Impact of vaccination against chicken Newcastle disease on food intake and food security in rural households in Tanzania

Danielle Knueppel, Carol Cardona, Peter Msoffe, Montague Demment, and Lucia Kaiser

Abstract

Background. *Small-scale poultry production has the potential to increase animal-source food consumption, improve household income, and reduce food insecurity.*

Objective. *To assess the impact of a chicken Newcastle disease vaccination program on consumption of chicken and eggs among women and children, income, and food insecurity in rural Tanzanian households.*

Methods. *Comparisons were made between households from three project villages, which participated in a Newcastle disease vaccination program for chickens, and three control villages, which did not participate. Household interviews were done with mothers from a random sample in March 2008 (237 households) and March 2009 (261 households).*

Results. *After the first year of vaccinations (three rounds), project households kept significantly more chickens and tended to be more food secure than control households. Mothers from project households ate significantly more eggs than their counterparts in control households. A similar trend was observed among children. In 2009, fewer chickens were vaccinated in the project villages than in 2008, and more chickens were independently vaccinated in the control villages. This corresponded with an increase in ownership of chickens, a reduction in food insecurity, and improved consumption of eggs in control villages, whereas chicken ownership and egg consumption decreased and food insecurity remained relatively stable in project villages. We saw no differences between project and control villages in income earned from chicken and egg sales.*

Conclusions. *Our findings suggest that an increase in chicken Newcastle disease vaccination can lead to an increase in ownership of chickens and egg consumption and may also have an effect on reducing household food insecurity.*

Key words: Agricultural development, animal-source food, food security, impact assessment, Newcastle disease, poultry, Tanzania

Introduction

Small-scale, family-based poultry production can provide a practical and effective way to alleviate poverty, particularly for women and resource-poor farmers [1]. Households often keep chickens as a source of quick money to pay for medicine, food, transportation, or school fees, and, unlike meat from larger livestock that may spoil without refrigeration, chicken can be consumed quickly. However, family-based poultry production systems are characterized by low productivity and face constraints related to disease and consequent high mortality rates, housing, feeding, breeding, marketing, credit, training, and a lack of available information [2, 3].

Despite these challenges, village chickens play a vital role in many poor rural households by providing an important source of high-quality nutrition and income with very little cost and management. Poultry meat and eggs provide high-quality protein, B-complex vitamins, vitamins A, E, and K, and the minerals iron, zinc, copper, and manganese. These nutrients play a critical role in immune function, cognitive function, and linear growth [4–6], particularly affecting child development, lifelong productivity, and economic development [7]. In Tanzania, deficiencies of these nutrients, largely due to a monotonous maize-based diet low in animal-source foods, have been associated with high prevalences of morbidity and stunting in children and

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of vitamin A deficiency and anemia among children and women [8–11].

A major constraint to rural poultry production in Tanzania is viscerotropic velogenic Newcastle disease [12–14] (hereafter referred to as Newcastle disease), which is caused by a virus and is capable of causing up to 100% mortality in unprotected flocks [15]. However, several studies [13, 14, 16-18] have documented the beneficial effects of Newcastle disease vaccination on village chickens in Tanzania and other countries, describing significant decreases in chicken morbidity and mortality. The heat stable I-2 vaccine, administered as an eyedrop, has reported efficacy rates ranging from 77% to 100% [14, 16, 17], is inexpensive, and is easily administered by trained owners or vaccinators. At the time of this study, a dropper vial of the I-2 vaccine, enough to vaccinate about 400 chickens, cost 2,000 to 3,000 Tanzanian shillings (US$1 ≈ 1,200 TSH).

An increase in village poultry production can lead to an increase in household income and/or consumption of chicken and eggs and, subsequently, an improvement in household food security. Food security is defined as a state in which "all people at all times have both physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life" [19]. Food insecurity, the inverse, therefore occurs when people lack access to sufficient food. Several studies have documented the impact of poultry production programs on income and/or chicken and egg consumption of program participants [17, 20-23]. Only a few have documented the socioeconomic impacts of an increase in poultry production due solely to Newcastle disease vaccination. Woolcock et al. [23] reported that Newcastle disease vaccination, implemented through the Southern Africa Newcastle Disease Control Project in Mozambique, resulted in an increase in village chicken flocks and in consumption and sale of chickens and eggs. Another study in Kenya reported that Newcastle disease vaccination alone resulted in a higher return on investment than Newcastle disease vaccination plus supplemental chicken feeding or supplemental chicken feeding alone [22]. In a study in Bangladesh, participants in a poultry production program were found to consume more fish than nonparticipants due to additional income from chicken and egg sales [21]. In Myanmar, outcomes due to improved chicken management and Newcastle vaccination included increases in the number of chickens kept, in household income, and in the consumption of home-produced chicken meat [20]. Administration of Newcastle disease vaccination, as reported in a study in eastern Tanzania, resulted in an increase in income and an average of 5.3 times the returns on investment from chicken sales [17]. None of the above studies examined the impact of chicken Newcastle disease vaccination on household food insecurity.

The purpose of this study was to assess the socioeconomic impact of a chicken Newcastle disease vaccination project on households in rural Tanzania. Three control villages were selected to make comparisons with the three project villages to test the following hypotheses: households in project villages experience less food insecurity than households in control villages; households in project villages have a greater income from chicken and egg sales than households in control villages; and women and children in project villages consume greater amounts of chicken and eggs than women and children in control villages.

Methods

Study context and design

This study took place within the context of a larger project aimed at improving poultry health and production in rural Tanzania, a component of the Global Livestock Collaborative Research Support Program located at the University of California at Davis. The poultry health and production project was developed by researchers from the University of California at Davis and Sokoine University of Agriculture in Morogoro and was implemented in collaboration with the Wildlife Conservation Society Ruaha Program (WCS) in Iringa, Tanzania. Program activities included training policy makers at the district and ward levels on village chicken health and production, with emphasis on the importance of disease control; training village vaccinators and record keepers to implement vaccination and record chicken and egg numbers; and providing Newcastle disease vaccination for all village chicken flocks.

Three project villages — Nyamahana (356 households), Malinzanga (715 households), and Mafuluto (320 households) — were chosen by the WCS office to receive vaccination on the basis of village government support and cooperation. Control villages were not selected initially, as the aim of the vaccination project was not to conduct a comparative study but to study the processes within the project villages. However, for the purpose of the current study, three control villages — Luganga (318 households), Magozi (179 households), and Ilolo Mpya (171 households) — were chosen by the primary author based on similarities (socioeconomic characteristics, location, and infrastructure) to the first three villages. In the three project villages, village vaccinators were selected, trained, and supplied with dropper vials of the I-2 Newcastle disease vaccine. They conducted vaccinations in May and September 2007 and in February, June, and October 2008 (**fig. 1**). All vaccinations were free, except for the last one in October 2008, when people were required to pay 30 TSH (less than US$0.03) per chicken vaccinated. The control villages were located in relatively close proximity to the project villages but did not receive chicken

FIG. 1. Chicken vaccination and household survey timeline

Date	Event
May 2007	Vaccination (free)
Sep 2007	Vaccination (free)
Feb 2008	Vaccination (free)
Mar 2008	Household surveys
Jun 2008	Vaccination (free)
Oct 2008	Vaccination (not free)
Mar 2009	Household surveys

vaccinations through the vaccination program; however, control households were free to vaccinate their chickens independently.

Study area

The six villages in the study are located near Ruaha National Park in the Iringa Rural District, Iringa Region, Tanzania. One main dirt road connects the villages with Iringa town, the administrative capital and marketing center of Iringa Region, approximately 50 km away. Numerous agricultural and agropastoral ethnic tribes live in the area. The numerically dominant tribes are the Hehe, Bena, Maasai, and Gogo. Approximately 90% of the people in the district are employed in small-scale agriculture [24, 25], with the majority of these being subsistence farmers.

Participants and data collection

All study procedures were approved by the Human Subjects Institutional Review Board of the University of California, Davis, and Sokoine University of Agriculture in Morogoro, Tanzania. The study used key informant interviews to guide instrument development and household surveys, but only findings from the surveys will be reported here [26]. Household surveys were done twice — once in March 2008, after three rounds of free vaccinations in the project villages, and again in March 2009, after two rounds of vaccinations in the project villages, one free and one not free (**fig. 1**). The surveys took place during the "hungry season," the period before the harvesting of crops when households often experience food shortages. Oral consent was obtained and the respondents received a small gift for their participation in the approximately 1-hour interview. It was not possible to interview the same households in both years, but in each year a random sample was selected for the survey. Over 40 households from each village were randomly selected from a register of village households with the use of a table of random numbers. A household was eligible for inclusion in the study if it had a child between 1 and 5 years of age and owned chickens at the time of the study or 1 month prior to the study. If the household had more than one child within the required age range, the youngest child was selected. Eight trained local research assistants interviewed the mother or primary caregiver at her home. The interview consisted of a structured questionnaire containing questions on household socioeconomic characteristics, frequency of animal-source food consumption by the mother and child, household food insecurity, and chicken and egg production and sales.

Wealth and income measures

To measure household wealth, we developed and validated a wealth score, based on the type and number of assets that a household owned [26]. Measures of wealth included livestock and material assets, such as number of goats, cows, sheep, and pigs; acres of land; ownership of kiosks, radios, beds, bicycles, sewing machines, and cell phones; and whether or not the household lived in a brick house or had a metal roof. A household wealth score was produced by summing the scores for both livestock and material assets. A livestock wealth score was produced by summing only the livestock asset scores.

If the respondents sold chickens and eggs, they were asked how many chickens and eggs their household had sold in the week and month prior to being interviewed, and at what price. Income from chicken and egg sales for each household was calculated by multiplying the number of chickens and eggs sold by the price obtained for each.

Chicken and egg consumption

To measure the frequency of chicken and egg consumption, a 10-item food frequency questionnaire was used. The food items were beef, fish, chicken, milk, pork, eggs, goat or lamb, wild game, other poultry, and sardines. The mother was first asked how often she ate each item (0 = never, 1 = less than once per month, 2 = once per month, 3 = once per week, 4 = a few times per week, and 5 = almost every day), and then how often her youngest child between 1 and 5 years of age ate each item.

Food-insecurity measures

A nine-item food-insecurity scale, based on the Household Food Insecurity Access Scale (HFIAS), developed by the United States Agency for International Development (USAID) Food and Nutrition Technical Assistance (FANTA) Project [27], was used to measure household food insecurity. A more detailed description of the HFIAS and the validity and reliability of the scale in measuring household food insecurity in the study site has been provided elsewhere [26]. In brief, the scale is based on a household's experience of problems regarding access to food and represents the various

aspects, or domains, of food insecurity found to be universal across cultures [27–30]. The lowest possible food-insecurity score is 0 and the highest 27. A higher score represents greater food insecurity.

Statistical analysis

Data were hand-entered and sorted using Microsoft Excel, and all data were rechecked for accuracy to minimize entry errors. Comparisons between households in project and control villages were made by the *t*-test and the chi-squared test. Bivariate relationships were assessed using the *t*-test and Pearson's correlation to compare socioeconomic characteristics, including household wealth, across household food-insecurity scores and the frequency of consumption of chicken and eggs among women and children. Using the combined 2008 and 2009 data, multivariate regression analyses were performed to examine predictors of household food insecurity, income from chicken and egg sales, and consumption of chicken and eggs by women and children. Analysis of variance was used to compare adjusted means, looking for interactions between the intervention and year. The multivariate analyses included a village variable, which referred to the unmeasured variation among the villages, and an intervention variable, which referred to variation between the project and control groups. The village variable was nested within the intervention variable, as the villages belonged to either the project or the control group. Statistical analyses were carried out with SAS for Windows, version 9.1, and results were considered significant if $p < .05$.

Results

In 2008, a sample of 237 households was included in the study. Of the 274 households asked to participate, 4 declined to participate, and of the 270 households interviewed, 33 households were excluded from the study for not meeting the eligibility criteria. In 2009, a separate random sample of 261 households was included in the study. All selected households agreed to participate, and all met the eligibility criteria.

Data gathered in 2008 (referred to as the year 2008 in this paper) pertain to the first three vaccination campaigns conducted in May and September 2007 and February 2008. Data gathered in 2009 (referred to as the year 2009) pertain to the vaccination campaigns conducted in June and October 2008.

Sample characteristics

Characteristics of the households included in the study are shown in **table 1**. There were no significant differences in socioeconomic characteristics between the project and control village households in 2008. In 2009, the only significant difference between the project and control groups was the mother's age. No significant differences in socioeconomic characteristics were observed between households interviewed in 2008 and 2009.

Trends in total number of chickens owned and number of Newcastle disease vaccinations

In 2008, the mean number of chickens owned by a household was 14.0 ± 12.5 in the project villages and 8.4

TABLE 1. Characteristics of the sample households in project and control villages in 2008 and 2009[a]

	2008			2009		
Characteristic	Project (n = 119)	Control (n = 118)	p	Project (n = 134)	Control (n = 127)	p
Mother's age (yr)	32.3 ± 10.3	30.5 ± 8.9	NS	34.1 ± 10.3	31.2 ± 7.4	.024
Children < 16 yr (no.)	2.9 ± 1.2	3.0 ± 1.4	NS	3.1 ± 1.2	3.4 ± 1.3	NS
Household size (no.)	5.2 ± 1.5	5.4 ± 1.7	NS	5.5 ± 1.5	5.7 ± 1.6	NS
Child's age (yr)	2.5 ± 1.4	2.5 ± 1.4	NS	2.9 ± 1.4	2.9 ± 1.4	NS
Mother's educational level (yr)	5.3 ± 3	4.7 ± 3.3	NS	5.0 ± 3.0	4.9 ± 3.2	NS
Husband's educational level (yr)	5.8 ± 2.7	6.2 ± 2.9	NS	5.6 ± 2.8	5.8 ± 2.8	NS
Sex of child — % (no.) male	47.9 (57)	48.3 (56)	NS	49.3 (66)	51.1 (69)	NS
Religion — % (no.)						
Christian	93.3 (111)	89.2 (99)	NS	93.9 (122)	92.1 (116)	NS
Muslim	6.7 (8)	10.8 (12)		5.4 (7)	5.6 (7)	
Tribe — % (no.)						
Pastoralist	13.5 (16)	19.8 (23)	NS	6.0 (8)	8.1 (10)	NS
Agriculturalist	86.5 (103)	80.2 (93)		94.0 (125)	90.9 (114)	
Household wealth score	18.2 ± 3.2	17.8 ± 3.3	NS	18.4 ± 3.2	18.7 ± 3.3	NS

NS, not significant

a. Plus–minus values are means ± SD. The actual n for each analysis varied slightly depending on missing data.

± 7.0 in the control villages ($p < .0001$). In 2009, there were no significant differences in the mean number of chickens owned by a household between project village (11.2 ± 10.8) and control village (12.1 ± 9.4, $p = .487$) households.

To maintain immunity and to assure that all chickens over 3 weeks of age were vaccinated, the aim was to vaccinate all chickens in the project villages three times during each year of the project. However, **table 2** shows that this aim was achieved among only 20.2% of the project households in 2008 and 13% in 2009. Nevertheless, the frequency of any vaccination was higher in the project than in the control village households in both years. The proportion of households not vaccinating their chickens declined from 2008 to 2009 in the control villages (from 92.4% to 67.7%), suggesting that more households independently chose to vaccinate their chickens.

Control village households reported being willing to pay more to vaccinate chickens and perceived vaccinating chickens to be more important than did project village households. In 2008, the mean amount of money project village households were willing to pay to vaccinate one chicken was 100 ± 145 TSH, whereas control village households were willing to pay 211 ± 289 TSH ($p = .0003$). In 2009, the mean amount of money project village households were willing to pay to vaccinate one chicken was 78 ± 141 TSH, whereas control village households were willing to pay 175 ± 485 TSH ($p = .033$). Households were asked how important they thought it was to vaccinate chickens for Newcastle disease (0 = not important, 1 = somewhat important, 2 = important, 3 = very important, 4 = extremely important). In 2008, the mean importance score was 2.7 ± 1.1 for project village households and 3.1 ± 1.1 for control village households ($p = .027$). In 2009, the mean importance score was 2.4 ± 1.1 for project village households and 2.8 ± 1.1 for control village households ($p = .012$).

Income

In these villages, chickens were primarily used for sale, secondarily used for household consumption, and thirdly given as gifts. Eggs were primarily reserved for hatching into chickens, secondarily used for household consumption, thirdly used for sale, and fourthly given as gifts. Respondents who sold chickens or eggs reported that income earned from chicken and egg sales in the past 6 months was used for the following purposes, ranked in order of most common to least common: household items (e.g., salt, matches, kerosene), clothes, food, school fees, medicine, farm supplies, and village development contribution.

The mean prices obtained for chickens in project and control villages in 2008 and 2009 ranged from 3,071 to 4,656 TSH, and the mean prices obtained for eggs ranged from 100 to 140 TSH. In general, for both years, there were no significant differences in the mean price obtained for chickens and eggs during the previous week and month between the project and control villages (data not shown). The only exception was that in 2009 control village households obtained a higher price for chickens sold in the previous month (4,656 ± 1,293 TSH) than project village households (3,637 ± 1,303 TSH, $p = .008$). The findings showed no significant difference in income earned from chicken and egg sales between households in project and control villages in either 2008 or 2009 (data not shown). Consistently, a greater number of project village households than control village households sold chickens and eggs each year. In 2008, 33 project and 28 control households sold chickens during the previous week, 41 project and 26 control households sold chickens during the previous month, 4 project and 4 control households sold eggs during the previous week, and 7 project and 5 control households sold eggs during the previous month. In 2009, 23 project and 16 control households sold chickens during the previous week, 38 project and 18

TABLE 2. Frequency of Newcastle disease vaccinations in project and control villages in 2008 and 2009 (% [no.])[a]

No. of vaccinations	2008			2009		
	Project	Control	*p*	Project	Control	*p*
0	9.2 (11)	92.4 (109)	< .0001	20.2 (27)	67.7 (86)	< .0001
1	25.2 (30)	6.8 (8)		36.6 (49)	18.9 (24)	
2	43.7 (52)	0		28.4 (38)	11.0 (14)	
3	20.2 (24)	0.9 (1)		13.4 (18)	2.4 (3)	
4	1.7 (2)	0		0.8 (1)	0	

a. The year 2008 refers to the data collected in 2008, which includes the three vaccination campaigns that took place during the year prior to data collection. The year 2009 refers to the data collected in 2009, which includes the two vaccination campaigns that took place during the year prior to data collection. If vaccinations occurred more frequently than the number of official campaigns during the year (e.g., three or four times in the second year instead of two times), it is due to individuals vaccinating their chickens on their own outside of the campaign. **P values refer to the comparison of the distribution of vaccination frequencies between project and control households.**

control households sold chickens during the previous month, 12 project and 3 control households sold eggs during the previous week, and 16 project and 3 control households sold eggs during the previous month.

Chicken and egg consumption

The majority of women responded that they and their child typically ate chicken and eggs either once per month or once per week. As shown in **table 3**, there were no significant differences in the frequency of chicken consumption among mothers and children from project and control village households in 2008. However, in 2008 both mothers and children from project village households consumed eggs more often than did mothers and children from control village households. In 2009, the only significant difference was that mothers from project households consumed chicken more often than did mothers from control households.

Food insecurity

In 2008, project village households had a mean food-insecurity score of 8.1 ± 7.6 and were more food secure than control village households, which had a mean food-insecurity score of 10.4 ± 7.9 (p = .020). In 2009, no significant differences between the food-insecurity scores of project and control households were observed (7.6 ± 7.3 and 6.3 ± 7.4, respectively; p = .168).

Bivariate relationships

Because of the design of the intervention, there may have been many confounding factors related to consumption and food insecurity. Since socioeconomic characteristics did not differ, data from 2008 and 2009 were combined in identifying potential confounders and in the multivariate analysis that follows.

As shown in **table 4**, higher levels of maternal education, paternal education, and household wealth were associated with less food insecurity. Households with older mothers, households with more members, and pastoralist households reported higher levels of food insecurity (data not shown). Household wealth and maternal and paternal education were also positively related to chicken and egg consumption in mothers and to egg consumption in children. Older children also tended to eat more chicken. Mothers from pastoral households consumed significantly less chicken than mothers from agricultural households (chicken consumption score, 1.9 ± 1.3 and 2.5 ± 1.2, respectively; p = .0024), and mothers from pastoral households consumed significantly fewer eggs than mothers from agricultural households (egg consumption score, 1.7 ± 1.6 and 2.4 ± 1.3, respectively; $p < .0001$). Likewise, children from pastoral households consumed significantly less chicken than children from agricultural households (chicken consumption score, 1.9 ± 1.5 and 2.4 ± 1.3, respectively; p = .0295), and children from pastoral households consumed significantly fewer eggs than children from agricultural households (egg consumption score, 2.1 ± 1.8 and 2.9 ± 1.6, respectively; p = .0017). Mothers who were Christian tended to consume fewer eggs than mothers who were Muslim (egg consumption score, 2.6 ± 1.6 and 3.1 ± 1.4, respectively; p = .0443), and girls consumed chicken more frequently than did boys (chicken consumption score, 2.5 ± 1.3 and 2.2 ± 1.2; respectively; p = .006).

Multivariate relationships

After controlling for household wealth, parent education, village effects, and household size, we found a significant interaction between intervention group and year (p = .0008) (**table 5**). The food-insecurity status in project households remained relatively constant from 2008 to 2009, whereas control households showed an improvement.

After controlling for household wealth and tribe and for child's age and sex, intervention status was not associated with chicken consumption among either mothers or children. However, in the adjusted models, intervention status was associated with egg consumption among both mothers and children. For the combined 2008 and 2009 data, mothers from project households consumed significantly more eggs (2.5 ± 0.1) than mothers from control households (2.0 ± 0.1, p = .0013), and children from project households tended to eat more eggs than did children from control households. This difference

TABLE 3. Frequency of chicken and egg consumption by mothers and children in project and control households in 2008 and 2009 (mean ± SD)[a]

	2008			2009		
Consumption	Project	Control	p	Project	Control	p
Chicken by mothers	2.5 ± 1.1	2.4 ± 1.4	.935	2.6 ± 1.2	2.3 ± 1.2	.023
Eggs by mothers	3.0 ± 1.6	2.2 ± 1.6	.0003	2.8 ± 1.4	2.6 ± 1.6	.224
Chicken by children	2.4 ± 1.2	2.3 ± 1.5	.553	2.5 ± 1.3	2.4 ± 1.3	.494
Eggs by children	3.2 ± 1.6	2.5 ± 1.8	.003	3.0 ± 1.5	2.8 ± 1.5	.594

a. Consumption scores for eggs and chicken: 0 = never, 1 = less than once per month, 2 = once per month, 3 = once per week, 4 = a few times per week, 5 = almost every day.

TABLE 4. Bivariate relationships between household socioeconomic characteristics and food insecurity and consumption patterns (Pearson correlation coefficients and significance)

Characteristic	Food insecurity[a]	Mother		Child	
		Chicken consumption[b]	Egg consumption[b]	Chicken consumption[b]	Egg consumption[b]
Mother's age (yr)	0.10*	–0.04	0.02	0.05	0.01
Household size (no.)	0.10*	0.04	–0.02	0.06	–0.002
Children < 16 yr (no.)	0.08	0.06	–0.005	0.02	–0.02
Mother's educational level (yr)	–0.25****	0.10*	0.19****	0.06	0.16***
Husband's educational level (yr)	–0.29****	0.12*	0.11*	0.08	0.11*
Household wealth score[c]	–0.37****	0.17***	0.19****	0.22****	0.26****
Household livestock wealth score[d]	–0.01	0.005	0.02	0.03	0.08
Child's age (yr)	ND	ND	ND	0.11*	0.04
Mother's ASF consumption score[b]	–0.27****	ND	ND	ND	ND
Child's ASF consumption score[b]	–0.24****	ND	ND	ND	ND

ASF, animal-source foods; ND, not done

*$p < .05$, **$p < .01$, ***$p < .001$, ****$p < .0001$

a. Food-insecurity scores range from 0 to 27; a high score indicates greater food insecurity.

b. Consumption scores for eggs, chicken, and ASF: 0 = never, 1 = less than once per month, 2 = once per month, 3 = once per week, 4 = a few times per week, 5 = almost every day. ASF score is the sum of the frequency of consumption of beef, fish, chicken, milk, pork, eggs, goat or lamb, wild game, other poultry, and sardines.

c. Household wealth score (range, 0 to 37) is based on material and livestock assets; a high score indicates high wealth.

d. Household livestock wealth score (range, 0 to 12) is based on livestock assets; a high score indicates ownership of many livestock.

TABLE 5. Household and village characteristics that are predictors of food insecurity and chicken and egg consumption and that are included in the best-fit model

Characteristic	Predictor	*p*	β[a]	SE[a]	*n*, R^2, *F*, *P*
Food insecurity	Household wealth score[b]	< .0001	–0.83	0.10	$n = 470$
	Husband's educational level (yr)	< .0001	–0.50	0.12	$R^2 = 0.34$
	Village[c]	< .0001	—	—	$F = 21.31$
	Year[d]	.0002	—	—	$p < .0001$
	Household size	.0004	0.68	0.19	
	Intervention group by year[e]	.0008	—	—	
	Mother's educational level (yr)	.0186	–0.26	0.11	
Mothers' chicken consumption	Household wealth score[b]	< .0001	0.07	0.02	$n = 489$
	Tribe (pastoral or agricultural)	.0008	—	—	$R^2 = 0.06$
					$F = 6.29$
					$p < .0001$
Mothers' egg consumption	Household wealth score[b]	< .0001	0.09	0.02	$n = 489$
	Intervention group[f]	.0009	—	—	$R^2 = 0.11$
	Tribe (pastoral or agricultural)	.0016	—	—	$F = 10.25$
	Mother's educational level (yr)	.0354	0.05	0.02	$p < .0001$
Children's chicken consumption	Household wealth score[b]	< .0001	0.1	0.02	$n = 485$
	Tribe (pastoral or agricultural)	.0056	—	—	$R^2 = 0.09$
	Child's sex	.007	—	—	$F = 6.88$
	Child's age	.0211	0.1	0.04	$P \leq .0001$
Children's egg consumption	Household wealth score[b]	< .0001	0.14	0.02	$n = 488$
	Tribe (pastoral or agricultural)	.0003	—	—	$R^2 = 0.13$
	Intervention group[f]	.0152	—	—	$F = 8.19$
	Village[c]	.0274	—	—	$p < .0001$

a. β and SE are not included for categorical variables.

b. The household wealth score (range, 0 to 37) is based on material and livestock assets; a high score indicates high wealth.

c. Village effect, unmeasured variation among all villages.

d. Year, unmeasured variation between years.

e. Intervention group by year, unmeasured variation between the project and control groups by year.

f. Intervention group, unmeasured variation among project and control villages.

was largely driven by the wide gap in egg consumption scores between project and control households in 2008, because in 2009 the difference in scores was much smaller, with mothers and children from project households eating fewer eggs and mothers and children from control households eating more eggs.

Multivariate regression analyses were done to examine and control for confounding factors related to household income from chicken and egg sales. We found no significant differences in income earned between project and control villages in 2008, 2009, and over time (data not shown).

Discussion

To our knowledge, this study is the first to examine the potential impact of chicken Newcastle disease vaccination on household food security. Our findings suggest that an increase in Newcastle disease vaccination can increase the numbers of chickens owned and egg consumption and may also reduce household food insecurity. However, if vaccination is not maintained over time, the beneficial effects diminish.

After the first year of vaccination, project households kept significantly more chickens than did control households, and mothers from project households consumed significantly more eggs than did mothers from control households. Project households tended to show improved food security compared with control households. After the second year, vaccinations increased in the control village households compared to the previous year. This increase in vaccinations is very likely associated with the increase in the numbers of chickens kept and the frequency of egg consumption by mothers and children. These changes may also be related to improvement in food security in control households. At the same time in the project villages, the numbers of chickens kept and the frequency of egg consumption by mothers and children were slightly lower in 2009 than in 2008. As the number of vaccinations decreased in the project villages and increased in the control villages, the food-insecurity status in the project villages remained relatively constant, perhaps because of the lingering effect of widespread vaccinations in the first year through the survival of previously immunized birds. Our data suggest that the food-insecurity status in control villages showed an improvement over time as a result of an increase in vaccinations, numbers of chickens kept, and frequency of egg consumption.

While the rate of chicken Newcastle disease vaccinations was not as widespread as intended, the vaccine can spread from vaccinated to unvaccinated chickens if they are housed in close proximity [12]. It is possible, therefore, that the vaccination may actually have had greater coverage than it appears from self-reported vaccination records. Interestingly, the project households demonstrated less support for chicken vaccination than did the control households in both years, which potentially contributed to the decrease in vaccinations in the project villages and an increase in vaccinations over time in the control villages. Discussions with local project stakeholders lead us to believe this is due to project households not being willing to pay to vaccinate their chickens after having received the vaccination for free, and the proximity of project and control villages, allowing control households to see or hear about the benefits of the vaccination.

Although in both years more project than control village households sold chickens and eggs overall, relatively few households sold chickens and eggs, resulting in a small sample size for the measurement of income related to chicken and egg sales. The higher price of chickens sold by control households than project households in the month prior to being interviewed in 2009 may be due to a smaller supply of chickens in control villages than in project villages.

A logical progression of events due to increased chicken survival may be as follows: (1) households begin to keep more chickens; (2) a larger number of eggs are collected and consumed; (3) when household egg consumption is satisfied, households begin to sell a greater number of eggs; (4) households begin to sell chickens for several reasons, such as a limited capacity for keeping chickens, the need for money, or access to markets and/or buyers; (5) thereafter, households may begin to consume more chickens either from household stocks or by purchasing them; and (6) increased household food supplies begin to improve the level of food security. In this study, we see that with an increase in vaccinations in the project and control villages, more chickens are kept and eggs are consumed more frequently.

To examine this progression of events and to address the limitations of this study, an improved study design would be necessary. For example, baseline information from project and control groups, collected before beginning vaccination, is necessary to know the initial status of the groups and to more effectively track changes. To better attribute causation to the vaccination of chickens, ideally, measures should be taken to stop the control group from vaccinating their chickens. However, the program implementers did not want to prevent the villagers from taking steps to improve their livelihood. It is additionally important to maintain consistency in the implementation of an intervention. Although it was intended as a step toward the sustainability of the vaccination campaign, requiring the project group to pay to vaccinate their chickens during the last vaccination campaign may have caused a decline in vaccinations in the project villages.

Another limitation of the study was that we were not able to follow the same households in 2008 and 2009. However, we found that the project and control groups

were very similar in socioeconomic characteristics in both 2008 and 2009, with mother's age in 2009 the only significant difference between the groups. We also found no significant differences in socioeconomic characteristics between the two years of the study.

The strengths of this study were the use of a random sample, key informants to guide development of the household questionnaires, and a food-insecurity measurement instrument that has been shown to be valid and reliable in measuring food insecurity in the study area. Household interviews were done during the same time period in two consecutive years, which decreased the effects of seasonal differences. The study took place during the "hungry" or preharvest crop growing season, which is an optimal time to find measurable impacts from programs to reduce food insecurity [27]. Additional strengths are the variety of socioeconomic characteristics assessed for correlations between food insecurity and chicken and egg consumption among women and children.

To promote the use of chicken Newcastle disease vaccination, as well as numerous other beneficial interventions, it is sometimes necessary to demonstrate the benefits first. Sensitization programs are initiated with the goal that participants will see the benefits of interventions and will continue to carry out the intervention after the project has finished. It is important, however, that programs, particularly programs where free services are provided, include a plan for management and sustainability to avoid a cessation of activities once outside support has ended. Furthermore, to be able to implement effective chicken vaccination programs, future efforts should include research on household decision-making processes regarding the vaccination of chickens.

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