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POULTRY INTERVENTIONS AND CHILD NUTRITIONAL STATUS IN LOW-INCOME COUNTRIES

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ABSTRACT

Poultry production with the majority of free-range chickens is widely practiced in rural communities of low-income countries. Chickens and their eggs are important sources of income and food for the family. Eggs are nutritious with high quality protein and several macro-and micro-nutrients. Evidences showed that increased consumption of eggs improved the nutritional status of children under the age of two years. Projects aimed at increased egg intake among infants and young children have been implemented with different models and approaches, resulting in different outcomes. This paper reviewed the effectiveness of interventional studies in increasing egg intake among infants and young children in low-income countries. A total of eight articles were selected using PubMed and Google Scholar search engines with inclusion criteria of interventions with randomized and controlled study design that measured egg intake among children under the age of two years in low income countries, published in the last five years (from 2015 to 2019) and written in English. The interventions were systematically classified into three categories based on their implementation model: agriculture/poultry only, nutrition education only, and integrated poultry and nutrition interventions. All the models showed increased egg intake with different levels of significance. Poultry only interventions were successful in egg production in excess quantity increasing egg consumption of infants and young children. However, the interventions were challenged by caregivers' priority for income from the sale of the eggs and birds than feeding the children. Hence, egg intake did not increase high enough to the level of an-egg-a-day despite production and availability. Promoting egg for complementary feeding, interventions of nutrition education only resulted in significantly increased egg intake among children under the age of two years. Nevertheless, its sustainability might be challenged as it requires buying eggs every time, creating an economic burden to the rural low-income families. The third model integrated poultry and nutrition interventions, significantly increased egg consumption even with small scale poultry using local chickens by improving nutrition awareness of caregivers and increasing egg availability at household level, demonstrating greater potential of sustainability. Poultry interventions targeting increased egg intake among infants and young children in low-income countries need to be integrated with nutrition education for maximum effect with minimal cost. Moreover, the implementation of strategies to reduce chicken excreta contamination of the environment is equally important for the children to benefit the maximum from increased egg intake.

Key words: egg intake, poultry, nutrition education, egg-a-day, low-income countries

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RURAL POULTRY PRODUCTION

Poultry production is commonly practiced, and chickens are the most widely used poultry for their eggs and meat globally, compared to guinea, turkey, geese, ducks, and pigeons [1]. Nearly all households, including the poor and landless own poultry in the rural of underdeveloped countries where the burden of undernutrition is very high [2]. While it might be assumed that keeping poultry such as chickens would improve the nutritional status of those in the household, there is some indication this may not be the case [3,4]. This paper focuses on chicken production as nutrition interventions in low-income countries with particular emphasis on Africa to determine efficacy in improving the health and nutritional status of infants and young children through increased egg intake.

Rural chicken production can be started with a single hen, and carried out with minimum husbandry. Chickens' reproduction cycle is short compared to other livestock like cattle and goats, tripling or quadrupling themselves within six months. A household with a hen can develop a flock size up to 10 chickens within a year producing a dozen of eggs per week, as long as a rooster is in the area. A typical rural African household maintains on average a flock size of 5-25 birds scavenging for most of their feed during the day and roosting on tress or perches inside family house at night [5]. Chickens scavenge along the road, in the nearby garden and farm fields as well as on garbage in the surrounding environment. They are very efficient in converting vegetation, agricultural wastes, insects, left over foods, garden and household wastes into nutritious egg and meat. Despite predation and diseases that cause high chicken mortality, the scavenging poultry system is a cheap and sustainable way of chicken and egg production in rural settings [6].

The low-input and low-output homestead chicken and egg production is an important source of income and food for the rural poor. The income from sale of the birds and eggs is often used to cover most household costs, including less expensive foods like maize, oil, coffee beans, salt, sugar, gas, and emergency expenses of clinic visits as well as school fees. Chickens are also socio-culturally important for rituals and sacrifice in traditional beliefs in some cultures, for example, South Africa and Ethiopia [6–9].

Role of women in rural poultry production

Women are the major actors in taking care of chickens in village poultry production. Starting from feeding and providing water to the chickens, it is the daily task of rural women to clean their house and the surrounding from chicken droppings. Also, they have to prepare a suitable place for the hens to lay an egg as well as collect and store the eggs. They also facilitate incubation of eggs with broody hens and look after the young chicks when hatched. Children may assist in taking care of the chickens performing simple tasks [3,8].

When the flock is small, women most likely have the power to decide what to do with the eggs and the income from the sale of birds and eggs. However, if the flock size gets bigger, having an economic impact, the power of decision-making shifts to the men, leaving the work of rearing the chickens to the women. Understanding community and household power dynamics is important for effective community-based poultry

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interventions, particularly those focusing on increasing egg consumption among infants and young children [3].

NUTRITIONAL ADVANTAGE OF CHICKEN EGGS

Nutrient composition of egg

Comprised of two distinct parts, yolk and white, chicken eggs contain a wide range of essential nutrients and biological compounds. Egg white contains mostly water, proteins and some minerals, while the yolk contains many essential nutrients, and is a rich source of dietary cholesterol. Egg yolks are important sources of omega-3 (n-3) and omega-6 (n-6) fatty acids critical for early brain development and visual acuity. Eggs are considered a perfect protein source with high quality and an amino acid profile against which other proteins are compared [6,10]. As shown in Figure 1, an egg contributes nearly more than half of the protein, which provides 60%-90% of the dietary requirement of essential amino acids for children 6 months to 2 years old [10]. An egg is a good source of all B vitamins and choline, as well as fat-soluble vitamins A, D, E, and K. Eggs contain selenium, iodine, zinc, phosphorus, and iron, all of which may be low in many children's diets. They are also a source of highly bioavailable antioxidants of carotenoids, lutein, and zeaxanthin [11].

The nutrition profile of eggs can be affected by the diet of the chickens. Lipid, protein, and mineral macro-element contents, particularly calcium, phosphorous, sodium, and potassium content of eggs, remain stable with less variation. However, fatty acid profiles (triglycerides and phospholipids), fat-soluble and some water-soluble vitamins (A, D, E, K, pantothenic acid, and B_{12}) and trace elements including iodine and selenium, are highly variable and directly influenced by the amount ingested by the chicken [12].

Free-range chickens in rural areas that depend entirely on scavenging might be particularly affected by poor nutrition as the feed resource base may not satisfy their nutrient requirement all the time. Hence, supplemental feed is necessary, and/or the feed resource base needs to be upgraded for the better quality of egg in terms of nutrient content [13].

Effect of egg intake on children's nutritional status

Adding just one egg in the daily diets of young children significantly increases their nutrient intake that will have a prominent effect on their health and nutrition status. Figure 1 depicts the level one whole egg complements breast milk to satisfy the daily requirements of 1-3 years old children in some selected macro and micronutrients [6].

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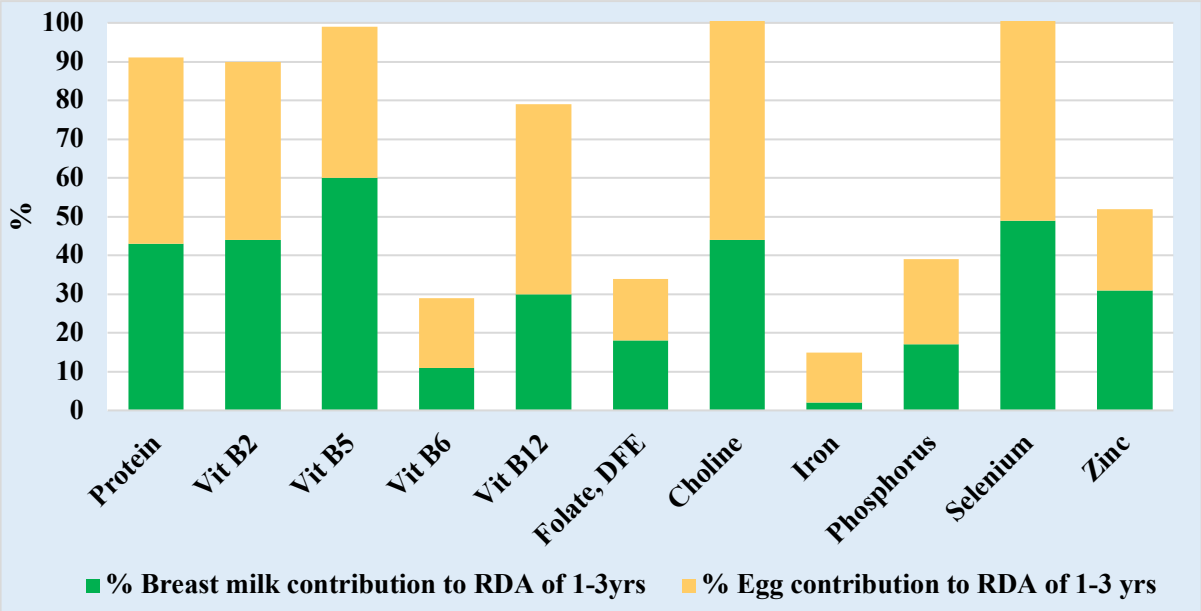

Figure 1: Nutritional contribution of an egg a day in breast-fed children age 1-3 years old

Evidence for a beneficial effect of egg intake on health and nutritional status of young children is emerging following the recommendations of early introduction and daily intake of thoroughly cooked whole egg (Table 1) [14–17]. A trial in Ecuador reported an increase of length for age by 0.63 Z-scores and a reduction of stunting by 47% among 6-9 months old children through feeding one cooked whole egg per day for six consecutive months in addition to the existing diet [18]. In line with this, providing up to 17 eggs/month (hardboiled and smashed whole egg) resulted in a significant reduction of underweight and anemia by 65% and 52% respectively, among under two children of southern Ethiopia in a six-month community-based poultry interventional study. Also, stunting increased less among the treatment group compared to control showing protective effect [19]. An observational study in India associated lower egg intake with two-fold increased odds of stunting [20]. Comparatively, an increased egg yolk intake among infants of rural china resulted in increased hemoglobin and reduced anemia prevalence [21]. Taken together, these findings demonstrated the potential of eggs to mitigate undernutrition and anemia among under two children.

INTERVENTIONS FOR INCREASED EGG INTAKE

Despite the nutritional value, egg consumption is extremely low, particularly in Africa. Demographic and Health surveys from developing countries show that eggs are consumed by children less than 24 months most frequently in Latin America, followed by Asia and with extremely low consumption in Africa (6). Ethiopia is among the lowest consuming countries having only a 12.5% consumption rate [22].

To increase egg intake among infants and young children, interventional studies have been carried out with different approaches/models resulting in different outcomes. PubMed and Google Scholar were searched for interventions with randomized and

controlled study design that measured egg intake among children under the age of two years in low income countries. Articles published in the last five years (from 2015 to 2019) and written in English were included. Key terms entered for searching were ((Poultry intervention) OR (Nutrition AND egg) OR (Nutrition education AND dietary diversity) OR (Nutrition education AND poultry)). As a result, a total of 785 papers were screened that were further filtered out to 314 by publication year. Title and abstract review sorted out 242 articles based on their study design and relevance to egg intake. Finally, eight papers passed for review after thorough assessment for eligibility.

All the selected articles were community-based interventional studies with a minimum of six months of follow up period. The studies can be broadly classified into three groups for systematic analysis, based on their interventions: agriculture/poultry only, nutrition education only, and integrated agriculture/poultry and nutrition.

Agriculture/poultry only

These interventions mainly focus on activities and supplies supporting chicken and egg production at different scales to increase egg availability and intake. However, egg intake of infants and young children may not necessarily increase as the level of egg production is increased. In Zambia, a poultry intervention was conducted with two distinctive programs targeting farmers in a food-insecure village. In the improved village chicken management program, regular new castle disease vaccination and improved chicken care (elevated house, providing fresh water, and supplemental feed) significantly increased mean flock size of 25.7 and 20.4 local chickens, respectively, and household (HH) income from poultry. However, chicken and egg consumption was unchanged over the study period. Producers preferred to allow the eggs to hatch to have more adult birds to sell in the future. In the semi-intensive program, three facilities were established with a total of 50 hybrid layer hens providing training on flock management and chicken care to the producer households. As a result, although most eggs were sold for income, weekly egg consumption increased in young children of 6-36 months old from 0.8 to 2.9 eggs/week and women from 0.9 to 2.4 eggs/week. However, compared to their neighbors (22.5 eggs/HH/month), egg intake in producers (13.4 eggs/HH/month) was significantly lower and the same as households from the control areas (12.6 eggs/HH/month) suggesting that they considered egg production to be primarily an income-generating activity rather than a source of household food. The income from the poultry was mainly used for school fees and uniforms, to pay for food items and home-improvements with planning to reinvest in new layer hens to continue production. The semi-intensive egg production impacted a substantial increase in income for producer households and a significant increase in community consumption of eggs [9,23].

Nutrition education only

Some interventions were successful in increasing egg consumption of young children just by providing intensive nutrition education alone. Alive and Thrive, a global initiative to improve nutrition of women and children in the first 1000 days, provided nutrition education combining intensive counseling by frontline workers and the national mass media to improve complementary feeding practices in Bangladesh emphasising on animal source foods. As a result, egg consumption in the previous 24 hours of dietary assessment was found to be significantly higher by 19 percentage points in the

intervention group [24]. Similarly, large scale social and behaviour change communication intervention program of Alive and Thrive Ethiopia achieved an increased egg consumption in the South and Tigray regions [25]. Nutrition education only interventions might be challenged as families require to buy eggs every time and that could probably affect the sustainability of the new behaviour unless and otherwise, households produce their own eggs.

Integrated agriculture/poultry and nutrition education

A study from Cambodia implemented agricultural intervention including chicken production for more than a year in both of its treatment and control study groups. The intervention arm had an additional component of a weekly/biweekly nutrition education for 2-3 months with key messages of promoting feeding of infants and young children with egg and other animal source foods. Cooking demonstration sessions were also conducted. Egg intake in the past 24 hours before the baseline survey was 30% and 33% in the control and intervention groups, respectively. At the end line, it increased significantly in the intervention group (46%) while showing a modest change in the control (36%) where poultry production was implemented without nutrition education [26]. Similarly, egg intake has been reported to be increased significantly in an integrated nutrition education and food security intervention that provided seeds, fertilizer, fruit tree seedlings, and livestock, compared to control without the nutrition education component [27]. A three years research project conducted in India that promoted backyard poultry production and home gardening integrated with nutrition education demonstrated markedly increased egg intake by under two children with an average consumption of more than four eggs per week [28].

A one-year poultry-nutrition integrated intervention in Ghana provided 30-40 exotic breeds of chickens with training of proper poultry husbandry and frequent technical support on poultry production and poultry health management. Participants received nutrition education with food demonstration sessions promoting diet diversity and egg consumption. The baseline egg intake (whole egg) based on 24hr dietary recall was about 24% among 6-23 months children. The intervention resulted in increased household egg production of 110.7$\pm$50.6 eggs/week and significantly higher egg consumption compared to the control group (31.5% vs. 23%, respectively) who received only the existing nutrition and agricultural services. Considering the high input and increased household egg production, egg intake among young children of the intervention group remained low. That the children did not consume one egg per day suggests that caregivers placed greater emphasis on egg sales for income and success of their poultry enterprise rather than home consumption. The authors also revealed that they did not see a group difference in egg consumption in intention to treat analysis; however, the as-treated analysis showed that those who received the intervention inputs, which included nutrition education, tended to be more likely to consume eggs [29].

A different model of integrated poultry-nutrition intervention named ‘Chicken Gift Ceremony’ was conducted in a clustered randomized and controlled community trial in Southern Ethiopia. Under two children received a gift of two egg-laying local chickens in a ceremonial event where caregivers promised to add at least two more hens, replace if they die, and not to share nor sell the birds and eggs in front of religious and community

leaders. After six months, 94% of children had three or more chickens and mean egg intake significantly increased from almost nill to 17eggs/month/child [30]. This model took advantage of the natural sensitivity of parents for everything related to their children approaching the community through influential leaders for sustainable child owned chicken production and egg consumption.

Integrated poultry and nutrition interventions aimed to increase household or community level egg production as well as awareness of caregivers on egg feeding to infants and young children. It is the synergetic effect of both interventions that resulted in increased egg intake despite the flock size. As households became egg producers and nutrition education was integral in such interventions, this paved way for the sustainability of egg feeding behavior.

CHALLENGES OF POULTRY KEEPING

Disease is a major challenge in poultry production, causing chicken mortality. New castle disease is one of the leading causes of chicken deaths that can be prevented by vaccination. Lack of sustainable and easy to reach vaccination services at the community level presents a big challenge to poultry keepers due to higher mortality of infected chickens [9].

Keeping chickens within the family house is a common practice in rural Ethiopia and other developing countries. Recently, observational studies showed that stunting and chicken corralling are highly associated [31]. Chicken excreta contaminates the environment with bacteria like *Campylobacter* that is considered to cause environmental enteric dysfunction that disrupts the intestinal integrity with villi atrophy increasing the gut permeability leading to leaky gut. Separate chicken houses are essential to minimize environmental contamination and keep chickens away from infants and young children [32].

Chicken houses help not only reduce the transmission of zoonotic diseases but also keep chickens safe from predators. Particularly, scavenging chickens are more liable to predation attacks. Net fencing or housing keeps chickens safe but limits the area where they scavenge. Thus, it may require to feed the chickens, which can be an economic burden to the rural poor [6,33,34]. In addition, construction of a separate chicken house or even simple fencing requires some finance to buy the required materials and labor that rural households may not be able to afford. Let alone a cage that keeps chickens inside all day and night, a simple night coop can be expensive for the rural poor. A small coop framed with thin wooden timber and covered with mesh wire to accommodate up to eight chickens has been priced at $20.00-25.00 [33–35].

CONCLUSION

Small-scale homestead poultry plays great role in increasing egg availability even using local chickens. However, increased household egg production alone does not necessarily change egg consumption of infants and young children significantly, mainly due to caregivers' priority for income from their poultry. What matters most in increasing egg

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intake is not having large flock size nor highly increased egg production. Rather, it is the nutrition awareness that brings sustainable change in egg feeding practice and consumption regardless of the scale of the poultry and the chicken breed. When poultry/egg production and nutrition education interventions are implemented together, they work synergistically to increase egg intake to a higher level with minimal cost and long-lasting effects. Therefore, poultry interventions targeting increased egg intake need to have a strong nutrition promotion component for effective behavior change in egg feeding practice. A baby-friendly poultry system (that is environmentally safe) is essential for the maximal benefit from increased egg intake.

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Table 1: Summary of One-Egg-A-Day Interventions Targeting Under 2 Children in Low-Income Countries

Citation	Country of study	Study design	Study population (# of subjects, age, population)	Intervention	Key findings
Sudargo *et al.*[36]	Indonesia	Experimental, cross over design with three months follow-up period	Stunted and underweight children (WAZ and HAZ < 2SD), with no chronic illness, and did not receive any therapeutic feeding intervention 17 children in vitamin-mineral sprinkles group (Taburia) and 22 children in vitamin-mineral sprinkle and egg group (Taburia PLUS)	Nutrition intervention: - Providing vitamin and mineral fortification sprinkle for one group and vitamin and mineral fortification sprinkle with egg for another group	No changes in WAZ score in both groups HAZ score increased in Taburia PLUS ($p=0.022$) but not in Taburia ($p > 0.05$) Hemoglobin significantly increased only in Taburia ($p = 0.039$) No significant changes in visual motoric scores in both groups but slightly increased in Taburia PLUS
Marquis *et al.*[29]	Ghana	Cluster randomized controlled trial with a one-year follow-up period	Intervention group: 8 clusters, 19 communities, and 287 households Control group: 8 clusters, 20 communities, and 213 households	Poultry Intervention: - Providing 30-40 exotic breeds of chickens - Training on proper poultry husbandry - Frequent technical support on poultry production and poultry health management Nutrition Intervention: - Nutrition education with cooking demonstration sessions promoting diet diversity and egg consumption	Egg production (110.7+50.6 eggs/week) and egg intake significantly increased in the intervention group compared to control (31.5% vs. 23%) Stunting increased (14.0% to 24.3%; $P < 0.001$), wasting decreased (6.3% to 2.9%; $P < 0.05$); underweight didn't change (11.9% to 12.2%; $P= 0.89$) LAZ/HAZ declined less in the intervention group than the control (unadjusted change: -0.38 ± 1.0 z-score vs. -0.64 ± 0.86 z-score; $P = 0 < 0.01$)

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				Home gardening:	Intervention group had a higher LAZ/HAZ (β = 0.22, 95% CI [0.09, 0.34]) and WAZ (β = 0.15, 95% CI [0.00, 0.30]) compared to control
Omer *et al*., [19]	Ethiopia	Cluster randomized controlled community trial with six-month follow up period	Intervention: n=122 children Control: n=128 children	Poultry Intervention: - Two egg laying local chickens provided as a gift for children Nutrition Intervention: - Demonstrations of egg cooking and eggshell powder preparation - Nutrition education of promoting one egg a day and eggshell powder consumption	- WAZ increased by 0.24 (95% CI, 0.11-0.37) - Underweight reduced by 65% (RR, 0.35; 95% CI, 0.16-0.74) - Stunting increased in both groups, but by 28 % less in the treatment group (RR, 0.72; 95% CI, 0.53-0.98) compared with control - Mean hemoglobin increased and anemia decreased in both groups, however, much greater anemia reduction [52% (RR, 0.48; 95% CI, 0.24-0.96)] seen in the treatment group
Iannotti *et al*. [18] Iannotti *et al*.[37]	Ecuador	Randomized controlled trial (March-Dec 2015) with six months follow up	Egg group (Intervention)- n=83 Control- n=80	Nutrition Intervention: - Providing one egg per day for 6 months every week - Social marketing campaign encouraging mothers to feed their children with an egg every day	LAZ and WAZ increased by 0.63 (95% CI, 0.38–0.88) and 0.61 (95% CI, 0.45–0.77), respectively Stunting reduced by 47% (prevalence ratio [PR], 0.53; 95% CI, 0.37–0.77) and underweight by 74% (PR, 0.26; 95% CI, 0.10–0.70) Higher dietary intakes of eggs (PR, 1.57; 95% CI, 1.28–1.92) and reduced intake of

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					sugar-sweetened foods (PR, 0.71; 95% CI, 0.51–0.97) No effect on the reduction of morbidity symptoms Significantly increased plasma concentrations of choline, betaine, methionine, docosahexaenoic acid, dimethylamine, and trimethylamine-N-oxide No significant group difference in vitamin B_{12}, retinol, linoleic acid (LA), α-linolenic acid (ALA) or ratios of betaine to choline and LA to ALA
Dumas *et al.* [38]	Zambia	Interventional study with four-time points cross-sectional data collection Controls were selected purposively to match the intervention groups	Children of 6-36 months in egg production centers (EPCs) and households within 1.5 km radius to the EPCs Baseline 1; dry season (June 2014; *n* = 906 households, Baseline 2; rainy season (December 2014); *n* = 886, Midline; rainy season (December 2015); *n* = 885 End line; dry season (June 2016); *n* = 869)	Poultry Intervention: - Intensive poultry production (20 egg-producing centers [EPC]) each stocked with 40-layer hens Nutrition Intervention: - Promotion of egg intake	Odds of egg intake increased significantly in the intervention group at midline that decreased at end line due to a decline in egg production The Control group showed slightly increased odds of egg intake and decreased highly at end line No significant difference in the frequency of egg intake among the groups No impact on children's HAZ score

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