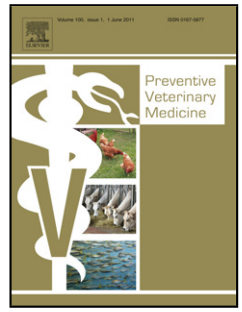

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Backyard poultry production in Chile: animal health management and contribution to food access in an upper middle-income country

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Abstract

Backyard production systems (BPS) that involve poultry are a good way to improve food security and poverty alleviation. Few studies have been carried out to quantify the contribution of poultry production to these households and the constraints they might face if a priority animal disease enters these systems. This study aims to characterize the poultry-rearing BPS in central Chile and to identify socio-economic factors associated to households' consumption of poultry. Data was collected from 384 BPS through a face-to-face semi-structured questionnaire. Value chain framework associated with BPS poultry rearing and cash flow analysis of BPS was done to identify the inputs/outputs of the system and to know the profitability of the system. Multiple linear regression was performed to identify the BPS and household factors associated to poultry consumption. The results of this study suggest that BPS in central Chile have biosecurity deficiencies such as: lack of confinement, lack of veterinary assistance and incorrect handling of dead animals. Cash flow analysis indicated that 62% of the BPS had a positive balance from production. Distance to closest market and per capita income were factors associated to poultry value to farmers. Different factors were significant predictors of household poultry consumption. Positive predictors of consumption were identified as: (i) older owners, (ii) higher transportation price to closest market, (iii) larger flock size (iv) birds raised by women and (v) owning a car. On the contrary, (i) higher per capita income and (ii) bigger household size predicted a reduction in consumption. The results indicate the importance of BPS to low-income families and those living in remote areas while also highlighting the vulnerability of these systems to disease risks.

Keywords: Policy decision, rural households, food access, backyard poultry, family poultry

1. Introduction

Over the last fifteen years, the Food and Agriculture Organization of the United Nations (FAO) and the International Fund for Agricultural Development (IFAD) have paid special attention to small-scale livestock production systems as they may play an important role in the achievement of several of the Millennium Development Goals (MDGs) (and more recently the Sustainable Development Goals, SDGs) agreed on by the United Nations (UN). Particular emphasis has been given to the improvement of food security, income generation, women's empowerment, reduction of child mortality and poverty alleviation (UN, 2005, 2016; Wong et al., 2017). Thereby, the promotion of poultry farming as part of a nutrition-sensitive agricultural intervention among poor families living in rural areas has been gaining renewed interest in the literature (Darrouzet-Nardi et al., 2016; Dumas et al., 2016; Berti and Araujo Cossio, 2017). Poultry rearing allows vulnerable families to have a constant supply of animal-source food (ASF); as well as giving them the possibility of generating income through the marketing of animals and/or their products. Consequently, this income helps these families meet essential needs such as medicine, clothes and school fees (Alders and Pym, 2009). It has already been well documented that indigenous chickens, through their meat and eggs, constitute a high-quality food source and providing macro and micronutrients that are often deficient in the mostly vegetarian diets observed in rural resource-poor settings, such as: iron, vitamin A, vitamin B12, zinc and riboflavin (Wong et al., 2017). However, to assess the real contribution of poultry production to poor rural households (HH), it is necessary to delve into the operation of these production systems, as it has been described that smallholder farmers in developing countries depend on a complex interaction where social, ecological, and agricultural systems work together to craft livelihood strategies and achieve advantageous livelihood outcomes (e.g. food security, freedom from poverty) (Dumas et al., 2016).

Small-scale production can be classified into different groups. In 2014, FAO created the term "family poultry" to describe the full variety of all small-scale poultry production systems found in rural, urban and peri-urban areas of developing countries (FAO, 2014a). Among these varieties of small-scale poultry production, backyard production system

(BPS) is the most widespread form of animal production in the world (Hamilton-West et al., 2012). The definition of BPS considers several variables such as: productive purposes, inputs/resources used, flock size and biosecurity levels, among others (FAO, 2010; Smith and Dunipace, 2011; Hamilton-West et al., 2012). According to these authors, backyard poultry production systems are an important component of small farmers' livelihoods. These systems require a relatively small investment, have a flock size of up to 100 birds, poultry is raised and kept in a low input/low output system and the feed resource base is mostly based on scavenging with some occasional supplement of food scraps and grains (Hamilton-West et al., 2012). It is noteworthy that most BPS do not apply basic hygiene and biosecurity measures while raising their animals as well as having poor supervision of public health officials, as they are usually not registered (FAO, 2014b). Hence, small-scale producers may handle, sell and consume sick animals without considering that those infections can also be potentially harmful to them or neighboring production systems as a whole (Hamilton-West et al., 2012). In this way, animal diseases can impact human wellbeing by reducing their food security and the household's economy (Perry et al., 2002). On the other hand, transboundary animal diseases represent a serious risk to commercial poultry systems and international trade. Actions implemented by public Veterinary Services to fight endemic or exotic animal diseases can therefore affect local animal production systems, and consequently impact household food security. Isolating animals, improvement of farm hygiene, use of effective vaccines, close monitoring and quick culling when necessary, are some of the known and proven practices to control and prevent the spread of animal diseases (Domenech et al., 2006). For example, outbreaks of highly pathogenic avian influenza (HPAI), have caused the culling of millions of poultry to control the spread of the disease. In the 1999 outbreak in Italy, 16 million birds were culled; while in the 2003 epidemic in the Netherlands, 30 million birds were culled (Backer et al., 2015), among other major outbreak events in the last decades. In Chile, an outbreak of H7N3 HPAI occurred in 2002, where a total of 483,536 birds were culled (Rojas and Moreira, 2003). More recently, in 2017, during a H7N6 low pathogenic avian influenza (LPAI) outbreak that affected Chile, a total of 385,000 commercial turkeys were culled (ProMED-mail, 2017). These events entail important negative economic consequences for large-scale producers, but in the case of smallholders these losses are more consequential as they may convey a loss in income and investments, as well as the loss of related animal products and, perhaps more importantly, the loss of ASF availability (Dolberg, 2003; FAO, 2009, 2010; Kavle et al., 2015). Gender issues due to avian influenza and its control strategies have also been described, particularly in households headed by women, where reductions in the size of flocks or loss of animals contributed to increased stunting in preschool children (Kavle et al., 2015) and decreased enrolment of girls in school (Bagnol, 2009). It is therefore essential that these systems are well understood allowing for an effective design of disease control programs while mitigating the impact of interventions strategies on the wellbeing and food security of vulnerable households. However, still too few efforts aimed at evaluating the impacts of risk-reducing measures of animal diseases, including their effects on the livelihoods of small farmers and their families, have been undertaken in recent years (Adeniyi and Oguntunji, 2011).

Little information is available about the contribution of backyard poultry rearing in ASF availability and its role in the economy of rural households in upper middle-income countries and Latin America. There is literature that describes and demonstrate the linkages between small-scale production and food security in low- and middle-income countries (LMICs) with limited resources (resource-poor settings) (Wong et al., 2017). To date, poverty levels in Latin America reach 28% of the population (CEPAL, 2014), where 34 million people are still undernourished and 27 million people live in extreme poverty (considering Latin America and the Caribbean countries) (FAO, 2015). In Chile the proportion of the population with food consumption below the minimum dietary energy is less than 5%, and the poverty rate currently stands at 11.7% of the population (CEPAL, 2014). According to the last agricultural census published in 2007, there are more than 170,000 families who rear poultry in Chile (Hamilton-West et al., 2012). This is likely a major underestimation since the mentioned census only covered households/farms that have formal tax records in the national public revenue system. Despite the importance of backyard poultry systems, there are no precedents in the literature of their contribution to the food security, and the economy of rural households in Chile, nor of their risks or vulnerability to the entrance of animal diseases. This study aims to characterize the poultry-rearing BPS in central Chile and to identify their possible contribution to food access of these households.

2. Material and methods

2.1 Study area and study design

Chile has different agro-climatic zones, with a Mediterranean climate predominating in the central area of the country (Di Castri and Hajek, 1976). This climate has favored agricultural and animal production (Aguayo et al., 2009). Thus, approximately 95% of poultry production is located in the central zone of Chile, rearing more than 43.5 million birds that represent 83% of the national poultry population. This same area also concentrates a great amount of BPS rearing poultry (Hamilton-West et al., 2012) which are, from here on, considered the study unit of this investigation.

A cross-sectional study was conducted on 384 poultry BPS in 2013-2015 in three regions in the central zone of Chile. According to the last agricultural census of 2007, this area contains 16,289 BPS breeding poultry. For this survey, poultry BPS were defined as those production systems that raised poultry with a relatively small investment and mostly targeted for own-household consumption (Hamilton-West et al., 2012). The variable of interest was a binary variable, represented by consumption or non-consumption of poultry reared in the BPS. A conservative estimate of 50% frequency for this variable was used to maximize the sample size. The accepted error and confidence level used were 5% and 95%, respectively (Eq.1) (Dohoo et al., 2012).

Eq. 1:

$$n = \frac{Z_{\alpha}^{2}pq}{L^{2}}\text{, where:}$$

Where;

n= Sample size

Z_α= Z_α value for a confidence level of 1-α (1.96)

p= expected proportion of households consuming chickens reared in their production system

q= 1-*p*

L= Precision of the estimate

Once the sample size (maximum variance) was obtained, a simple random sampling approach was used, where the number of BPS sampled per province were proportional to the number of BPS registered in each province according to the census. A spatial sampling approach was followed using Surface Tool in ArcGIS-10 software (Esri, California, USA), which randomly placed the 384 points on a map (following proportionality by province). Following the allocation of the points, with the use of a Global Positioning System device (Garmin GPSMAP® 64s), coordinates were reached and a careful search of BPS was carried out within a radius of 10 kilometers around selected random point, as described in Alegria-Moran et al. (2017).

2.2 Data collection and data analysis

Data from BPS were collected using a face-to-face semi-structured questionnaire, which was applied to poultry owners during 2013-2015. The questionnaire included 62 questions, had a duration of approximately 20 minutes, and collected information to characterize the BPS structure, inputs and outputs of the system, animal handling and biosecurity measures of BPS. The collection of this information was achieved through nine open questions oriented to the identification of the BPS and social aspects (number of inhabitants per home), twenty-three closed questions regarding animal handling, sixteen closed questions regarding biosecurity measures and 14 open questions to identify inputs (and prices) and outputs (and costs) of the production system and the contribution of poultry to the household income and food security (poultry and eggs consumption). Some qualitative and quantitative data on BPS structure and biosecurity measures were also collected from observations done by the researchers on the ground. Within these observations, four variables were observed and recorded: characteristics of the fences, the presence of water courses that crossed the BPS, contact between poultry and wild birds and the presence of intensive poultry production units close to the BPS. The questionnaire was performed by trained graduate students from the School of Veterinary Medicine of the University of Chile. The questionnaire was previously evaluated in a pilot study of active influenza A surveillance in 2011 (Hamilton-West et al., 2012). The format of the interview, the questionnaire and the informed consent were approved by the faculty's bioethics committee in July 12, 2012.

Firstly, descriptive statistics were prepared to characterize the BPS. Secondly, a conceptual framework which described the inputs (and their origins) and the outputs (and their destinations) of these production systems was developed with the data collected in the questionnaire. This data collection allowed us to identify the inputs oriented to poultry production that could enter the production system in a year, as well as all the products generated from this production system throughout a year. Using this conceptual framework, an annual net cash flow analysis (CFA) per household was performed to assess profitability of the system (Eq. 2) (Rushton, 2009). This was done by estimating the total value of output of the BPS minus the out-of-pocket expenses incurred by the BPS during a year.

<u>Eq. 2:</u>

$$CFA = \sum(\text{Price}*\text{Output}) - \sum\text{Variable costs}$$

The inputs and outputs considered in these calculations are detailed in Table 1. Expenses are used as reported by farmers. Valuing output represented a more delicate task, particularly when the BPS does not incur in any market transaction of its poultry output. To value output in these latter cases, we asked producers for prices of poultry products in the nearest outlet where they could acquire these goods. All data was generated from the poultry owner's answers to the interview. Given that these small-scale producers did not manage artificial light sources to increase egg production, the egg production period lasted eight months, i.e. production achieved between August and March. Regarding bird replacement, most owners replaced their birds with their own offspring or exchanged embryonated eggs with neighbors to avoid inbreeding. When buying, they bought a cockerel every three years. As the CFA was performed for a full-year cycle, this cost was not incorporated into the production costs. Labor costs were not measured as it was assumed to be a fixed cost. Other costs and revenues were deemed too low and therefore were not measured.

Table 1 Outputs and costs calculated in the cash flow analysis for poultry breeding in BPS in central Chile.

To contrast the results from the CFA we additionally carried out a simple contingent valuation exercise to have an alternative estimation of the value of the BPS poultry operation for these households. Following a willingness to accept (WTA) approach (Hanemann, 1991), we asked owner if they were willing to forego their poultry breeding operation in exchange for a permanent monthly salary instead. We followed a bidding approach within a range of USD 76,4 to USD 1,528.

Finally, the contribution of poultry breeding to households' food security was assessed using the economic information above, complemented with additional information collected in the questionnaire, such as distance of the house to the closest market where they could access poultry products, monthly per capita income, poultry and egg consumption, among others. The information collected allowed us to evaluate mainly food access, i.e. one of the four dimensions of food security traditionally described by FAO (Burchi et al., 2011). This information was complemented with a simple reduced poultry consumption regression model. The latter was performed using STATA software (version 14, STATA corp., College Station, Texas, USA).

3. Results

3.1 BPS productive and economic flow

With the descriptive statistics obtained from field work, a conceptual framework was developed, which described the flow of the inputs and the outputs in these production systems and the different origins and destinations of each input and output (Fig 1). Thicker arrows represent the most important outputs/inputs flow.

Fig.1 Conceptual framework of rural poultry husbandry

3.1.1 Inputs of poultry production

The inputs of poultry production comprised feed, housing, veterinary care and bird replacement. In the case of feed, this was obtained from different sources, such as other production systems waste, household scraps, scavenging or poultry feed purchased on the market (Table 2). With respect to bird housing, when present, it was financed by government-funded local development projects or built by the owners themselves, generally from home debris. The few BPS where veterinary care was reported, it was mostly serviced by the same government local development projects which financed the housing. In the case of birds for replacement, these were obtained from neighbors (through sale or gifts) or from formal and informal markets. However most of them were obtained from the offspring of their own birds, represented in the flow as live poultry (Fig 1).

3.1.2 Flow of outputs of poultry production

The outputs generated were eggs, poultry meat and live birds. The main destination of eggs was for household consumption. However, these were also sold at local markets, to neighbors, outsiders, restaurants and middlemen; or used as gifts to family, neighbors and friends. Households reported no use of manure from poultry, and all of it was thrown away. Only one household used it as a fertilizer. Meat (slaughtered poultry) was used for household consumption and sold locally to friends and neighbors. No BPS reported giving meat as a gift, if they wanted to do so, they gave the live chicken as gift. Live poultry had the same destinations as eggs and was also used to replace their own birds.

3.2 BPS characterization

3.2.1 Households' characteristic and BPS structure

The average household was composed of four people. In 60% of the households there were children under 15 years of age, while only 11% had children under 2 years old. The monthly median per capita income was US$134.9 (IQR= 93.4 – 194.6), with 22% of the surveyed BPS belonging to the poorest decile of the country, while nearly half of these BPS (49%) have earnings within the poorest quintile (using critical values from the National Socio-Economic Survey, CASEN 2015). The median age of poultry owners was 59 years old (IQR= 49 – 67), with two owners being younger than 18 and 146 owners older than 60 years of age. Of all interviewees, 79% were women and 21% were men. Three households did not have access to electricity; therefore, did not have a cold storage to provide the cold chain necessary to guarantee food safety and food quality of poultry meat. Even when eggs do not require refrigeration, access to cold storage is important when it comes to poultry meat preservation.

There was a total of 16,200 birds across all surveyed farms, including 1,159 ducks, 575 turkeys, and 455 geese. The median flock size was equivalent 30 domestic chickens (IQR: 20 – 50), and a median of 33 (IQR: 20 – 50) for the poultry flock size when ducks, geese and turkey were included.

Forty-two percent of surveyed owners did not sell any poultry products. Of those that sold, in 70% of households, women were in charge of marketing (Table 2). On average, 0.5 eggs were collected per chicken per day, with an average price of sale of $0.18 USD per egg. Not all BPS sold live birds, but when transactions were recorded, the average price was $6.15 USD per chicken. Selling was done occasionally and mainly happened during winter, when the seasonal new born chickens were grown up. Considering just the households that sold animals and by-products, 59% of them sold to neighbors and family, while 41% also sold their products to outsiders and other markets outside their neighborhood. According to the cash flow analysis, only 62% of the BPS ended the year with a positive balance. The contribution of poultry to total per capita household income was on average ~13.3% (0.07%, 174.2%).

Table 2 Variables considered for the characterization of BPS structure, animal handling, and biosecurity conditions in BPS that keep poultry in central Chile, 2013 – 2015

3.2.2 Animal handling

In half of the BPS surveyed, the main source of livelihood of the household was different from agriculture or livestock rearing, which is consistent with what has been reported for Chilean farms in general (Valdés and Foster, 2009). All households declared using poultry for consumption and among them only 58% declared also using poultry for income generation, i.e., being mixed systems (consumption and sale). No BPS reported keeping poultry just for selling. In 60% of the cases, women were exclusively in charge of poultry management; while in 19% of the cases this activity was shared by different members of the household. The most common source of poultry feed was the combination of scavenging plus household scraps and grains. With respect to water consumption, 89% of the owners provided drinking water to their flock, however, in 11% of the cases poultry got water directly from environmental sources such as lakes, rivers or water channels. Regarding to poultry health, 87% of BPS flocks did not receive any veterinary care (Table 2). Nevertheless, 27% of the owners declared giving drugs (antibiotics and anti-inflammatories) to their sick birds and 17% treated sick birds with natural herbs.

3.2.3 Biosecurity conditions

The most common method of keeping poultry was in a mixed housing system (73% of the BPS), which consisted of housing the animals overnight and keeping them free-ranging during the day. However, 17% of the owners reported keeping their birds in a fully free-ranging system, while 10% kept them in a permanent housing system. Summing-up, in 90% of the BPS poultry could roam freely and in 99.7% of the systems close contact with wild birds were observed. Also, 71% of the BPS were located within a 3 km radius of a water body. When asked how they handled dead birds, the most common answers were that these were buried (44%). However, 21% of the owners also declared throwing their dead birds to the garbage or throwing them far away (19%). Four percent of the owners did nothing, leaving their dead birds just as they found them, and one owner said he sold or consumed the dead fowl (Table 2).

3.3 Contribution of BPS to food access

All the BPS surveyed declared that their main objective of poultry breeding was household consumption, regardless of whether they sold products and by-products or not. The average per capita egg consumption per month was 14 eggs and the average amount of birds consumed per capita per year was 7 birds. When asked if they bought eggs, 50% of owners answered they did not. People who bought eggs, bought them only at the time of the year when their hens did not lay eggs, with 8 being the average monthly number of eggs purchased per capita during that period. About 75% of households indicated that they usually gave away poultry/eggs as presents to relatives, neighbors and friends (Table 2). When asked about market access to a place where they could buy eggs or chicken meat, 33% answered that access was very difficult for them. The average distance to the closest market selling poultry meat was 13.8 kilometers (CI: 12.3 – 15.4) and just 31% of the households had the chance of getting there with their own vehicle.

Regarding to the WTA method (Table 3), 56% of the owners answered they would not give up birds even at the highest monthly income offered, which largely exceeded the market value of their operation. The fact that many owners were not willing to trade their poultry operation, even for the highest income considered in the survey, reflects that the opportunity cost of their poultry rearing operation is much higher than their market value. Based on the results, we can speculate that this is probably due to two main factors. In the first place, even though we use prices that producers declared to face when they accessed the market, these prices may not reflect the real opportunity cost for these producers. This is particularly true in cases where producers are old, live far from markets, and face an expensive and uneven public transportation system. For these types of producers, currency may not be a very good trade token. This hypothesis is supported in Table 3, that shows that the gap between the estimated value of output and the money they are willing to trade poultry rearing is higher for households farther away from markets. The other reason why producers may not be willing to trade their reared poultry for money, is that they may attach non-market values to their operations. For example, they value the time spent caring for their flock, and may value it beyond their market price. In other words, there are positive externalities attached to their poultry rearing operation at the BPS.

When analyzing the value at which owners were willing to trade their poultry-rearing BPS, it was possible to observe that households that are farther away from markets attribute a higher value to their flock (Table 3). This relationship is different when analyzing poultry value according to per capita income, where poorer families attribute a higher value to their flock. Altogether, these results are consistent as poorer households tend to live farther away from markets. Regarding the value of output (VO), there does not appear to be a clear correlation with distance; however, it was again possible to observe that those families that live farther from the closest markets are those that obtain a greater gross benefit from poultry rearing. On the other hand, when analyzing this variable by per capita income, it can be observed that families with a higher per capita income are those that have a higher value of output. While in those with lowest income, poultry represent 20% of their income. With respect to the relation between the value of output and the income perceived by the household, it can be observed that the benefits generated by poultry breeding with respect to the households' income is greater in those families with a lower income per capita. Finally, when observing the relationship between the value of sales of poultry products and the total value of output of fowl rearing, an indicator of market participation, it can be observed that this decreases with market distance, as expected. The same can be observed when comparing the relative value of sales with per capita income, where sales are a relatively larger portion of total value of output for wealthier households.

Table 3 Value of BPS poultry output by ranges of distance to closest market and per capita income

The regression results performed to identify the BPS and household factors associated to poultry consumption showed statistical significance, with the F test on parameters with a p-value <.000, but with a low fit, adjusted R^2 of 13%. To deal with heteroscedasticity we used White's robust standard errors. The results showed that age of poultry owner, transportation price to closest market, per capita income, total number of domestic chickens owned, gender of person responsible of birds, presence of a car (wealth), and household size were significant predictors of poultry consumption (Table 4). Annual per capita poultry consumption increases with the increase of the age of the owners, the distance to markets (measured as the transportation price to closest market) and the total number of domestic chickens owned. It also increases when the household owns a car and when a woman is in charge of poultry rearing. On the other hand, poultry consumption decreased with an increase of per capita income and household size. The presence of children does not appear to significantly affect poultry consumption.

Table 4 Regression results for annual poultry consumption per capita (standard errors from the mean)

4. Discussion

Poultry breeding by rural families has been widely perceived as a good option to ensure food security, generate income, and promote women's empowerment at a relatively low investment (FAO, 2014b). However, when promoting ownership of poultry by families to achieve the above objectives, it is crucial to assess the feasibility and possible constraints of this activity.

The fact that in 60% of the cases women are the ones in charge of poultry rearing and that in 70% they are in charge of sales as well, reveals the contribution of poultry production to women's empowerment. Therefore it contributes to the objective of making progress toward gender equality and the empowerment of women highlighted among the MDGs (Kaudia and Kitalyi, 2002). Furthermore, Wong et al. (2017) describes that when small-scale poultry productions are reared by women, this increased their empowerment and will in turn enhance household food security.

Moreover, to date there is evidence of the risk of disease entry into poultry rearing BPS in Chile. These risks are highlighted in Hamilton-West *et al* (2012) and are reinforced with the results of Bravo-Vasquez et al. (2016) and Jimenez-Bluhm et al. (2018a). Almost 11% of the owners declared that their animals got water from environmental sources, representing a risk of exposure to pathogens from neighbors' animals or wildlife. Altogether, some deficiencies in biosecurity measures observed in this study, such as lack of confinement, lack of veterinary assistance, incorrect handling of dead birds, among others, are consistent with other international (Harvey et al., 2003; Rola et al., 2003; Chang, 2004; Mandal et al., 2006; Chatterjee et al., 2007; Garber et al., 2007; Madsen et al., 2013) and national studies (Hamilton-West et al., 2012; Bravo-Vasquez et al., 2016). Concerningly, Bravo-Vasquez et al. (2016) identified the presence of influenza A virus in BPS in central Chile, with seroprevalence ranging from 42 to 60% at BPS level while

Jimenez-Bluhm et al. (2018a) found that influenza virus positivity by real-time RT-PCR (qRTPCR) ranged from 0% to 45.8% at the farm level. Furthermore, influenza virus has been isolated in pigs in BPS in Chile; results that are very interesting as the isolated virus was a swine-human reassortant that could represent a potential threat to public health (Bravo-Vasquez et al., 2017). Hence, not only the productive systems may be in risk, but also public health. The introduction of diseases to these production systems may kill the animals, decrease their production and, in cases of notifiable diseases, may force the Chilean Veterinary Service to intervene with measures ranging from culling poultry of the infected premises up to the elimination of every single fowl kept within a determined radius (SAG, 2006b, 2007). These actions are mainly aimed at reducing the risk of transmission to commercial farms, which together represent in Chile an important high-value exporting industry. In December 2016, Chile was affected by two outbreaks of low pathogenic avian influenza in commercial turkey farms. Measures applied to control the outbreak included the elimination of positive and at risk commercial turkey stocks, together with the elimination of poultry kept in a nearby agar gel immunodiffusion (AGID) positive BPS, as a strong epidemiological link between the BPS and the outbreaks at the commercial farms was identified (OIE, 2017).

If animal and public health is to be protected, it becomes imperative that education on biosecurity measures and animal diseases reaches this socially vulnerable population. Dead animals due to disease outbreaks could become a constraint not only for the owners, but also for the community living around that BPS. Diseases may spread, and food security may be impaired, especially when 75% of households indicated that they usually give away eggs/poultry to their neighbors, which contributes to the food security of the community.

Not surprisingly, 56.2% of the owners declared that no monthly monetary amount would be sufficient to forego having their eggs and chickens constantly available. People who were unwilling to make this hypothetical trade, explained that even if they received money instead of having their poultry, they do not have either physical access to markets where they could buy products to replace them, or health conditions compatible with the long travel to the closest market. Additionally, 69% of the owners did not own a vehicle, and 59% of the owners were older than 55 years old.

This qualitative perception about the importance of poultry for these households is in agreement with the quantitative trends described in Tables 3 and 4. BPS poultry rearing makes an important contribution to one dimension of food security of many of the households surveyed. The contribution to food security is to the availability and access to animal-source macro and micronutrients. This access clearly does not come from an income (market perspective), as the BPS operations only contribute 12-15% of household income, even in this relatively poor population surveyed. However, we have shown that poultry is valued at much higher than market prices by households that live far from markets; that consumption increases with distance to markets; that the market value of production is higher for BPS located farther from markets; and the relative contribution of the BPS is higher for those that are poorer. Altogether, these results suggest that the elderly, the more isolated households, the female managed BPS and the smaller and lower per capita income households are those that depend more on their poultry production for protein intake. This is in line with what has already been described, where the access dimension of food security, which refers to the ability of people to obtain available food, is more difficult for economically, physically, or socially disadvantaged population groups (Wong et al., 2017).

The information gathered in this study provides therefore key insights for public policies when facing sanitary emergencies, which become even more important considering the new epidemiological insights in influenza virus identified in Chile, such as the presence of a great diversity of subtypes in wild bird populations, and the passage of these viruses to BPS (Jimenez-Bluhm et al., 2018a; Jimenez-Bluhm et al., 2018b).

In Chile there are currently no foreseen economic compensation mechanisms when culling of poultry is enacted as a result of an outbreak, for example of avian influenza. In fact, in most countries that have suffered sanitary emergencies, it has been observed that the absence of such compensatory mechanisms is an incentive for the non-reporting of cases and the rapid channeling of sick birds to the market, with an increase in the spread of the disease (SAG, 2006a). Moreover, not only the culling of animals in BPS production systems is important from a sanitary perspective, but perhaps more importantly, compensatory alternatives are required for the socio-economically vulnerable population identified in this study. In this sense, it might be more sensible to consider a policy where eggs and chicken or other animal protein source were delivered to the families against the removal of birds, as direct income transfers likely do not compensate the food lost for many of the vulnerable households surveyed.

Nevertheless, this study had biases and limitations. Only households keeping poultry were surveyed, so we do not know how this (consumption) compares with households not keeping poultry. In this manner, the low R^2 may be explained by important unobserved household characteristics that determine consumption, so further studies are needed. Another important limitation is that the calculated per capita consumption did not account that people in each household have different nutritional needs (such as the requirements of children compared to adults).

Conclusions

Backyard poultry production in central Chile contributes to food access, household economy and women empowerment. However, some deficiencies in biosecurity and animal handling can cause these production systems to be exposed to greater risk of introduction of priority diseases. Chile has had outbreaks of both HPAI and LPAI in domestic birds and a great diversity of LPAI viruses have already been described in wild birds and BPS in central Chile. Additionally, BPS in Chile have faced poultry culling as control measure to prevent avian influenza spread. These results highlight the social aspects that should be considered when intervention strategies are taken. Educational programs on biosecurity, together with improved and comprehensive disease management policies that considers the food security of affected vulnerable populations, are needed.

Conflict of interest

The authors declare no conflict of interest

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References

Adeniyi, O.R., Oguntunji, A.O., 2011. A socio-economic survey of cultural practices and management of village poultry production in Ondo area, Nigeria. Livestock Research for Rural Development 23.

Aguayo, M., Pauchard, A., Azócar, G., Parra, O., 2009. Cambio del uso del suelo en el centro sur de Chile a fines del siglo XX: Entendiendo la dinámica espacial y temporal del paisaje. Revista chilena de historia natural 82, 361-374.

Alders, R.G., Pym, R.A.E., 2009. Village poultry: still important to millions, eight thousand years after domestication. World's Poultry Science Journal 65, 181-190.

Alegria-Moran, R., Lazo, A., Urcelay, S., Hamilton-West, C., 2017. Using spatial tools for high impact zoonotic agents' surveillance design in backyard production systems from central Chile. Veterinaria México OA 4.

Backer, J.A., van Roermund, H.J.W., Fischer, E.A.J., van Asseldonk, M.A.P.M., Bergevoet, R.H.M., 2015. Controlling highly pathogenic avian influenza outbreaks: An epidemiological and economic model analysis. Preventive Veterinary Medicine 121, 142-150.

Bagnol, B., 2009. Gender issues in small-scale family poultry production: experiences with Newcastle Disease and Highly Pathogenic Avian Influenza control. World's Poultry Science Journal 65, 231-240.

Berti, P.R., Araujo Cossio, H., 2017. Raising chickens for increased egg consumption in a rural highland Bolivian population. Food Security, 1-13.

Bravo-Vasquez, N., Di Pillo, F., Lazo, A., Jimenez-Bluhm, P., Schultz-Cherry, S., Hamilton-West, C., 2016. Presence of influenza viruses in backyard poultry and swine in El Yali wetland, Chile. Preventive Veterinary Medicine 134, 211 - 215.

Bravo-Vasquez, N., Karlsson, E.A., Jimenez-Bluhm, P., Meliopoulos, V., Kaplan, B., Marvin, S., Cortez, V., Freiden, P., Beck, M.A., Hamilton-West, C., Schultz-Cherry, S., 2017. Swine Influenza Virus (H1N2) Characterization and Transmission in Ferrets, Chile. Emerging Infectious Diseases 23, 241-251.

Burchi, F., Fanzo, J., Frison, E., 2011. The role of food and nutrition system approaches in tackling hidden hunger. International journal of environmental research and public health 8, 358-373.

CEPAL, 2014. Comisión Económica para América Latina y el Caribe. Panorama Social de América Latina (LC/G.2635-P). Santiago de Chile.

Chang, H.S., 2004. Cross-sector comparisons of poultry production in the Philippines. In: University of New England. Graduate School of Agricultural and Resource Economics (Ed.).

Chatterjee, R.N., Rai, R.B., Pramanik, S.C., Sunder, J., Senani, S., Kundu, A., 2007. Comparative growth, production, egg and carcass traits of different crosses of Brown Nicobari with White Leghorn under intensive and extensive management systems in Andaman, India. Livestock Research for Rural Development 19, 1-6.

Darrouzet-Nardi, A.F., Miller, L.C., Joshi, N., Mahato, S., Lohani, M., Rogers, B.L., 2016. Child dietary quality in rural Nepal: Effectiveness of a community-level development intervention. Food Policy 61, 185-197.

Di Castri, F., Hajek, E.R., 1976. Bioclimatología de Chile. Vicerrectoría Académica de la Universidad Católica de Chile Santiago, Chile.

Dohoo, I.R., Martin, S.W., Stryhn, H., 2012. Methods in epidemiologic research. VER Inc Charlottetown, Prince Edward Island, Canada.

Dolberg, F., 2003. Review of household poultry production as a tool in poverty reduction with focus on Bangladesh and India. FAO Pro-Poor Livestock Policy Initiative Working Paper No. 6. Food and Agriculture Organizations of the United Nations. Rome.

Domenech, J., Lubroth, J., Eddi, C., Martin, V., Roger, F., 2006. Regional and international approaches on prevention and control of animal transboundary and emerging diseases. Annals of the New York Academy of Sciences 1081, 90-107.

Dumas, S.E., Lungu, L., Mulambya, N., Daka, W., McDonald, E., Steubing, E., Lewis, T., Backel, K., Jange, J., Lucio-Martinez, B., 2016. Sustainable smallholder poultry interventions to promote food security and social, agricultural, and ecological resilience in the Luangwa Valley, Zambia. Food security 8, 507-520.

FAO, 2009. Highly pathogenic avian influenza: a rapid assessment of its socio-economic impact on vulnerable households in Egypt. Prepared by Georgina Limon, Nicoline de Haan, Karin Schwabenbauer, Zahra S. Ahmed and Jonathan Rushton. AHBL Promoting strategies for prevention and control of HPAI. Rome.

FAO, 2010. Smallholder Poultry Production - Livelihoods, Food Security and Sociocultural Significance. FAO Smallholder Poultry Production Paper. K. N. Kryger, K. A. Thomsen, M. A. Whyte and M. Dissing, Roma.

FAO, 2014a. Decision tools for family poultry development. In, FAO Animal Production and Health Guidelines No. 16, Rome, Italy.

FAO, 2014b. Family poultry development − Issues, opportunities and constraints. Animal Production and Health Working Paper. No. 12. Rome.

FAO, 2015. Challenges and Perspectives for Food and Nutritional Security in Latin America and the Caribbean: from the Millennium Development Goals (MDGs) to the Sustainable Development Goals (SDGs).

Garber, L., Hill, G., Rodriguez, J., Gregory, G., Voelker, L., 2007. Non-commercial poultry industries: surveys of backyard and gamefowl breeder flocks in the United States. Prev Vet Med 80, 120-128.

Hamilton-West, C., Rojas, H., Pinto, J., Orozco, J., Hervé-Claude, L.P., Urcelay, S., 2012. Characterization of backyard poultry production systems and disease risk in the central zone of Chile. Research in Veterinary Science 93, 121-124.

Hanemann, W.M., 1991. Willingness to pay and willingness to accept: how much can they differ? The American Economic Review 81, 635-647.

Harvey, S.A., Winch, P.J., Leontsini, E., Torres Gayoso, C., López Romero, S., Gilman, R.H., Oberhelman, R.A., 2003. Domestic poultry-raising practices in a Peruvian shantytown: implications for control of Campylobacter jejuni-associated diarrhea. Acta Tropica 86, 41-54.

Jimenez-Bluhm, P., Di Pillo, F., Bahl, J., Osorio, J., Schultz-Cherry, S., Hamilton-West, C., 2018a. Circulation of influenza in backyard productive systems in central Chile and evidence of spillover from wild birds. Preventive Veterinary Medicine 153, 1-6.

Jimenez-Bluhm, P., Karlsson, E.A., Freiden, P., Sharp, B., Di Pillo, F., Osorio, J.E., Hamilton-West, C., Schultz-Cherry, S., 2018b. Wild birds in Chile Harbor diverse avian influenza A viruses. Emerging microbes & infections 7, 44.

Kaudia, T.J., Kitalyi, A.J., 2002. The Bangladesh model and other experiences in family poultry development: Commercializing rearing of village chicken in Kenya. In, INFPDE-Conferences International Network for Family Poultry Development (INFPD)(available at

http://www.fao.org/AG/AGAInfo/themes/en/infpd/documents/econf_bang/add_paper12.html).
Kavle, J.A., El-Zanaty, F., Landry, M., Galloway, R., 2015. The rise in stunting in relation to avian influenza and food consumption patterns in Lower Egypt in comparison to Upper Egypt: results from 2005 and 2008 Demographic and Health Surveys. BMC public health 15, 285.
Madsen, J.M., Zimmermann, N.G., Timmons, J., Tablante, N.L., 2013. Avian Influenza Seroprevalence and Biosecurity Risk Factors in Maryland Backyard Poultry: A Cross-Sectional Study., PLoS ONE
Mandal, M.K., Khandekar, N., Khandekar, P., 2006. Backyard poultry farming in Bareilly district of Uttar Pradesh, India: an analysis. Livestock Research for Rural Development 18, 20-39.
OIE, 2017. Low pathogenic avian influenza (poultry), Chile, (Follow-up report No. 3).
Perry, B.D., Randolph, T.F., McDermott, J., Sones, K.R., Thornton, P.K., 2002. Investing in animal health research to alleviate poverty. International Livestock Research institute Nairobi, Kenya.
ProMED-mail, 2017. Avian Influenza (155): Chile, turkeys, H7. In: International Society for Infectious Diseases (Ed.).
Rojas, H., Moreira, R., 2003. Influenza aviar en Chile 2002: una sinopsis. Gobierno de Chile. Ministerio de Agricultura. Servicio Agrícola y Ganadero.
Rola, A., Rola, W., Tiongco, M., Delgado, C., 2003. Livestock intensification and smallholders: a rapid reconnaissance of the Philippines hog and poultry sectors. MTID Discussion Paper No. 59. Washington DC, Markets, Trade and Institutions Division, International Food Policy Research Institute.
Rushton, J., 2009. The economics of animal health and production. Cabi.
SAG, 2006a. Proyecto nacional de prevención de influenza aviar. In: Servicio Agrícola y Ganadero (Ed.), Instituto Interamericano de Cooperación para la Agricultura, 27.
SAG, 2006b. Vigilancia en zonas de riesgo asociadas a la presencia de aves silvestres y/o de corral para la detección precoz de la influenza aviar. In, 23.
SAG, 2007. Procedimiento - Contingencia de Influenza Aviar. P-PP-VE-006. Ministerio de Agricultura. Servicio Agrícola y Ganadero.
Smith, G., Dunipace, S., 2011. How backyard poultry flocks influence the effort required to curtail avian influenza epidemics in commercial poultry flocks. Epidemics 3, 71-75.
UN, 2005. Millenium Project. Objetivos de Desarrollo del Milenio: una mirada desde América Latina y el Caribe. United Nations Publications.
UN, 2016. Sustainable Development Goals.
Valdés, A., Foster, W., 2009. Structural characteristics of agricultural households and policy options in Chile. A typology of rural households and income determinants from the 2003 CASEN. informe preparado para la OECD, para su informe sobre la agricultura Chilena (2008). Versión en español en Revista de Estudios Públicos (CEP).
Wong, J.T., de Bruyn, J., Bagnol, B., Grieve, H., Li, M., Pym, R., Alders, R.G., 2017. Small-scale poultry and food security in resource-poor settings: A review. Global Food Security 15, 43-52.

Table 1 Outputs and costs calculated in the cash flow analysis for poultry breeding in BPS in central Chile.

Output and costs	**Equations**
Output (Poultry)	
Eggs sales	Number of eggs sold/month x price per egg x 8 months
Live poultry sales	Number of birds sold/year x price of bird
Slaughtered poultry sales	Number of slaughtered bird sold/year x price per slaughtered bird
Egg consumption	Number of eggs consumed/year x price per egg
Poultry meat consumption	Number of poultry consumed/year x price per poultry
Costs (Poultry)	
Feeding costs	Money spent per household for poultry feeding/month x 12 months
Veterinary and medicine costs	Money spent in Veterinary care/month x 12 months

Table 2 Variables considered for the characterization of BPS structure, animal handling, and biosecurity conditions in BPS that keep poultry in central Chile, 2013 – 2015

Farm management	**Definition and classification**	**Nº**	**%**
BPS main livelihood source	Agricultural	31	8.1
	Livestock	94	24.5
	Mixed	64	16.7
	Other	195	50.8
Declared use of poultry	Household consumption and sale	224	58.3
	Household consumption	160	41.7
Poultry management	All family is in charge of poultry management	71	18.5
	Man is in charge of poultry management	84	21.9
	Woman is in charge of poultry management	229	59.6
Feeding	Scavenging, household scraps and grains	307	79.9
	Supplement with poultry feed	77	20.1
Water	Poultry drink potable water	343	89.3
	Poultry get water from environmental sources	41	10.7
Veterinary care	Poultry receive veterinary care	49	12.8
	Poultry do not receive veterinary care	335	87.2
Biosecurity conditions			
Housing	Mixed housing	282	73.4
	Free ranging	64	16.7
	Permanent housing	38	9.9
Water body	Existence of a water body in a radius of 3 km around the BPS	274	71.4
	No existence of a water body in a radius of 3 km around the BPS	110	28.6
Replacements	Replace poultry from their own offspring	247	64.3
	Replace poultry from their own offspring and from neighbors	70	18.2
	Replace poultry buying in markets	67	17.4
Mortality handling	Burn dead poultry	43	11.2
	Bury dead poultry	169	44.0
	Throw dead poultry to the garbage	82	21.4
	Throw dead poultry far away	74	19.3
	Do nothing with dead poultry	15	3.9
	Consume/Sale dead poultry	1	0.3
Poultry / wild birds	Poultry do contact wild birds	383	99.7
	Poultry do not contact wild birds	1	0.3
Poultry / neighbor's animals	Poultry do contact neighbor's animals	157	40.9
	Poultry do not contact neighbor's animals	227	59.1
Economic characteristics			
Use animals/products as gift	Usually give away animals/products as present	283	73.7
	Do not use animals/products as present	52	13.5
	No data	49	12.8
Products trade	Family is in charge of selling animals/products	28	7.3
	Man is in charge of selling animals/products	39	10.2
	Woman is in charge of selling animals/products	157	40.9
	No sale	160	41.7
Poultry main buyer	Household consumption	160	41.7
	Neighbors and family	132	34.4
	Neighbors, family and outsiders	92	24.0

Table 3 Value of BPS poultry output by ranges of distance to closest market and per capita income

Variable	Categories	Nº Observations	Poultry value (WTA)[1]	VO[2]	VO/Y[3]	Sales/VO[4]	HH with positive GMA (%)
Distance to closest market (km)	1 (0-3.9)	68	45.2 (8.4)	45.1 (5.4)	0.13 (0.02)	0.34 (0.04)	55.9
	2 (4-9.9)	82	50.4 (6.2)	44.7 (5.2)	0.13 (0.02)	0.34 (0.04)	56.1
	3 (10-19.9)	69	62.0 (10.1)	39.3 (4.0)	0.15 (0.03)	0.27 (0.04)	60.9
	4 (>20)	89	66.8 (12.1)	51.0 (6.3)	0.12 (0.02)	0.26 (0.03)	68.5
Per capita Income (USD)	1 (0–92.8)	70	62.6 (14.9)	39.2 (4.3)	0.20 (0.03)	0.22 (0.02)	61.4
	2 (92.9–134)	82	52.9 (6.9)	46.9 (4.6)	0.12 (0.02)	0.28 (0.03)	64.6
	3 (134.1–193.3)	76	54.9 (7.4)	40.0 (4.3)	0.12 (0.02)	0.29 (0.04)	55.2
	4 (>193.4)	80	55.3 (9.3)	54.5 (7.6)	0.09 (0.02)	0.40 (0.04)	61.3

[1] Poultry value (USD): Monthly salary to give up poultry.
[2] VO (Value of output USD): Monthly revenues generated from the sale of eggs and meat plus the value (at their declared market prices) of their consumption of eggs and meat produced by the BPS.
[3] VO/Y: Value of poultry outputs (VO) as a proportion of the total household income.
[4] Sales/VO: Value of eggs and poultry sales as a proportion of the overall value of poultry output.
* Values in parenthesis correspond to each standard error

Table 4 Regression results for annual poultry consumption per capita (standard errors from the mean)

	Coefficient
Age of poultry owner	0.079**
	(0.031)
Transportation price to closest market	0.0004**
	(0.0002)
Per capita Income, log	-1.835**
	(0.711)
Total number of domestic chicken owned	0.070***
	(0.014)
Woman as responsible for poultry	2.323**
	(1.074)
Presence of a car	2.835**
	(1.201)
Household Size	-0.757**
	(0.376)
Presence of children under 15	-0.084
	(1.332)
Valparaiso Region	.
	.
LGB O'Higgins Region	0.114
	(1.348)
Metropolitana Region	-1.188
	(1.395)
Constant	19.378**
	-8.673
R2_adj	0.126
AIC	2229
Valor-p>F	0
Obs.	308

***, **, *, represent statistical significance at 1%, 5% and 10% level, respectively

Standard errors are reported in parenthesis

Fig.1 Conceptual framework of rural poultry husbandry