that are labour demanding.

Nowadays the on-farm conserved genetic diversity of cultivated species and landrace potatoes is predominantly conserved at altitudes between 3,700 and 4,200 m (De Haan et al. 2010b). Climate change and the expanded range of pest and diseases have 'pushed' landrace diversity upward. Communities at such high altitudes only have few options within their portfolio of food crop choices. Apart from potato, the other options include faba bean (*Vicia faba*), quinoa (*Chenopodium quinoa*), kañihua (*C. pallidicaule*), barley (*Hordeum vulgare*), oca (*Oxalis tuberosa*), ulluco (*Ullucus tuberosus*), mashua (*Tropaeolum tuberosum*), maca (*Lepidium meyenii*) and few other species. The agriculture at such high altitudes is characterized by being highly seasonal, rain-fed and prone to extreme weather events. Under such conditions varietal diversity is arguably an asset as differences in earliness and storability can spread household-level availability. Furthermore, diversity helps to confront abiotic and biotic stress.
The prevalence of growth retardation or stunting and anaemia continue to be high in rural populations of the Andes. In 2010, 34.4% of children under five years of age were stunted and more than half suffered from anaemia (INEI 2011). This is largely due to inadequate diets, especially in young children and women of reproductive age. Among the essential micronutrients that are particularly deficient in the diet are iron and zinc (Burgos 2006; Scurrah et al. 2012). Potato varietal diversity, both of landraces and modern varieties, is potentially a significant dietary source of these nutrients, hence in this paper we present information on the contribution of Andean potatoes to the diet with a focus on energy, protein, iron and zinc. The objective of this paper is to elucidate how the intraspecific diversity of potato contributes to the human nutrition of smallholder farmers. We do so by focussing on a specific geography in Peru's central highland where we analysed the nutrition content of common potato landraces and captured detailed information about foods and beverages consumed during two contrasting periods of the year.

Materials and Methods

Study site

Research was conducted in 6 farming communities in the Huancavelica department, central Peru. The number of households per community ranged from 34 to 148 with an average of 4.1 to 5.7 members per household. The production zones for crops and livestock were all located between 3,500 and 4,500 m of altitude.

Nutritional composition of landraces

A total of 12 and 9 of the most frequently cultivated and consumed floury and bitter landraces, respectively, from the department of Huancavelica were selected for compositional analysis. These belong to different species and cultivar groups (Table 1), some of which have known chemical composition values for iron, zinc, potassium and calcium in fresh or processed form (Figure 1). Tubers of each landrace were obtained from a single source (farmer) and environment (field). Analysis to determine the dry matter, gross energy, crude protein, iron and zinc content of boiled tuber samples of the 12 floury landraces was conducted. In the case of the bitter landraces, analysis was conducted for boiled tuber and *chuño* samples. Prior to the nutritional analysis, the traditional freeze-drying of so-called white *chuño* of each bitter landrace was done by an experienced farmer under uniform conditions following commonly practiced procedures. These included: (i) exposure to frost at night and sun during the day (3 days), (ii) removal of liquid by treading with bare feet (½ day), (iii) submergence of treaded tubers in a pond with water (5 days) and (iv) exposure to sun for drying (5 days).

Samples were prepared for 3 repetitions of each individual landrace (i.e., 3 samples from each taken for analysis): (i) boiled tubers of floury landraces, (ii) boiled tubers and *chuño* of bitter landraces. The analysis was done for boiled samples because that is how they are consumed. Prior to cooking, tubers were washed and rinsed with still water. Tubers were peeled and cut longitudinally into 4 parts. From 2 opposite sides a 50 g sample was obtained and dried in an oven at 80 ºC for24 hours; then weighed, pulverized, put in kraft paper bags and sent to Waite Analytical Services (University of Adelaide, Australia) for the determination of iron and zinc content. Samples were digested (0.6 g; 140 ºC; 70% HNO_3/$HClO_4$) and subjected to inductively coupled plasma optical emission spectrometry (ICO-OES; analyzer ARL 3580B ICP) for analysis of iron, zinc and aluminium content. Aluminium was used as an indicator of possible iron contamination (soil, dust). The remaining 2 opposite sides of each tuber were used to prepare samples for proximal analysis. Slices were taken from each tuber section (total 100 g) and each sample put in polyethylene bags, frozen at -20 ºC and dried in a lyophilizer. Dry samples were weighed, pulverized, stored in plastic bags and sent for analysis to the nutrition laboratory of the National Agrarian University La Molina, Peru (UNALM). Complete proximal analysis of samples was done following standard procedures as described in AOAC (1990). A completely randomized factorial design was applied and analysis of variance and simple effects was conducted with SAS 8.2 software.

Dietary intake and potato intraspecific diversity

Dietary intake studies were conducted during two contrasting periods of overall food availability: (i) after the main cropping season or *qantun tarpuy* in Quechua (period of abundance; May-June 2004), (ii) seven months after the main harvest and coinciding with the main off-season harvest or *miska* in Quechua (lean period; January-February 2005). The study was conducted to characterize the contribution of the potato and other foods to the diet of children between 6 and 36 months of age and their mothers. It was conducted in 6 representative highland rural communities. Healthy infants from the communities were included after prior signed informed consent by each of the participating households. Children with a congenital or other condition that could affect food intake or nutritional status were excluded (Burgos 2006).

A team of female, Spanish and Quechua speaking, fieldworkers from the study communities was trained during a 2-week period. They were trained in the use of standardized procedures for handling scales, correct weight measurements of food items, use of registration forms, recognition of predominant potato landraces and modern varieties, and conducting surveys. Only households including mothers with their children in the 6-36 months age group were selected. Children and mothers were recruited in each of the communities based on their willingness and interest to participate. This led to a sample of 76 and 77 households during the period of abundance and lean period respectively (19.4 and 19.7% of the total population). Most mothers and children were the same during both periods, yet minor variation occurred based on the age group selection criteria. Food intake data were collected by direct food weighing during a 24-hour period for the mother and child in each household. Each food ingredient, including species and varieties, included in the food preparations and each food item or liquid consumed at each meal by the mother and child were weighed. Particular attention was given to each of the potato landraces and modern varieties included in the preparation or in the dish of each person. The times infants and children were breastfed were also recorded.

The conversion of food intake to the nutritional contribution for energy, protein, iron and zinc was calculated using a food composition table (IIN 2005).The nutritional value of specific potato landraces, modern varieties or *chuño* was used when available from our own chemical analysis or the database of the Quality and Nutrition Laboratory of the International Potato Center (CIP). Otherwise, average values were assigned to landraces with unknown nutritional compositions. Total energy, protein, iron and zinc intakes were calculated. Furthermore, adequacy of intake was calculated as a percentage of the actual daily intake compared to recommended standard total daily intakes. Standard references to estimate adequacy of individuals depended on the age group and specific nutrient. International recommended daily intakes used for infants and children 6 - 23 months of age were based on Dewey and Brown (2003).Energy and protein requirements for mothers and children older than 24 months of age and recommended intakes for calcium, zinc and iron were based on FAO et al. (2002, 2004) and IOM (2002) reference standards.

Nutritional status of mothers and children

Weights and heights of the children between 6 and 36 months of age and their mothers were measured by a trained researcher following standard international techniques (WHO 2008). Recumbent length was measured for children 6-24 months, and standing height for children 24-36 months and their mothers. Data were entered using Microsoft

Visual Fox Pro 6.0 software and analyzed with SPSS 11.0 software. The software Anthro v 1.02 was used to calculate the nutritional status: z-score of weight/age, length-height/age and weight/age for children. We classified nutritional status: (i) global undernourished if weight-for-age was <- 2.0 of z-score, (i) stunting if height-for-age was <-2.00 of z-score, (iii) wasting if weight-for-height was <-2.00 (WHO 2008). To determine the nutritional status of mothers Body Mass Index (BMI = weight/height) was calculated: (i) undernourished < 18.5, (ii) normal 18.5-24.9, (iii) overweight 25.0-29.9, (iv) obese: ≥ 30.0 (WHO 2000). The dietary study was approved by the Research Ethics Committee of the IIN and each participating family gave signed informed consent prior to the research activity.

Results and Discussion

Nutritional composition and variability

Fresh potatoes: The energy, protein, iron and zinc provided by 100 g of boiled tubers of the 12 common floury landraces varied from 96.33 to 123.17 Kcal, from 1.76 to 2.95 g, 0.26 to 0.72 mg and from 0.28 to 0.41 mg respectively (Table 2). The diploid landraces Runtus and Yana Puqya contained the highest protein concentration (2.95 and 2.84 g/100 g, respectively). These values are higher than the mean protein content of 2.00 g/100g reported in the standard Peruvian food composition table for potato landraces (INS 2009). Only one common floury landrace, the tetraploid Sortijillas, had a protein content lower than the standard reference for potato landraces. The diploid landrace Chiqchi Pasña and tetraploid landrace Ayrampo contained the highest iron concentration (0.72 and 0.63 mg/100g, respectively). Again, these values are considerably higher than the mean value of 0.400 reported in the Peruvian food composition table (INS 2009). Only two common landraces, the tetraploid Sortijillas and Allqa Palta, had iron concentrations lower than the standard reference for potato landraces. These results clearly show that the intraspecific diversity of landraces is sufficiently variable to be taken into account when doing nutritional research in the crop's Andean center of origin and diversity, especially as most of the commonly consumed landraces have a higher nutrient density of protein and iron compared to the single-value reference of the Peruvian food composition table.

Processed potatoes: The energy, protein, iron and zinc provided by 100 g of boiled white *chuño* prepared from 9 bitter landraces ranged from 86 to 138 Kcal, 0.49 to 1.15 g, 0.29 to 0.76 mg and 0.04 to 0.12 mg, respectively (Table 3). The concentration of protein and iron of white *chuño* from all the bitter landraces was much lower than the mean reference of 1.90 g and 3.00 mg per portion of 100g, respectively, considered in the Peruvian food composition table for boiled *chuño* (INS 2009). Results show that while the protein and iron concentrations of the boiled floury landraces analyzed in our study were generally higher than the standard reference used, the opposite is true for content values of white *chuño* derived from bitter landraces. The concentrations of protein were up to 4-times lower and those for iron up to 10-times lower than the single-value reference of the Peruvian food composition table. In the case of white *chuño* it is not only important to take into account the varietal effect, but also the production environment and different freeze-drying processes employed (De Haan et al. 2009, 2012; Burgos et al. 2009).

We compared the energy, protein, iron and zinc concentrations of boiled unprocessed tubers versus boiled white *chuño* of the same bitter landraces. The energy and iron contents were not significantly affected by the process of freeze drying and remained comparable in boiled unprocessed tubers and boiled white *chuño*. However, protein and iron content were negatively affected by freeze-drying. Depending on the bitter landrace, a 1.9 to 5.8-fold decrease in protein content was measures for the nine landraces analyzed. For iron concentrations, the reduction was even larger: 3.2 to 6.3-fold.

Dietary intake and adequacy

The women included in the dietary study had an average age of 28 years and only 3 years of formal education (21.4% were illiterate). The children´s mean age was 20.0 months. The overall diversity of foods consumed was very low. Potatoes were consumed by most of the mothers and children during both the abundance and the lean periods. Other food items consumed by more than 30% of mothers and children were cereals (barley, rice, oats, quinoa, pasta), legumes (faba beans), and selected vegetables (onion, carrots). The intake of meat, fruits and other vegetables was very limited with less than 10% of mothers and children consuming them. Around 70% of the infants and children were breastfed at the time of the study. Only 26% of the children consumed milk from non-human sources. Although the diversity of species and foods consumed was extremely low, both mothers and children had high levels of potato varietal diversity in their diets. During the period of abundance, the total varietal diversity of potato consumed was higher than during the lean period, both for women and children: 90 versus 61 landraces/varieties for women and 81 versus 41 landraces/varieties for children.

Potato was the principal food staple. The women had an average daily consumption of 839.1g and 645.4g of potato during the period of relative abundance and lean period respectively (Figure 2). The children's diet showed an average daily intake of 202.3 g and 165.1 g of potato during each period respectively. In January and February, more than 6 months after the main harvests following the *qatun tarpuy* plantings, most households had only small quantities of floury landraces left in storage. However, many farmers obtained a harvest of early producing modern varieties such as Yungay and Canchan from their *michka* off-season plantings. Potato intake was dominated by landraces during the period of abundance while modern varieties were more important during the lean period (Figure 2). Levels of consumption of *chuño* were exceptionally low during the lean period. This was a consequence of the absence of frost needed for processing during the preceding season (June - July). Considerable differences were found between farmer communities. For example, in one of the communities the average daily potato intake of women during the period of abundance was as high as 1,348 g / day and in two of the communities modern varieties were predominant in the diets of women during both study periods.

Table 4 provides an overview of the contribution of floury landraces, bitter landraces processed into *chuño*, modern varieties, total potato and total food consumption to the average daily energy, protein, iron and zinc intakes of women and children. Potatoes contributed substantially to the total intake of all nutrients. Floury landraces and modern varieties complemented each other with the landraces proportionally providing most of the energy, protein, iron and zinc intake from potato during the period of abundance and the modern varieties during the lean period.

Potato provided most of the total energy intake for women (43.8%) and children (36.8%) during the period of abundance while cereals proportionally provided most energy during the lean period (Figure 3). A similar tendency can be observed for protein intake: most protein came from potato during the period of abundance and from cereals during the lean period. Even though the quantities of legumes, meat and dairy products consumed were low, they did make an important contribution to the total protein intake of women and children (Figure 3). Cereals contributed most iron and zinc for both women and children during both study periods, followed by potato (Figure 3). Iron and zinc intakes from rich, bioavailable sources of these nutrients such as meat were very limited.

The mean overall diet of women and children as measured in this study was deficient in energy, iron and zinc while sufficient in protein (Table 5). Potato provided between 23.0 and 38.6% of the recommended total energy requirements depending on the group (women / children) and study period (abundance /lean). Potato contributed valuable amounts of protein, especially for children, during both study periods. The potato only covers a small percentage of the total iron recommended daily intakes of women and children. Average potato intake contributed22.6 and 19.6% for women and 7.5 and 7.0% for children of recommended daily zinc intake for the abundance and lean periods respectively. This is a small but important contribution, especially for children, considering that the overall diet is severely deficient in zinc.

Under nutrition in a potato diversity hotspot

More than half of the children showed low height-for-age (stunting),54% in both periods, and 5.6% and 1.9% of children showed low weight-for-height (wasting) during the abundance and the lean periods, respectively. This indicates that the level of child under nutrition at the time of the study was higher than the national average but similar to the overall situation in Huancavelica (INEI, 2001). The women studied had an average weight of 50.7 kg and height of 1.48 m.17.9% and 13.0% of mothers were overweight at the time of abundance and lean period, respectively. None of the mothers were obese nor undernourished as measured by BMI.

Discussion

Nutrition research should ideally take intraspecific diversity and its inherent variability in nutrient density into account when trying to understand relationships between diets and adequacy of intake (Bioversity International 2017). This is especially so when the intraspecific diversity of the mainstay crop species in local diets is high. It is clear this variability and its deviation from standard single-value references used for a sole crop species or derived products may actually translate into substantial differences in nutrition quality and outcomes. Specifically, in our case study, the higher iron content of the majority of predominantly consumed floury potato landraces does translate in a greater contribution of this landrace group to iron intake. Potato generally contains high levels of ascorbic acid, which is known to enhance bioavailability of iron (Grudzińska et al. 2016; Teucher et al. 2004). Therefore, the contribution of potato to the overall iron nutritional status may in fact be more important if it is consumed together in the same meal with iron from cereals. Boiled white *chuño* as prepared in Huancavelica, on the other hand, does contain and thus contributes significantly less protein and iron then one might estimate using the standard food composition table reference. Therefore, it is not only important to gain fine-grained insights into the nutritional composition of varietal diversity, but also into the effects of food processing, storage and preparation practices on nutrition contents (De Haan et al. 2012). Furthermore, genotype by environmental interaction effects and crop management practices can play a role in the nutritional composition of crops and individual varieties (Burgos et al. 2007; De Valença et al. 2017).

It is a stark paradox to find that a microcenter of enormous potato landrace diversity (CIP 2006) can at the same time also be a hotspot of child undernutrition (Scurrah et al. 2012). Indeed, it reaffirms that varietal diversity is not enough and needs to be complemented by species diversity, sufficient carrying capacity of family farms, and food access through markets and off-farm employment (Arce et al. 2016). High levels of genetic variability within a single crop species may actually be the main diversity used by farmers to confront the extreme conditions of high-altitude and rain-fed agriculture, and add intraspecific variability to a normally monotonous diet. The potato is historically and culturally embedded in the Andean food system. Households consume varietal diversity rather than a single variety because they value the rich genetic resources of the region and recognize that different food preparations and dishes either require a mix or a specific cultivar. Varietal diversity itself is an established and appreciated source of diversification within a diet dominated by potatoes. A large repertoire of combined preference, quality and use traits is offered by a pool of landraces and modern varieties rather than a single genotype. Additionally, potato landraces and modern varieties complement each other well providing food at different moments in time. Floury landraces provide the bulk of the potato consumed in May-June after the main harvest season while modern varieties dominate the diet during the months of January-February when the longer cycle landraces are still growing.

In the Peruvian context, the potato is sometimes erroneously accused of being a contributor to undernutrition. This because the potato dominates the relatively monotonous diets in the Andes - populations with high rates of undernutrition- and is generally considered a source of energy rather than of protein or minerals. Nevertheless, the data from our intake study confirms that potato sustains rather than inhibits local food security in these populations. The potato contributes significantly and positively to the nutritional balance and the recommended requirements for energy, protein, iron and zinc of women and children during the period of abundance and lean period. Potato contributes a significant portion of the total dietary intake. It has been recently shown that from 63 to 79% of the iron in potato is released from the food matrix after gastrointestinal digestion in vitro, and therefore available for absorption (Andre et al 2015), percentage that is higher than those in cereals and legumes. The contribution of the potato to the iron and zinc requirements is limited, yet still important within a context of standard diets being deficient in micronutrients. Our study shows that the total food intake from the current diet provides only 40.4 to 54.4% of the recommended intakes of iron for women and 29.6 to 41.6% of that of zinc for children. This is a direct consequence of the lack of species and food diversity, especially meat, milk, egg, fruit and/or vegetable intake which also provide other essential nutrients. The consumption of these products by the study population is almost negligible.

Conclusions

The potato and its high levels of intraspecific diversity provide a solid basis for Andean food security. Intraspecific variability and inherent unevenness of variety-level nutrient densities need to be more consistently considered in nutrition studies striving to characterize links between consumption and dietary adequacy, especially in regions where the dominant staple food crop has high levels of varietal diversity. The precision of food intake studies can gain substantially by taking into account the accurate composition of common landraces and modern varieties. Landraces or modern varieties complement each other during different periods of the year in the Andean food systems. It is an apparent paradox that the high level of diversity of potato landraces in our case study site coincides with unacceptable levels of child undernutrition. Varietal diversity itself is not sufficient to assure nutritionally adequate diets. It needs to be complemented by species and food diversity, as well as land use systems and rural economies that allow for sustainable production capacity and income generation to support household-level needs for nutritious food. Food-based interventions could target a diversification strategy through promoting micro livestock, horticulture, inclusive markets, and off-farm employment opportunities, among others. Improving the amount of iron and zinc from potato varieties in the diets (e.g., through biofortification) could also make a contribution to reducing the levels of undernutrition in Andean food systems. However, it is especially important to take a whole food basket approach and enhance consumption of high bioavailable animal sources of iron and zinc (meats) as well as other animal source products (eggs, milk), pulses, fruits and vegetables.

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Fig. 1 Chemical composition of raw and processed potato landraces
nd=non-determined; *=raw sample; #=boiled sample; •=mg/100 gr WB; ▲=%
[1]CIP et al. 2015
[2] MINAGRI et al. 2017
[3] De Haan et al. 2009
[4] De Haan et al. 2012
[5] INS 2009

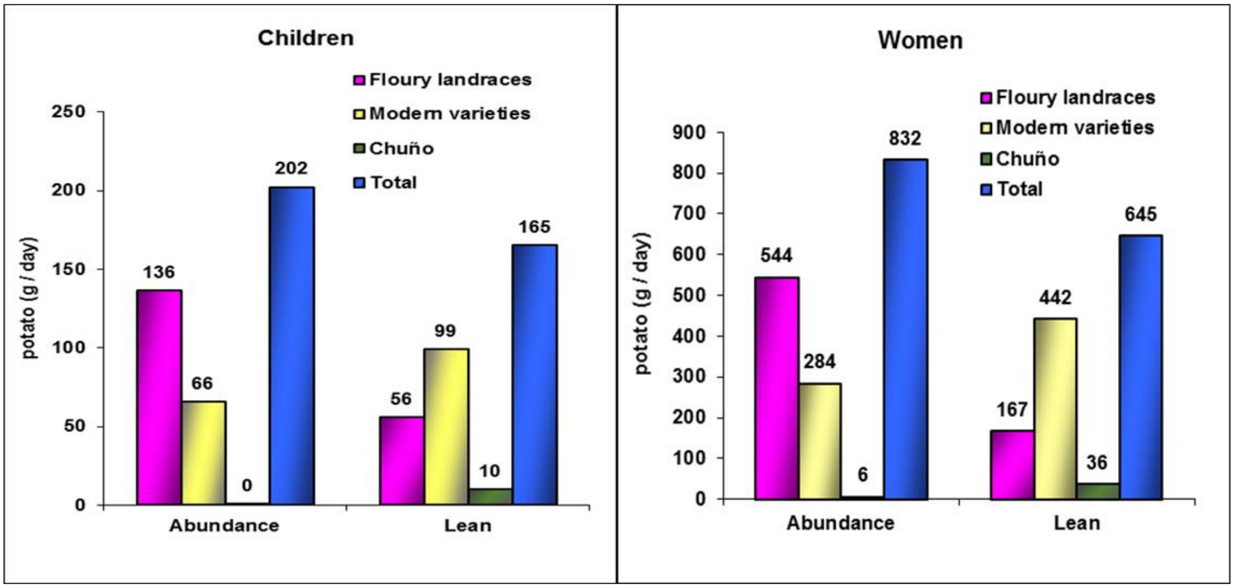

Fig. 2 Daily total and varietal potato intake (g / day) of women and children for abundance and lean study periods

Fig. 3 Contribution of potato and other foods to the total energy, protein, iron, and zinc intake of women and children.

Table 1 Common floury and bitter potato landraces used for nutritional analysis

Vernacular name	Category	Species (cultivar group)	Ploidy
Allqa Palta	Floury	*S. tuberosum* (Andigenum)	2*n*=4*x*=48
Ayrampu	Floury	*S. tuberosum* (Andigenum)	2*n*=4*x*=48
Sortijillas	Floury	*S. tuberosum* (Andigenum)	2*n*=4*x*=48
Qori Markina	Floury	*S. tuberosum* (Andigenum)	2*n*=4*x*=48
Ajo Suytu	Floury	*S. tuberosum* (Chaucha)	2*n*=3*x*=36
Puka Wayru	Floury	*S. tuberosum* (Chaucha)	2*n*=3*x*=36
Sirina	Floury	*S. tuberosum* (Chaucha)	2*n*=3*x*=36
Ritipa Sisan	Floury	*S. tuberosum* (Chaucha)	2*n*=3*x*=36
Chiqchi Pasña	Floury	*S. tuberosum* (Goniocalyx)	2*n*=2*x*=24
Peruanita	Floury	*S. tuberosum* (Goniocalyx)	2*n*=2*x*=24
Runtus	Floury	*S. tuberosum* (Goniocalyx)	2*n*=2*x*=24
Yana Puqya	Floury	*S. tuberosum* (Stenotomum)	2*n*=2*x*=24
Yana Manwa	Bitter	*S. tuberosum* (Andigenum)	2*n*=4*x*=48
Yuraq Lui	Bitter	*S. tuberosum* (Andigenum)	2*n*=4*x*=48
Kumpus Siri	Bitter	*S. juzepczukii*	2*n*=3*x*=36
Yuraq Siri	Bitter	*S. juzepczukii*	2*n*=3*x*=36
Yana Siri	Bitter	*S. juzepczukii*	2*n*=3*x*=36
Puka Qanchillu	Bitter	*S. juzepczukii*	2*n*=3*x*=36
Yuraq Waña	Bitter	*S. curtilobum*	2*n*=5*x*=60
Yana Waña	Bitter	*S. curtilobum*	2*n*=5*x*=60
Ipillu Culebra	Bitter	*S. tuberosum* (Stenotomum)	2*n*=2*x*=24

Table 2 Dry matter, gross energy, crude protein, iron and zinc content of 12 boiled floury potato landraces grown in Huancavelica (fresh weight basis)

	Dry Matter (%)	Gross Energy (kcal/100g)	Crude Protein (g/100g)	Iron (mg/100g)	Zinc (mg/100g)
Allqa Palta	28.71 ± 1.69	109.67 ± 6.25	2.02 ± 0.18	0.28 ± 0.03	0.35 ± 0.05
Ayrampu	29.63 ± 1.71	118.17 ± 13.73	2.51 ± 0.12	0.63 ± 0.15	0.43 ± 0.09
Sortijillas	29.98 ± 0.80	111.17 ± 5.12	1.76 ± 0.12	0.26 ± 0.04	0.31 ± 0.05
Qori Markina	25.85 ± 0.59	96.33 ± 3.08	2.44 ± 0.17	0.47 ± 0.04	0.28 ± 0.02
Ajo Suytu	30.34 ± 0.94	123.17 ± 10.42	2.62 ± 0.27	0.52 ± 0.06	0.28 ± 0.02
Puka Wayru	28.13 ± 1.74	111.33 ± 5.85	2.23 ± 0.11	0.57 ± 0.02	0.32 ± 0.02
Sirina	29.56 ± 1.14	112.67 ± 9.46	2.56 ± 0.20	0.54 ± 0.03	0.41 ± 0.04
Ritipa Sisan	33.00 ± 1.11	118.67 ± 7.69	2.41 ± 0.19	0.56 ± 0.05	0.33 ± 0.02
Chiqchi Pasña	30.48 ± 2.57	121.00 ± 8.22	2.87 ± 0.13	0.72 ± 0.07	0.38 ± 0.06
Peruanita	30.43 ± 2.07	118.50 ± 2.43	2.30 ± 0.18	0.43 ± 0.03	0.34 ± 0.02
Runtus	24.70 ± 0.44	103.50 ± 6.69	2.95 ± 0.26	0.60 ± 0.05	0.34 ± 0.01
Yana Puqya	25.91 ± 0.37	108.83 ± 7.28	2.84 ± 0.24	0.57 ± 0.04	0.41 ± 0.02

Table 3 Gross energy, crude protein, iron and zinc content of white *chuño* samples from potato landraces grown and processed in Huancavelica (fresh weight basis)

	Gross Energy (kcal/100g)	Crude Protein (g/100g)	Iron (mg/100g)	Zinc (mg/100g)
Yana Manwa	106.00 ± 8.19	0.49 ± 0.10	0.29 ± 0.16	0.04 ± 0.03
Yuraq Lui	91.33 ± 5.86	0.59 ± 0.03	0.36 ± 0.06	0.04 ± 0.00
Kumpus Siri	97.33 ± 4.62	0.95 ± 0.12	0.52 ± 0.04	0.09 ± 0.01
Puka Qanchillu	107.33 ± 7.51	1.15 ± 0.07	0.42 ± 0.01	0.10 ± 0.01
Yuraq Waña	120.00 ± 9.54	0.83 ± 0.17	0.46 ± 0.04	0.12 ± 0.01
Yana Waña	112.67 ± 2.89	0.66 ± 0.06	0.44 ± 0.04	0.11 ± 0.01
Yuraq Siri	138.67 ± 5.77	1.12 ± 0.11	0.52 ± 0.05	0.10 ± 0.01
Yana Siri	108.00 ± 6.24	0.63 ± 0.01	0.65 ± 0.07¥	0.14 ± 0.02
Ipillu Culebra	86.00 ± 5.57	0.57 ± 0.02	0.76 ± 0.09¥	0.05 ± 0.01

¥ = high values because of possible contamination of samples with soil residues as suggested by high aluminium content of Yana Siri (20.97 ± 3.26 mg / kg; DWB) and Ipillu Culebra (33.91 ± 2.88 mg / kg; DWB)

Table 4 Average daily energy, protein, iron and zinc intake for women and children by study period

Source	Period of Abundance				Lean Period			
	Energy (kcal/day)	Protein (g/day)	Iron (mg/day)	Zinc (mg/day)	Energy (kcal/day)	Protein (g/day)	Iron (mg/day)	Zinc (mg/day)
WOMEN								
Native cultivars	642	13.87	2.63	1.85	194	4.30	2.21	0.58
Improved cultivars	283	6.13	1.42	0.63	472	10.23	0.83	1.64
Chuño	18	0.11	0.19	0.05	39	0.23	0.14	0.02
All potatoes	944	20.11	4.24	2.52	706	14.77	3.18	2.24
Total intake[a]	2155	49.72	19.11	8.47	2173	56.22	24.31	9.93
CHILDREN								
Native cultivars	161	3.49	0.66	0.47	65	1.41	0.28	0.20
Improved cultivars	65	1.41	0.33	0.14	106	2.31	0.50	0.37
Chuño	1	0.01	0.01	0.00	11	0.07	0.04	0.01
All potatoes	227	4.91	1.00	0.61	183	3.79	0.82	0.57
Total intake[a]	616	14.7	5.3	2.43	684	17.9	7.1	3.43

[a] = from all food sources

Table 5 Adequacy of the diet: nutrient intakes expressed as a percentage of the Recommended Daily Intakes (RDI) for energy and nutrients from total food and potato intake

	Period of Abundance				**Lean Period**			
	% of RDI total diet		**% of RDI from potato**		**% of RDI total diet**		**% of RDI from potato**	
	Women (n=76)	**Children (n=75)**	**Women (n=76)**	**Children (n=75)**	**Women (n=77)**	**Children (n=78)**	**Women (n=77)**	**Children (n=78)**
Energy	88.7	84.0	38.6	29.2	87.3	85.6	28.7	23.0
Protein	96.4	183.9	38.2	57.8	104.5	193.0	28.0	43.7
Iron[a]	29.5	40.4	6.5	7.7	35.5	54.4	4.9	6.2
Zinc[a]	76.0	29.6	22.6	7.5	85.2	41.6	19.6	7.0

[a] based on a low bioavailability scenario