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Original Article

Understanding the role of potatoes in the Peruvian diet: An approach that combines food composition with household expenditure data

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ABSTRACT

Agricultural research in developing countries has increasingly focused on meeting nutritional objectives. Biofortified varieties and increased use of fertilizers have been studied to improve the nutrient profile of staple foods and thereby reduce micronutrient malnutrition. To understand where and for which crops this is appropriate, a better understanding of population-level consumption patterns is needed. In this paper, we demonstrate an approach to understanding the role of the potato in the Peruvian diet, and how it varies by geographic and socio-economic group. We combine readily available data on household expenditures from a Peruvian living conditions survey (ENAHO) with food composition data to derive estimates on the amount of potatoes consumed per adult equivalent, and the contribution of potatoes to meeting the energy, protein, calcium, iron, and vitamin C needs of Peruvians. Households in the highlands, where potatoes are often the basis of cropping systems, consume the greatest quantities of potatoes, averaging 421 g/adult equivalent/day (g/ae/d). In this region, potatoes contribute 18%, 16%, 17%, and 97% of the recommended needs for energy, protein, iron, and vitamin C, respectively. Sensitivity testing using different cultivars previously examined from the Peruvian highlands shows that potatoes could supply a range from 7–31% of the recommended intakes for iron in this population. This work gives support for continuing agricultural research to reduce micronutrient malnutrition and provides guidance for where and with whom such research might have the greatest impact.

1. Introduction

Agricultural scientists are increasingly orienting their research towards improving human nutrition (Graham et al., 2006). This new focus is well justified. Malnutrition is extensive and at the root of many other problems of development (Bhaskaram, 2002; Mason et al., 2001; World Health Organization, 2002). In the developing world, undernutrition is particularly prevalent among rural farm households. The need to increase the role of agriculture in addressing malnutrition has, in fact, been persuasively argued by various panels and authors (Lomborg, 2004; Rouse and Davis, 2004; Welch and Graham, 1999).

Various agricultural strategies have been suggested for improving nutrition (Graham et al., 2006). These include improving micronutrient availability through plant breeding, also known as bio-fortification, and increased use of fertilizers to improve the nutrient profile of staple foods (Bonierbale et al., 2007). Altering the cropping mix in a given food system can be used to promote diet diversity and thus introduce crops rich in nutrients previously lacking in the diet. Increasing incomes of farmers, allowing them to purchase a more diversified diet, can also be promoted through agricultural research that increase the yield of existing crops.

Understanding the food consumption habits of a population is essential for orienting agricultural research to improve human nutrition. The International Potato Center (CIP) in Peru, one of the research centers of the Consultative Group on International Agricultural Research, has long conducted research to improve the livelihood of potato farmers by increasing yields. One of the projects at CIP, which has as a main goal to determine the potential for potatoes to contribute to reducing malnutrition, generated the following questions. Could increasing the content and availability of nutrients in potatoes make a significant impact on nutritional status? If so, where and among which populations should efforts be focused? For which nutrients might potato intakes be significant enough among the population, so that such research efforts would be fruitful?

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Studies in high-income countries which seek to estimate the consumption habits of an entire nation typically rely on nationally representative surveys with a 24-h dietary recall component (Dwyer et al., 2001). There are well-documented problems with the 24-h recall instrument, including its imprecision at estimating usual intakes with data for only 1 or 2 days, as well as inaccuracies in the linkage between the foods that the respondent reports and those for which food composition data are available. Equally important in developing countries, the 24-h recall instrument is very costly to implement on a national basis, often requiring human resources (trained dietitians), infrastructure (transportation, computing services), and funding beyond available capacity. The weighed food intake method may give more accurate results, but is even more difficult to implement on a national basis.

This article demonstrates an alternative approach for developing countries that uses data from a household income and expenditure survey. Since food often comprises the largest share of household spending in low-income countries, the food component of this type of survey is usually the most detailed. Income and expenditure surveys – also referred to as living conditions, living standards, or poverty surveys – usually collect very detailed information on household demographics, socioeconomic status, and geography. This information, as well as the large samples that are drawn, are important in their use for assessing poverty and orienting policy interventions to address it. They also allow for understanding where and with whom food-based interventions are most likely to succeed. In most countries, income and expenditure surveys are conducted on a periodic basis. Additional details about these surveys as well as access to data in specific countries can be found online (World Bank, 2008).

In Peru, for women and children alike, the most important energy sources are rice, potatoes, and sugar. Although 80% of women and 70% of children consume vegetable oil, intakes are in relatively small quantities. In urban areas the main sources of protein, iron, and zinc come from legumes, meat, and fish, while in rural areas tubers and legumes are the main sources of these nutrients (CENAN, 2003). Potatoes are a more expensive source of calories than rice or wheat flour for urban consumers, though with recent increases in relative prices of these goods, potatoes have become more competitive. For rural consumers who grow their own potatoes, potatoes are much more economical as a source of calories than these grains, providing 1.5–2 times the amount of calories for the same amount of money (V. Suarez, personal communication, August 28, 2008).

To better understand the role that potatoes play in the Peruvian diet, this article combines information from the type of survey described earlier – specifically, a 2005 living-conditions survey – with data from a Peruvian food composition table. This approach is used to estimate the contribution of potatoes to the overall energy consumption by Peruvian households. Also estimated are the consumption amounts – both in absolute levels and as a percent of requirements – provided by potatoes for protein, calcium, iron and vitamin C. This approach allows a ''mapping'' of the areas, both geographic and socio-economic, where potatoes play an important role in the diet.

2. Methods

2.1. Data source and sample

Data are analyzed from the 2005 National Survey of Household Living Conditions and Poverty, known in Spanish as the Encuesta Nacional de Hogares Sobre Condiciones de Vida y Pobreza (ENAHO). This is an ongoing monitoring effort by Peru's national statistical agency, the Instituto Nacional de Estadística e Informática (INEI), to provide information to policymakers, researchers and others on the evolution of poverty, well-being and household living conditions in Peru (INEI, 2005).

ENAHO, which is conducted throughout the calendar year, is a nationally representative survey of the non-institutionalized residential population of urban and rural Peru. This excludes members of the armed forces that live on military bases as well as others living in collective housing, such as jails, hospitals, hotels, and religious quarters. INEI uses a stratified, multi-stage sample design with the 1999–2000 Pre-Census as the sampling frame. The sample size for 2005 was 19,895 households allowing for a 95% confidence level with inferences being made down to the level of the departments in Peru. There are 24 departments in Peru, which are administrative divisions analogous to states or provinces in other countries. Other details regarding sampling design have been published previously (INEI, 2005).

2.2. Food consumption

ENAHO measures consumption of foods, and other household goods, using a detailed version of a typical living standards expenditure questionnaire. The respondent is asked about all foods acquired for household consumption in the previous 15 days. Acquisition is viewed in its broadest sense to include all food that is purchased, consumed and supplied from own production, received as payment for work, received as a gift, donated from a social program, or acquired by other means. ENAHO uses specific prompts to ask about each of these possibilities. Purchase frequency and amounts are also queried, as are consumption frequency and amounts for all non-purchased foods. ENAHO asks separate consumption questions for the most commonly consumed products as well as open-ended prompts about ''other foods'' in each category that allow for the coding of additional products. Altogether, the module captured specific quantities of 15 different potato products (e.g. white potato, yellow potato, colored potato) and an additional dozen root and tuber products (e.g. yellow sweet potato, olluco, white cassava). For each household, we calculated total potato consumption by summing consumption amounts from purchases and from other means of acquisition for all potato items listed in the survey.

Food expenditure surveys measure what is consumed by households, rather than what is eaten by individuals. This is the economist's, rather than the nutritionist's definition of consumption, i.e. that which is acquired by the household. Refuse in the preparation of foods, plate waste, and other potential losses are not assessed, so they are not subtracted from household consumption amounts reported here. ENAHO does not assess the content of restaurant and other meals (e.g. at a friend's house) that do not come from the household food supply. For all these reasons we refer to our measure as ''apparent household consumption,'' and label it as such in our main data tables.

Since households vary in size, we converted annual household consumption to per person amounts using the concept of adult equivalence, a common technique in consumption analysis to apportion household level amounts to the individual. A per capita measure of consumption, obtained by dividing total household consumption by the number of people in the household, would give an underestimate of the likely consumption of individuals, since babies would be counted the same as adults. Instead, we assessed each member's equivalence to an adult male based on their relative energy needs. For example, a 1-year-old girl was counted as 0.41 adult male equivalents (ae), since her energy requirement was equivalent to 41% of an adult male's requirement (1310/2797), and an adult female was counted as 0.75 ae, since her energy requirement was equivalent to 75% of that of an adult male

(2100/2797). Total household consumption was converted to consumption per adult equivalent (ae) on a daily basis, by dividing total household consumption by the sum of adult equivalents in each household.

2.3. Nutrient consumption

To analyze the nutrient contribution of potatoes, we assembled a food composition table specifically for this project (see Table 1). The ENAHO consumption files have codes for 15 different potato products, including those with specific prompts in the questionnaire and those that have been post-coded based on other potato items reported by respondents. These are reported in the form in which they are acquired, so that consumption quantities from the ENAHO data listed in this table typically refer to amounts of raw potatoes with peel. We linked these items to items in the food composition table developed by the Peruvian National Food and Nutrition Center, known in Spanish as the Centro Nacional de Alimentación y Nutritción (CENAN, 1996). In one case, for harina de chuño, a type of flour made from artisanally freeze-dried potato, we used data for food composition data for Latin America from the online database of the Food and Agriculture Organization of the United Nations (FAO, 2008). The table we developed contained quantities per 100 g edible portion of energy, protein, calcium, iron, and vitamin C. We calculated the nutrients contributed by apparent potato consumption for energy, protein, calcium, iron, and vitamin C by multiplying the total consumption amounts on a daily per adult equivalent basis by the nutrient content of each potato product and then summing these nutrient amounts across all potato products.

To estimate the contribution of potato products to meeting the needs of Peruvian households, we calculated the needs of each household member based on their age and sex, and international requirements for energy, protein, calcium, iron, and vitamin C (FAO and WHO, 2004; FAO et al., 2004; FAO et al., 1985). Calculation of energy and protein requirements required assumptions about individuals' weights; we used average weights by age and sex estimated previously for the Peruvian population (James and Schofield, 1990). We assumed a moderately active population. For calculation of the recommended nutrient intake for iron, we assumed an overall dietary iron bioavailability of 10%. After calculation of each individual's requirements, we summed the requirements of all members within a household to derive a recommended nutrient intake at the household level.

2.4. Demographic and socio-economic variables

ENAHO's sample design allows for the reporting of consumption by urban and rural areas, and by eight geographic regions, including the northern, central, and southern coastal regions, the northern, central, and southern regions of the Sierras, the Amazon jungle area, and the capital district of Metropolitan Lima.

INIE classifies households into three categories of economic status: extremely poor, poor, and not poor. Households are considered extremely poor if the money value of all expenditures (including the value of home-produced goods, gifts, donations, and program benefits) is less than the cost of a basic food basket needed to meet their members' energy needs. This cost varies from household to household based on the age–sex composition of the household and on variations in food prices. The basic food basket, derived from previous consumption studies and consisting of 48 items, is priced in urban and rural areas in the 24 departments. Those with total expenditures greater than the cost of this basic food basket, but less than the cost of all basic household needs, including housing, clothing, and other goods and services, are considered poor (INEI, 2008). Households whose expenditures total more than the cost of these basic needs are considered not poor.

Rural households in the highland region were disaggregated and investigated separately, because of early results indicating their above-average consumption of potatoes. To do this, households were combined from the rural areas of the northern, central, and southern highlands. They were then divided into two groups, those who were either poor or extremely poor by the INIE standard and those who were not poor.

3. Results

Table 1 presents the food composition table that we developed for use with analyzing the ENAHO consumption data on 15

Table 1
Matching potato products from ENAHO 2005 to CENAN 1996 food composition data.

Data from ENAHO 2005[a]					Data from CENAN food composition table[a,c]					
Potato product[b]	ENAHO code	Consumption frequency (% of all households consuming)	Mean consumption among consumers (kg/hh/year)	Mean consumption among entire sample (kg/hh/year)	CENAN code	Energy (kcal)	Protein (g)	Calcium (mg)	Iron (mg)	Vitamin C (mg)
Chuño flour	4	0.9	13	0	B449	338	6.4	82	1.0	8.9
Potato "Amarilla"	13	35.1	117	41	417	103	2.0	6	0.4	9.0
Potato "Amarga"	14	0.0	224	0	418	97	2.1	9	0.5	14.0
Potato "Blanca"	15	70.1	253	177	418	97	2.1	9	0.5	14.0
Chuño	16	6.8	91	6	402	323	1.9	92	3.3	1.1
Potato "Guagalina"	17	0.0	303	0	418	97	2.1	9	0.5	14.0
Potato "Huayro"	18	5.7	168	10	418	97	2.1	9	0.5	14.0
Dried Potato	19	3.1	104	3	421	322	8.2	47	4.5	3.2
Potato "Compis"	20	0.0	417	0	418	97	2.1	9	0.5	14.0
Potato–other varieties	21	7.1	281	20	418	97	2.1	9	0.5	14.0
Potato "Sacha"	22	0.2	277	1	427	112	1.8	3	0.7	3.1
Potato "Color"	27	10.5	293	31	418	97	2.1	9	0.5	14.0
Chuño Entero	28	3.6	60	2	402	323	1.9	92	3.3	1.1
Chuño Remojado	29	0.0	19	0	402	323	1.9	92	3.3	1.1
Potato "Larga"	30	0.0	363	0	418	97	2.1	9	0.5	14.0

[a] ENAHO is the Spanish acronym for Peru's National Survey of Household Living Conditions and Poverty (INEI, 2005). CENAN is the Spanish acronym for Peru's National Food and Nutrition Center, which is a part of the Ministry of Health (CENAN, 1996).
[b] Potato products are as listed on the ENAHO data file. Amounts are for apparent household consumption and are reported in the form as purchased or acquired. Chuño is a freeze-dried potato product.
[c] Nutrient values are per 100 g edible portion.

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different potato products. To give a sense of importance in the overall Peruvian diet of each product, we calculated consumption frequencies and amounts for each of them for the entire sample. The three most frequently consumed products were white potato, yellow potato, and colored potato, consumed by 70%, 35%, and 10% of the population, respectively. In Peru, white potatoes are predominantly improved, meaning they have been developed by a scientific breeding program, whereas yellow and colored potatoes are mostly native potato landraces, i.e. cultivated plants from farmers' selections that have not been developed by a scientific breeding program. Average amounts consumed among those reporting consumption of these products were 253, 117, and 293 kilograms per household per year (kg/hh/y), respectively. Some potato products were consumed in large amounts, though by only a small percentage of the population. For example, the potato landrace Compis, a type of *Solanum andigena*, was consumed by less than a 0.1% of the population, but those that did had an average consumption of 417 kg/hh/y. Over the entire population, white potato was consumed in the greatest amounts, 177 kg/hh/y.

Of the 19,895 households in the sample, 29% live in Metropolitan Lima, the capital; overall 65% of households live in urban areas (Table 2). About 40% of households are classified as poor or extremely poor. Over a third of households live in the Sierras and 22% live along the coast. According to the sources used here, the overall average apparent consumption of potatoes is 253 grams per adult equivalent per day (g/ae/d). Not surprisingly, rural households consume more than urban households, as do poor versus not poor. The central Sierra region has the highest potato consumption with 394 g/ae/d, followed by the south and north Sierra regions. The lowest consumption is along the north coast. We also estimated consumption for those living in all rural areas of the Sierras, a group comprising close to a quarter of the Peruvian population. Their average apparent consumption was 421 g/ae/d with similar amounts among households that were poor and not poor.

Table 2 also presents the energy contribution of potatoes to the Peruvian diet in kilocalories and in percentage terms. Potatoes contribute greater percentages of calories to the diets of rural households, those in extreme poverty, and those living in the Sierras. For the rural poor living in the Sierras, potatoes contribute 18% of the calories consumed.

The apparent contribution of potatoes to the nutrient intake of Peruvian households is described in Table 3. On average, potatoes contribute 273 calories per adult equivalent per day, or about 10% of the energy allowances for a moderately active population. Potatoes also contribute about 9% of nutrient allowances for protein, 2% for calcium, 8% for iron, and 60% for vitamin C.

The contribution of potatoes to iron nutrition may be particularly significant among poor and rural households, and particularly among those living in the rural Sierras, where average intake is 3.2 mg/ae/d, or close to 17% of recommended intakes. Potatoes also contribute significantly to meeting the needs for protein (16%) and vitamin C (97%) among this rural Sierran population. In contrast, for those living along the north coast, potatoes contribute 3%, 4%, and 27% of recommended intakes for iron, protein, and vitamin C, respectively.

Results on apparent consumption from the ENAHO data were compared with other sources of food consumption data from the Peruvian population. CIP conducted an intensive study of rural farm households in six villages in the Department of Huancavelica (Graham et al., 2006). They used a 1-d weighed food intake method to assess consumption by adult women and children, aged 6–36 months. They found that potato intake ranged from 645 to 839 g/d for women during respective periods of scarcity and abundance (Table 4). Measured during the same periods, children's intakes ranged from 165 to 202 g/d. ENAHO consumption data are at the household level, so we do not know the consumption of adult women, children or other specific types of individuals in the household. However, by narrowing the sample to just rural households from the same Department as the CIP study, and by analyzing data across the calendar year, we found that apparent potato consumption averaged 369 g/ae/d and ranged from 257 g/ae/d in the lowest month of consumption to 531 g/ae/d in the highest.

Table 2
Apparent household consumption of potatoes by socio-economic characteristic, ENAHO 2005[a,b].

Characteristic	*N*	Frequency (%)	Mean potato consumption (g/ae/d)[c]	Energy from potatoes (kcal/ae/d)[c]	Percent of total energy from potatoes (%)
All households	19,895	100.0	253	273	8.4
Urbanization					
Rural	8,815	34.9	330	379	12.2
Urban	11,080	65.1	212	215	6.4
Poverty status					
Extremely poor	3,119	13.7	301	342	15.2
Poor	5,449	26.8	266	291	9.4
Not poor	11,327	59.5	237	248	6.3
Region					
North Coast	2,705	13.5	117	118	3.4
Central Coast	1,420	6.6	208	205	5.4
South Coast	1,118	2.3	211	218	6.8
North Sierra	1,115	6.8	316	315	10.1
Central Sierra	3,617	14.2	394	394	13.8
South Sierra	2,909	15.5	385	512	16.0
Selva	4,791	12.3	124	124	3.8
Metropolitan Lima	2,220	28.8	232	230	6.3
Rural Sierra	4,560	23.3	421	495	16.1
Poor	1,423	16.0	419	492	18.0
Not poor	3,137	7.3	426	501	11.7

[a] ENAHO is the Spanish acronym for Peru's National Survey of Household Living Conditions and Poverty (INEI, 2005).
[b] Data represent amounts acquired for the household food supply and are not adjusted for refuse, plate waste, and other potential losses, or for additions from restaurant meals. All data in the table are weighted using sampling weights with the ENAHO survey, except the *N*s which are unweighted.
[c] Units are grams per adult male equivalent per day or kilocalories per adult male equivalent per day. Adult equivalence is an alternative to a "per capita" measure that better takes into account relative energy needs of individuals of different age and sex (see text, Section 2.2).

In the early 1990s, Peru's nutritional surveillance system did an intensive study of food consumption by preschool children (aged 12–35 months) and their families (Montes et al., 1997). Using a 1-d weighed food intake method, they found that preschoolers consumed an average of 96 g/d of potato in the Sierra regions of the Departments of Cusco and Madre de Dios (referred to as the Inka region). A similar level of 99 g/d was found in the Sierra regions of Amazonas, Cajamarca, and Lambayeque Departments (referred to as the Nor-Oriental Marañón, or NOM region). Family consumption was also assessed by weighed food intake, but the report does not give information for household size. We divided household consumption from this report by average household size in adult equivalent units for the same departments (obtained from the ENAHO data) and found that potato intakes ranged from 542 to 632 g/ae/d. ENAHO apparent consumption data from the same departments were lower, ranging from 318 to 525 g/ae/d for the same respective regions.

The Peruvian Ministry of Agriculture reports potato production data, as well as other data on imports, exports, and waste, for FAO's food balance sheets (FAO, 2007). We used annual potato quantities available for human consumption from these data and calculated amounts per adult equivalent using mean values on household size

Table 3
Apparent contribution of potatoes to nutrient intake and to meeting nutrient requirements by socio-economic characteristics, ENAHO 2005[a].

Characteristic	Energy (kcal/ae/d)[b]	Energy (% req)	Protein (g/ae/d)[b]	Protein (% req)	Calcium (mg/ae/d)[b]	Calcium (% req)	Iron (mg/ae/d)[b]	Iron (% req)	Vitamin C (mg/ae/d)[b]	Vitamin C (% req)
All households	273	9.7	5.4	9.3	29.6	2.2	1.6	7.9	32.3	60.1
Urbanization										
Rural	379	13.6	7.2	12.2	47.6	3.5	2.4	12.4	41.7	77.0
Urban	215	7.7	4.5	7.7	19.9	1.5	1.1	5.4	27.2	51.0
Poverty status										
Extremely poor	342	12.2	6.4	11.1	43.0	3.2	2.1	10.7	38.1	70.9
Poor	291	10.4	5.7	9.8	33.2	2.5	1.7	8.7	34.0	63.7
Not poor	248	8.9	5.1	8.6	24.8	1.9	1.4	6.9	30.2	55.9
Region										
North Coast	118	4.2	2.4	4.2	9.9	.8	.6	2.8	14.4	26.8
Central Coast	205	7.3	4.4	7.4	17.9	1.3	1.0	5.0	27.3	51.0
South Coast	218	7.8	4.5	7.7	23.5	1.8	1.2	5.9	28.6	54.2
North Sierra	315	11.3	6.8	11.7	29.3	2.2	1.7	8.4	42.9	79.9
Central Sierra	394	14.1	8.3	14.1	37.3	2.8	2.1	10.5	53.0	97.7
South Sierra	512	18.3	8.7	14.7	78.8	5.8	3.7	19.2	45.0	82.9
Selva	124	4.4	2.6	4.5	11.3	.9	.6	3.2	16.2	31.0
Metropolitan Lima	230	8.2	4.9	8.4	19.6	1.5	1.1	5.5	29.4	55.1
Rural Sierra	495	17.7	9.2	15.6	64.6	4.7	3.2	16.6	52.8	97.2
Poor	492	17.6	9.1	15.5	65.0	4.8	3.2	16.2	52.4	96.8
Not poor	501	17.9	9.6	15.9	63.8	4.6	3.3	17.5	53.7	97.8

[a] ENAHO is the Spanish acronym for Peru's National Survey of Household Living Conditions and Poverty (INEI, 2005). Data come from amounts acquired for the household food supply and are not adjusted for refuse, plate waste, and other potential losses, or for additions from restaurant meals. Requirement data are aggregated at the household level and are based on international standards (FAO and WHO, 2004; FAO et al., 2004, 1985).

[b] Units are grams per adult male equivalent per day or kilocalories per adult male equivalent per day. Adult equivalence is an alternative to a "per capita" measure that better takes into account relative energy needs of individuals of different age and sex (see text, Section 2.2).

Table 4
Comparing ENAHO data on apparent consumption of potatoes to other Peruvian sources of data.

Source of data	Reference	Year	Sample	Consumption method	Consumption (g/ae/d)[a]
CIP Farming Systems Survey	Graham et al. (2006)	2003–2004	Farm households in six rural communities, Huancavelica Department	1-d weighed food intake	165–202 (child); 645–839 (woman)
ENAHO Living Conditions Survey	INEI (2005)	2005	Rural households in Huancavelica Department	2-week expenditure survey	369; 257–531
Peru Nutrition Surveillance Study	Montes et al. (1997)	1990–1995	Households from Inka[b] Sierra Region	1-d weighed food intake	96 (child); 632
ENAHO Living Conditions Survey	INEI (2005)	2005	Households from Inka[b] Sierra Region	2-week expenditure survey	525
Peru Nutrition Surveillance Study	Montes et al. (1997)	1990–1995	Households from NOM[b] Sierra Region	1-d weighed food intake	99 (child); 542
ENAHO Living Conditions Survey	INEI (2005)	2005	Households from NOM [b] Sierra Region	2-week expenditure survey	318
FAO Food Balance Sheet data	FAO (2007)	2005	National agricultural data	Aggregate national consumption data	281
ENAHO Living Conditions Survey	INEI (2005)	2005	Households from nationally representative sample	2-week expenditure survey	253

[a] Unless otherwise indicated, amounts refer to grams per adult equivalent per day and are developed from household consumption totals (see text, Section 2.2 for an explanation of adult equivalence). Quantities for children and women in the CIP study are grams/day for low and high seasons. CIP Comparison quantities from ENAHO are either the mean for the year (i.e. 369), or the means for low and high months for the year. Quantities in the Peru Nutrition Surveillance Study are grams/day for children and g/ae/d for household data. ENAHO data represent amounts acquired for the household food supply and are not adjusted for refuse, plate waste, and other potential losses, or for additions from restaurant meals.

[b] Inka region refers to the Departments of Cusco and Madre de Dios and the NOM, or Nor-Oriental Marañón, region refers to Amazonas, Cajamarca, and Lambayeque Departments

Table 5
Sensitivity of apparent household iron consumption to the use of differing potato cultivars for food composition data[a].

Place[a]	Name	Taxonomic group	Iron content	Mean intake—nationwide		Mean intake—rural Sierra	
			mg/100 g	mg/ae/d	% RNI	mg/ae/d	% RNI
Peru[b]	White potato	–	0.5	1.6	7.9	3.2	16.6
Inyaya	#703274	Phureja (2x)	1.02	2.6	18.8	4.3	31.3
Inyaya	Socco Huaccoto	Adigena	0.45	1.1	8.3	1.9	13.8
Aymara	#703274	Phureja (2x)	0.71	1.8	13.1	3.0	21.8
Aymara	EE-2057	Chaucha	0.39	1.0	7.2	1.6	12.0
Huancavelica	Pasna	–	0.77	1.9	14.2	3.2	23.7
Huancavelica	Sortiguillas	–	0.22	0.6	4.1	0.9	6.8

[a] Accesssions grown in Inyaya, Aymara, two sites in the Peruvian highlands, were from the germplasm collection at CIP. The native cultivars grown in Huancavelica were purchased locally. All iron content data are from Burgos et al. (2007) and show amounts acquired for the household food supply; they are not adjusted for refuse, plate waste, and other potential losses, or for additions from restaurant meals.
[b] Iron content for the white potato from the CENAN food composition table is listed as a reference here, but mean intakes for the nation or for the rural Sierras listed in this row are from Table 3 and are based on the nutrient content of all products listed in Table 1.

from ENAHO data. We calculated that there were 281 g/ae/d of potatoes available for human consumption. ENAHO data from the same year indicated an apparent consumption of 253 g/ae/d.

An area of active research for CIP is the micronutrient content of different potato cultivars. In the analysis of 49 native Andean potato varieties grown in three highland areas of Peru, Burgos et al. (2007) demonstrated a wide range of concentrations of iron and zinc. At the low end of the range, the Sortiguillas variety grown in Huancavelica had a concentration of 0.22 mg iron/100 g raw edible portion (Table 5). At the other end of the range, the cultivar, referred to as CIP accession #703274 and grown in Inyaya, had an iron concentration of 1.02 mg iron/100 g raw edible portion. ENAHO does not ask respondents to report on potato consumption by specific cultivar. To investigate the potential bias that could be introduced in estimating nutrient consumption levels without this information, we calculated the range of potential consumption of iron from potatoes, assuming, in sequential calculations, that all consumption came from each of the different cultivars grown in these highland localities. We calculated mean intakes for the entire country and also for those households living in the rural Sierra region. For example, if all consumption by households in the rural Sierras came from accession #703274 grown in Inyaya, apparent iron consumption per day would be 4.3 mg/ae/d and would contribute about 31% of iron needs. At the low end, consumption of Sortiguillas would yield intakes of 0.9 mg/ae/d, or about 7% of iron needs. Consumption estimates using other cultivars as the sole source of potatoes are also shown in Table 5.

4. Discussion

Potatoes are an important staple for the Peruvian population, but their role in the diet varies tremendously. On average Peruvians consume 253 g/ae/d. Rural households, poor households, and those living in the Sierras consume more, while urban, not poor, and those living in the jungle or along the coast consume less. For example, households living in the rural Sierra consume on average 421 g/ae/d, or 66% more than the national average. In the rural Sierras, potatoes contribute 16%, 17%, and 97% of needs for protein, iron, and vitamin C, respectively. For the poor in these areas, potatoes comprise 18% of their total energy intake. Potatoes are much less significant in the diets of those living along the coast, particularly along the northern coast, where potatoes contribute only 3% of total energy to the diet.

Linking food composition data with expenditure data from a living standards survey allows for a broad understanding of the role of particular foods in the diets of a population. With a very large and representative sample, surveys like ENAHO can give a detailed picture of how consumption varies by sub-group, and where targeting for specific types of interventions might be useful. Current consumption of potatoes with respect to iron nutrition is quite significant in the rural Sierras and suggests that improving varieties from these areas, with respect to both content and bioavailability of iron, could have a significant positive impact on the consumption of this nutrient. The dietary contributions are relatively low along the north coast or in the jungle populations, suggesting that other types of interventions might hold more promise in these areas.

Linking food composition data to other sorts of datasets allows for exploration of actions in the public health nutrition arena, such as targeting of interventions at a macro level, which is not possible with small-scale studies. Rose and Charlton (2002) linked food composition tables to household expenditure data in South Africa, and used the resulting household energy availability as a method for food security targeting. A similar approach was used for understanding how the macro-nutrient composition of the diet varied by urbanization and province in South Africa (Rose et al., 2002). Wuehler et al. (2005) linked food composition data to FAO national food balance data to estimate the risks of inadequate zinc intake at the national level for 176 countries.

Use of household expenditure data is not without its limitations. The ENAHO food consumption module is particularly detailed, with over 180 items listed and open-ended inclusion of non-listed items that allowed for capturing of 15 different potato products. However, consumption amounts (either purchased or consumed from home supplies) were queried for the previous 15 days, an interval that could lead to recall bias. For some items, such as staples that are purchased in constant amounts at regular intervals, this may be less of a problem. The ENAHO questionnaire leads respondents through a series of prompts about how a product was acquired, how often they shopped for it if it was purchased, and the usual purchase amount. But consumption from home-produced foods, though itemized and with similar prompts, may have been less easy for respondents to recall.

We investigated this by comparing other available sources of consumption data in Peru. In general, we found that the ENAHO data tend to underestimate potato consumption when compared to other sources. The CIP study used a 24-h weighed food intake to estimate the consumption of adult women and found mean lows and highs of 645 and 839 g/d, depending on the season (Table 4). The ENAHO study estimated consumption per adult equivalent, and found mean lows and highs to be considerably lower – 257 and 531 g/d.

While the 15-d recall methodology of ENAHO is a likely explanation for part of this difference, these comparisons are never straightforward, since sampling varies so much from one survey to the next. For example, the CIP study focused on six rural farming communities in the Department of Huancavelica in which potatoes were central to the cropping system while the ENAHO data were calculated on a representative selection of rural households from all villages in the same Department and included communities in which potato was not the principal staple. The estimates of preschooler consumption by the CIP study were also higher than the estimates on other preschoolers, based on the same type of weighed food intake. In the CIP study preschoolers consumed 165–202 g/d of potatoes, substantially higher than the estimates obtained from the Peruvian surveillance system study (Montes et al., 1997) for children living in the Sierras of the Inka or NOM regions, which had mean intakes of 96 and 99 g/d, respectively. The authors of the latter study cautioned that their geographic grouping of households in the Sierras was for convenience in presentation and should not be taken to imply that results were representative at that level (Montes et al., 1997). This might also explain in part why household estimates of consumption from ENAHO data were lower than household estimates from the Montes study.

One obvious limitation of using household level information to make inferences about nutrient consumption is that the individual is the relevant unit of analysis for dietary and nutritional studies. Because ENAHO and other such living-standard studies include complete rosters with the age and sex of all household members, we are able to adjust overall consumption to an adult equivalent basis. But using household data, even when adjusted to an adult equivalent basis, carries the implicit assumption that all individuals in a household eat in proportion to their nutritional needs. If certain individuals, such as adult males, get relatively more of their energy from animal products and less from potatoes than adult females, then the contribution of potatoes to meeting the energy requirements of adult males will be overstated by our adult-equivalent measure and understated for adult females. This might also explain some of the discrepancy with CIP study results on adult women described in the previous paragraph. Household-level consumption also does not take into account losses in food preparation or due to plate waste.

Another limitation of our approach may be the lack of information on the consumption of specific cultivars. Recent work in highland Peru has documented the wide range of nutrient content of potato cultivars depending on the specific variety and where it is grown (Burgos et al., 2007). Using ENAHO expenditure data and CENAN food composition data, we found that, on average, potatoes covered about 17% of the recommended iron intakes for those living in the rural Sierras. However, assuming that all potato consumption came from one of the varieties studied by Burgos and co-authors, we estimated that potatoes could supply anywhere from 7% to 31% of these recommendations.

Although this wide divergence in estimates is certainly a limitation of this type of approach, these results can also provide cause for optimism. In research on the rice farming system of rural Bangladesh, Kennedy et al. (2005) have shown that substantial majorities of respondents are able to give consumption information about specific cultivars. Given the appropriate data on food composition, such research suggests that future work on the nutrient contribution of specific crops may benefit from inclusion of cultivar-specific information.

The range of estimates for iron intake, particularly at the high end, should also provide optimism to agronomics researchers seeking to improve nutrient intakes. Clearly these results indicate that cultivars currently exist to make a substantial difference in the intakes of iron. What is now needed is the research to use this diversity to adapt and improve future cultivars. Results also suggest that a food system approach which includes potato as one component of the diet is likely to be most effective. Our approach gives an indication for which population groups such efforts may have the most impact.

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References

Bhaskaram, P., 2002. Micronutrient malnutrition, infection, and immunity: An overview. Nutrition Reviews 60, S40–S45.

Bonierbale, M., Amoros, W., Burgos, G., Salas, E., Juarez, H., 2007. Prospects for enhancing the nutritional value of potato by plant breeding. African Potato Association Conference Proceedings 7, 26–46.

Burgos, G., Amoros, W., Morote, M., Stangoulis, J., Bonierbale, M., 2007. Iron and zinc concentration of native Andean potato cultivars from a human nutrition perspective. Journal of the Science of Food and Agriculture 87, 668–675.

Centro Nacional de Alimentación y Nutrición, Instituto Nacional de Salud, Ministerio de Salud, 1996. Tablas Peruanas de Composición de Alimentos. Sétima Edición, Lima, Perú.

Centro Nacional de Alimentación y Nutrición, Instituto Nacional de Salud, Ministerio de Salud, 2003. Encuesta Nacional de Consumo de Alimentos en Niños de 12 a 35 meses y Mujeres in Edad Fértil. Informe Final. CENAN, Lima, Perú.

Dwyer, J., Ellwood, K., Moshfegh, A.J., Johnson, C.L., 2001. Integration of the continuing survey of food intakes by individuals and the national health and nutrition examination survey. Journal of the American Dietetic Association 101, 1142–1143.

Food and Agriculture Organization, 2007. FAOSTAT—Consumption Page. Retrieved 2007-7-18: <http://faostat.fao.org>.

Food and Agriculture Organization, Oficina Regional para América Latina y el Caribe, 2008. Tabla de Composición de Alimentos de América Latina. Retrieved 2008-3-21: <http://www.rlc.fao.org/es/bases/alimento/>

Food and Agriculture Organization, World Health Organization, 2004. Vitamin and Mineral Requirements in Human Nutrition: Report of A Joint FAO/WHO Expert Consultation, Bangkok, Thailand, 21–30 September 1998. World Health Organization, Geneva, Switzerland.

Food and Agriculture Organization, World Health Organization, & United Nations University, 1985. Energy and protein requirements: report of a joint FAO/WHO/UNU expert consultation. WHO Technical Report Series 724. Geneva, Switzerland.

Food and Agriculture Organization, World Health Organization, & United Nations University, 2004. Human Energy Requirements: Report of A Joint FAO/WHO/UNU Expert Consultation, Rome, Italy, 17–24 October 2001. Food and Agriculture Organization, Rome, Italy.

Graham, R.D., Welch, R.M., Saunders, D.A., Ortiz-Monasterio, I., Bouis, H.E., Bonierbale, M., et al., 2006. Nutritious subsistence food systems. Advances in Agronomy 92, 1–74.

Instituto Nacional de Estadística e Informática, 2005. Encuesta Nacional de Hogares Sobre Condiciones de Vida y Pobreza, Ficha Técnica. Retrieved 2007-7-25: <http://www.inei.gob.pe/srienaho/Consulta_por_Encuesta.asp>

Instituto Nacional de Estadística e Informática, 2008. Informe Técnico: Medición de la Pobreza 2004, 2005 y 2006. Retrieved 2008-3-21: <http://www.sepia.org.pe/apc-aa/img_upload/63a9a788f11e24822dcd0ba4d011c10f/Informe_Comisi_n_BM_2006_1.pdf>

James, W.P.T., Schofield, E.C., 1990. Human Energy Requirements: A Manual for Planners and Nutritionists. Oxford University Press, Oxford, United Kingdom.

Kennedy, G., Islam, O., Eyzaguirre, P., Kennedy, S., 2005. Field testing of plant genetic diversity indicators for nutrition surveys: Rice-based diet of rural Bangladesh as a model. Journal of Food Composition and Analysis 18, 255–268.

Lomborg, B., 2004. Global Crises, Global Solutions. Cambridge University Press, Cambridge, United Kingdom.

Mason, J.B., Lotfi, M., Dalmiya, N., Sethuraman, K., Deitchler, M., 2001. The Micronutrient Report: Current Progress and Trends in the Control of Vitamin A, Iodine, and Iron Deficiencies. Micronutrient Initiative, International Development Research Centre, Ottawa, Canada.

Montes, C., Segura, L., Miranda, M., Barrientos, M., Lescano, G., 1997. Consumo de Alimentos en el Perú, 1990–1995. Asociación Benéfica PRISMA, Lima, Peru.

Rose, D., Bourne, L., & Bradshaw, D., 2002. Food and nutrient availability in South African households: Development of a nationally representative database. Technical Report. Medical Research Council of South Africa, Tygerberg, South Africa.

Rose, D., Charlton, K.E., 2002. Quantitative indicators from a food expenditure survey can be used to target the food insecure in South Africa. Journal of Nutrition 132, 3235–3243.

Rouse, T.I., Davis, D.P., 2004. Exploring a Vision: Integrating Knowledge for Food and Health, A Workshop Summary. National Research Council, National Academy Press, New York, USA.

Welch, R.M., Graham, R.D., 1999. A new paradigm for world agriculture: Meeting human needs—Productive sustainable, nutritious. Field Crops Research 60, 1–10.

World Bank, 2008. Living Standards Measurement Study. Retrieved 2008-4-14: <http://go.worldbank.org/IPLXWMCNJ0>

World Health Organization, 2002. The World Health Report 2002. In: Campanini, B. (Ed.), Reducing Risks, Promoting Healthy Life. Geneva, Switzerland, World Health Organization.

Wuehler, S.E., Peerson, J.M., Brown, K.H., 2005. Use of national food balance data to estimate the adequacy of zinc in national food supplies: Methodology and regional estimates. Public Health Nutrition 8, 812–819.

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