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Benefits, perceived and actual risks and barriers to egg consumption in low- and middle-income countries

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Eggs like other animal-source foods (ASFs), contain an array of macro and micronutrients that promote physical and cognitive growth, nutrition, and health outcomes. Hence, they can be used to reduce rampant undernutrition in low-and middle-income countries (LMICs). Yet consumption of eggs remains low in such countries for various reasons. Given their potential as a tool for reducing malnutrition, this paper reviews the literature on the benefits, risks, and barriers to egg consumption in LMICs. Research indicates that egg consumption is associated with several nutritional and health benefits in newborns, young children, and pregnant and lactating women, but few studies on other groups exist. Effects of egg consumption on diet-related chronic diseases seem to be inconclusive, and early introduction of eggs to infants has reduced allergy risk of eggs later in life in several studies. Some main barriers to egg consumption in LMIC include unaffordability and unavailability, partly due to low poultry productivity, high poultry feed prices, cultural beliefs, and social taboos, many of which disproportionately restrict egg consumption among children and pregnant women. The evidence supports egg intake as a mechanism for meeting nutrient recommendations and a healthy diet in LMIC.

KEYWORDS

animal source foods (ASF), eggs, health, nutrition, health risks, low-and middle-income countries (LMICs)

1 Introduction

Consumption of animal-source foods (ASF) such as meat, fish, dairy, and eggs are linked to improvements in nutrition and health status due to their rich profile of nutrients, including as protein, essential fatty acids, minerals, and vitamins (Asare et al., 2022; Fite et al., 2022). ASF has been described as the best nutrient-dense source of food for children

under 2 years of age (WHO, 2014). They are also the best source of catalytic proteins that are important for cellular growth and differentiation but cannot be synthesized within the human body. Thus, they must be obtained via the diet (Headey et al., 2018). Adding small quantities of ASF to plant-based diets can augment nutritional and health outcomes in consumers (Neumann et al., 2007; Eaton et al., 2019).

Despite the significant potential contribution of ASF to nutritional security, ASF consumption is very low in low- and middle-income countries (LMICs), where diets are often highly comprised of starchy foods, relative to levels in high-income countries (HICs) (Adesogan et al., 2020). The low ASF consumption in LMICs is attributed to several factors, including low animal productivity, unaffordability, cultural norms, and religious beliefs. Usually, ASF are costlier per calorie in LMICs compared to grains and staple foods, which creates a significant economic barrier to ASF consumption (Headey, 2018), a problem disproportionately affecting the poorest populations (Rawlins et al., 2014; Hoddinott et al., 2015). Taboos on consumption of ASF also hinder their intake in several societies, unfortunately during important periods of development, such as pregnancy and infancy. For example, seafood and eggs are taboos for pregnant women and young children in Southeastern Nigeria (Ekwochi et al., 2016). In Ethiopia, which has one of the largest livestock populations on the planet, meat and fish consumption during pregnancy is low (Nguyen et al., 2013; Zerfu et al., 2016), and avoidance of ASF during fasting seasons is the custom in the Orthodox Christian faith. Many other major world religions also forbid the consumption of certain ASF. In India, most religious and ethnic groups, including Jains, Sikhs, and upper caste Hindus, prohibit the consumption of beef (Dasgupta et al., 2023), yet beef is a good source of iron and India has the highest global prevalence of anemia (Stevens et al., 2013).

Like many ASF, eggs are a rich source of micro and macronutrients (Lutter et al., 2018). Eggs have been considered among the best sources of protein because of the similarity of the amino acid profile to that of reference proteins (Rao et al., 1964; FAO, 2023). Eggs contain relatively high concentrations of vitamins A, D, E, K, B1, B2, B5, B6, B9, and B12 (Réhault-Godbert et al., 2019), as well as choline (Patterson et al., 2007). Eggs also contain phosphorus, calcium, potassium, iron, iodine, zinc, and essential fatty acids (EFAs) (Lutter et al., 2018).

Eggs are unique in their support for early growth and development (Iannotti et al., 2014). The essential omega-3 and 6 fatty acids in eggs, especially docosahexanoic acid (DHA) are important for vision and the early stages of brain development (Iannotti et al., 2014). Hence, such fatty acids from eggs are essential during pregnancy and infant development (Miranda et al., 2015). Adding eggs more frequently in diet can also help older people to maintain their muscle strength and function, thereby preserving their functional capacity (Smith and Gray, 2016).

In many HIC, but not most LMIC, eggs are nutrient-dense whole food, relatively low cost sources of protein (Drewnowski, 2010; Alexander et al., 2016) and have the lowest planetary impact amongst ASF (Myers and Ruxton, 2023). They are a renewable source of protein (Lesnierowski and Stangierski, 2018) that can contribute to household food security whether they are produced at home or purchased. Eggs, kept with intact shells under appropriate conditions, are sterile and easy to cook (Board et al., 1994), which are significant advantages over other ASF, for which food safety is a concern (Bukachi et al., 2021). Chickens or other egg-laying poultry, such as guinea fowl, are often ubiquitous in rural, smallholder farming communities of LMICs. Yet, the productivity of poultry and egg consumption is often low in such areas (Wong et al., 2017; Stark et al., 2021). This is partly because food taboos exist in many of such places limiting egg consumption (Onuorah and Ayo, 2003; Iradukunda, 2020), but may also be because of culturally derived norms and understandings of the chicken-egg lifecycle (Stark et al., 2021). Figure 1 shows that egg consumption has remained low in LMICs as compared to HICs over time.

Against this background, we present a review of the literature on benefits and risks of chicken egg (hereafter, egg) consumption (Figure 2), particularly in LMICs, and outline the rationale for further investigation of benefits of egg consumption and the attendant policy implications. First, the paper examines the literature on nutritional benefits of egg consumption and then it examines actual and perceived health risks of egg consumption. Finally, it explores the barriers to increasing egg consumption, particularly among LMICs. The conclusion provides a brief synopsis of key deductions and potential solutions for increasing egg consumption in LMICs.

2 Egg consumption and health benefits

The nutritional benefits of eggs to human health likely cover the lifespan, including infants, young children, adolescents, adults, childbearing, pregnant and lactating women, adult men, and the elderly (McKune et al., 2022). However, there is little published information on the benefits of egg consumption except in infants, young children and pregnant and lactating women. In the US, egg consumption is associated with greater energy intake, protein, total choline, lutein + zeaxanthin, fat and other micronutrients (Papanikolaou and Fulgoni, 2018). These authors reported that relative to non-egg consumers, egg consumers had lower prevalence of people with calcium, iron, magnesium, and vitamins A, C, and E levels below the respective estimated average requirements, and greater prevalence of people with potassium and choline levels above the average requirements. A recent review by Myers and Ruxton (2023) found increased muscle protein synthesis and reduced fat mass due to increased egg consumption.

2.1 Infants and young children

During infancy and early childhood, a nutritious, diverse diet is vital for optimal physical and cognitive growth (McKune et al., 2022). This stage demands more than double the energy requirement per kilogram compared to that for adults (Bégin and Aguayo, 2017). Eggs can contribute substantially to children's development because they provide approximately half of the daily

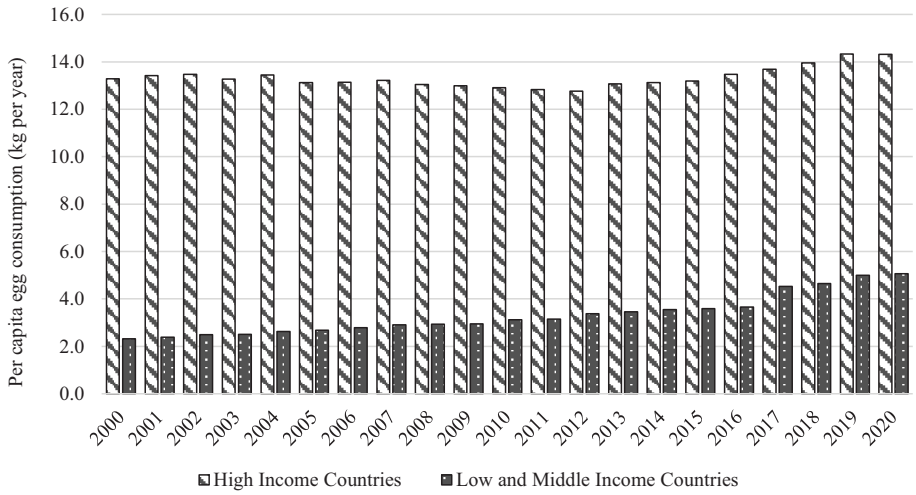

FIGURE 1
Pattern of per capita egg consumption in High Income Countries (HICs) and Low- and middle-income countries (LMICs) during 2000 to 2020. Data source: FAOSTAT, Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/faostat/en/#data/FBS on October 23, 2023.

nutritional requirements of children (Waters et al., 2018). In support, a 49-country study of children aged 6-23 months (Headey et al., 2018) found that egg consumption was associated with a lower (1.3%) prevalence of stunting.

A Randomized Controlled Trial (RCT) by Iannotti et al. (2017) compared nutritional outcomes among 6–9-month-old children in a treatment that supplemented one egg per day for 6 months versus those in a Control group with a usual unsupplemented diet in Ecuador. They found that length for age z-score (LAZ) increased by 0.63 Standard Deviation (SD), that stunting prevalence decreased by 47% in the treatment group compared to the Control group, and they attributed the difference at least partly to an increase in choline levels in the treatment group by 0.35. Other early growth outcomes, such as weight, length, and head circumference, were unaffected. However, the same research team (Stewart et al., 2019) conducted a similar RCT in Malawi with 660 children of the same age (6-9 months), but did not find any increase in LAZ, weight-for-age (WAZ), or weight-for-length z-scores (WLZ) due to egg consumption. The latter study attributed the lack of effect of egg consumption on nutritional measures to a fish-rich background diet and low prevalence of stunting at baseline. Nevertheless, authors reported that egg consumption increased head circumference for age, sometimes used to measure cognitive development (Veena et al., 2010; Wright and Emond, 2015).

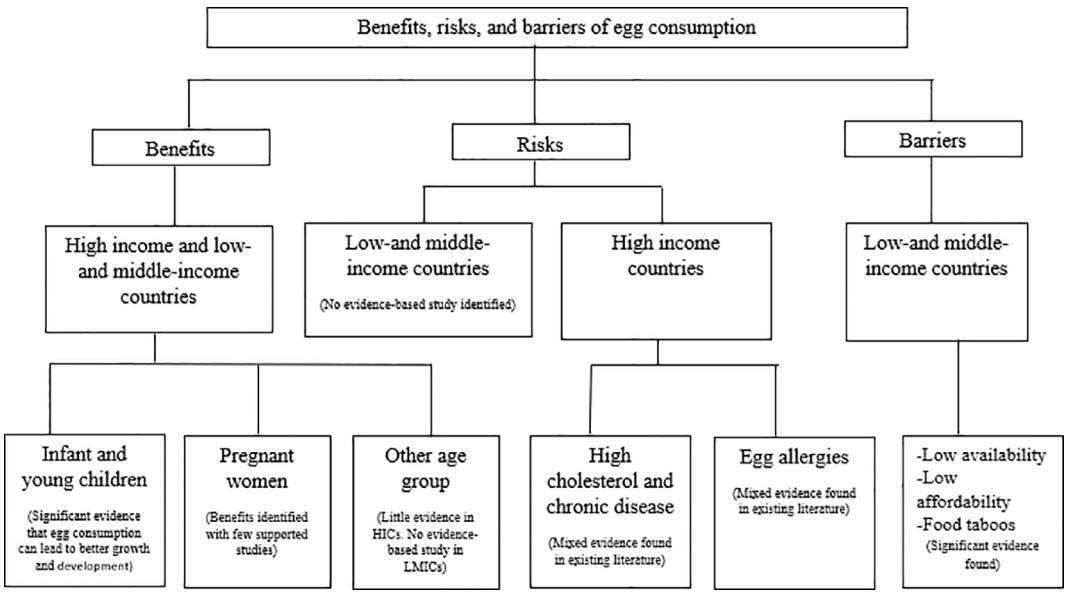

FIGURE 2
Overview of the study.

In Uganda, Baum et al. (2017) evaluated the provision of one versus two versus no eggs five days per week to children aged 6-9 months in a school feeding program. Compared to those receiving no eggs, children receiving two eggs had significantly higher growth and weight gain at 6 months as well as lower tricep skinfold thickness (-0.64 cm) and greater mid-upper arm circumference (MUAC) (+0.52 cm).

In a three-arm trial in Burkina Faso, McKune et al. (2020) examined effects of providing chickens and nutritional training (full intervention), only nutritional training (partial intervention) and no intervention (Control) to 270 mother-child dyads on egg consumption and anthropometry. The study reported increases in egg consumption among children in full and partial intervention groups. Wasting (increase in WLZ by 0.58) and underweight (increase in WAZ by 0.47) were reduced among children in the full intervention group versus the Control group. In a similar study in Ethiopia, Omer et al. (2022) compared an intervention of nutritional training (to mothers) combined with child-owned egg-laying hens to a Control group with only nutrition education. The intervention significantly increased egg intake and WAZ and WLZ by 0.38 and 0.43, respectively, among 6-18 months-old children. The study also noted that in the intervention group, children were 54% and 42% less likely to be underweight and stunted than in the Control group. Asare et al. (2022) examined the effects of ASF consumption in LMICs among 6–24-month-old children. They concluded that egg consumption non-statistically increased LAZ and WAZ with clinically relevant high effect sizes of 0.31 and 0.2, respectively. However, among 3-8-year-old children in Haiti, Stewart (2018) did not find any improvement in child growth outcomes with an intervention of two eggs per day (10 per week) in the diet for 6 months. The study attributed the null results to limited food access and non-compliance with the study design. In Malaysia, Ihab et al. (2014) conducted a trial examining the effect of milk and egg as supplements for malnourished children aged 2-10 years. No significant difference in height and weight gains was reported, but supplementation with milk and eggs almost doubled MUAC values relative to those in the Control group.

The improvements in nutritional status and anthropometry measures in the studies above are at least partly attributable to the macro and micronutrient supply from eggs. By increasing concentrations of DHA and other micronutrients like vitamin B12, zinc and iron, increased consumption of eggs by young children potentially impacts cognitive development. DHA is vital for neurodevelopment, but is often low in diets of young children in resource-poor settings (Forsyth et al., 2017). One 50g egg contains approximately 30 mg DHA, which translates to 30% of the recommended amount for children under 24 months of age by the European Food Safety Authority (100 mg DHA/day) (Papanikolaou and Fulgoni, 2018). A DHA supplement intervention study in Ghana (Van Der Merwe et al., 2013) among 3-9 month-olds resulted in greater a concentrations of plasma n–3 fatty acid and MUAC at 9 months. The previously described Ecuador study (Iannotti et al., 2017) found that egg consumption increased the effect size of DHA concentration by 0.43. In another study in Ecuador, Sibbald et al. (2021) found egg consumption to be a significant factor for cerebellar diameter. They observed trends for positive effects of maternal consumption of eggs on fetal brain dimensions. Omer et al. (2022) found that children in the intervention (with child-owned poultry and nutritional training for mothers) achieved higher scores in motor skills (running, kicking a ball, and throwing a ball) at a younger age than those in the Control group (with nutritional training for mothers alone). These children had 1.43, 1.39, and 1.37 times greater chances of attaining the milestones mentioned above than the Control group children. From the discussion above, it is evident that eggs can contribute often missing essential nutrients for optimal growth and development in the diets of young children in LMIC.

2.2 Pregnant and lactating women

Eggs can contribute to nutritional needs during adolescence—"a period of rapid growth, hormonal changes, and brain restructuring" (Bundy et al., 2017), as well as during pregnancy and lactation (Lutter et al., 2018). For several vital nutrients, eggs can contribute a large portion of the Recommended Daily Allowance (RDA) or adequate intake (AI) for pregnant and lactating women; for instance, two 50-g eggs provide between 20% and 35% of the AI/RDA for vitamin A, riboflavin, pantothenic acid, vitamin B12 and phosphorus for pregnant and lactating women, and more than 18% of the RDA for protein and 50% of the AI/RDA for choline and selenium (Lutter et al., 2018). Studies in the US and South Africa show that pregnant mothers had choline intakes below the AI, and this was associated with lower egg and dairy intake (Wallace and Fulgoni, 2017; Robb et al., 2021). Wallace and Fulgoni (2017) reported that meeting the AI for choline without egg consumption or a dietary supplement is challenging, even in the US. Choline supports various cellular membrane reactions and is a precursor of acetylcholine, an important neurotransmitter and non-neuronal signalling molecule essential for memory, muscle control, mood, and other brain and nervous systems functions (Wallace and Fulgoni, 2017). Yet published studies on the effect of egg consumption on nutritional and health outcomes in pregnant or lactating women are few. Such studies have shown that compared to pregnant non-egg consumers, pregnant egg consumers had higher intakes of protein, fat, vitamin K, vitamin E, selenium, beta carotene, lutein and zeaxanthin, cholesterol, total polyunsaturated fatty acids, and DHA among predominantly Puerto Rican Latinas (Bermúdez-Millán et al., 2009), lower gestational diabetes and blood pressure in Iran (Milajerdi et al., 2018), and lower prevalence of anemia in Ghana (Tibambuya et al., 2019). These beneficial responses highlight the need for more studies on the nutritional and health benefits of egg consumption in pregnant and lactating women in LMICs and in other adolescents and adults.

3 Risks associated with egg consumption

Despite the nutritional benefits mentioned above, egg consumption has been associated with adverse effects on human health (Miranda et al., 2015). Associated health risks of egg

consumption such as cancer, diabetes, cardiovascular diseases (CVD) are studied in several meta-analyses. But the evidence was often conflicting, complicating the making of dietary recommendations.(Zhang et al., 2020) Further, most of the studies investigating the risks of egg consumption are conducted in middle and high-income countries. Below we summarize the risks of egg consumption that might be relevant for LMICs.

3.1 High cholesterol content and its association with diet related chronic diseases

Health risks attributed to egg consumption have usually been associated with the high cholesterol content in eggs. Egg cholesterol accounts for 26-32% of total dietary cholesterol intake in the USA and 48% of total dietary cholesterol intake in Japan (Nakamura et al., 2006). However, the effects of egg consumption on plasma cholesterol levels is not straightforward. While some studies suggest that increased consumption of eggs increases plasma total cholesterol, others do not. One study noticed that daily consumption of 3 eggs for four weeks did not affect plasma cholesterol in people with metabolic syndrome (DiBella et al., 2020). Another study concluded that more than 70% of human subjects experience only little or no increase in plasma cholesterol concentration when they consumed high levels of dietary cholesterol, as could occur from consumption of eggs (Asare et al., 2022). A third study suggested that eggs do not increase plasma cholesterol concentration because the cholesterol they supply appears to regulate the endogenous synthesis of cholesterol so that the LDL-C/HDL-c ratio is maintained (Lemos et al., 2018). In another study, a 100 mg daily increase in dietary cholesterol from eggs, equivalent to 3-4 eggs a week, increased LDL cholesterol by approximately only 0.05 mmol/L (Natoli et al., 2007).

Further, there is some evidence that daily egg intake may favorably shift HDL lipid composition and function beyond increasing plasma HDL-C in individuals with metabolic syndrome (Andersen et al., 2013). However, it is also important to note that other studies have reported increased plasma cholesterol due to egg consumption. For instance, in a meta-analysis of 17 randomized controlled trials Li et al. (2020) concluded that egg consumption increased LDL-C/HDL-C ratio and LDL-C levels, especially with a longer intervention period. Another meta-analysis by Rouhani et al. (2018) concluded that egg consumption increased total cholesterol, LDL-C, and HDL-C, but not LDL-C:HDL-C, TC : HDL-C, and Triglycerides compared with low egg Control diets. Clayton et al. (2015) found a significant decrease in triglycerides levels among participants who consumed egg-based (2 eggs per day) versus bagel-based breakfasts for 12 weeks but reported no effect on total cholesterol.

Existing evidence, therefore, indicates a complex relationship between egg consumption and cholesterol levels due to factors such as preparation methods, other dietary components, and individual variations that might affect cholesterol metabolism (Miranda et al., 2015). Others have also attributed the inconsistent plasma cholesterol response to egg consumption in different studies to individual variation (Herron et al., 2006; Sanlier and Üstün, 2021).

Higher egg consumption has been linked to both positive and negative effects on specific health conditions. For example, higher egg consumption was associated with increased blood glucose levels among individuals with type 2 diabetes and/or impaired glucose tolerance (Guo et al., 2018). However, improved blood glucose levels associated with egg consumption were reported in people with pre-diabetes and type 2 diabetes (Pearce et al., 2011; DiBella et al., 2020). Meta analyses studies have also yielded conflicting results (Shin et al., 2013; Tamez et al., 2016; Wallin et al., 2016).

Another risk sometimes linked to egg consumption is CVD, but the literature findings are inconclusive. Some studies found no positive relationship between egg consumption and CVD, such as myocardial infarction or stroke (Rong et al., 2013; Zhong et al., 2019). In contrast, moderate egg consumption has been associated with a reduced risk of metabolic syndrome, lower risk of cardiovascular disease, and lower risk of developing hemorrhagic stroke (Myers & Ruxton, 2023; Qin et al., 2018; Woo et al., 2016). A meta-analysis by Alexander et al. (2016) indicated that daily intake of 1 egg was associated with reduced risk of stroke but no clear association for coronary heart disease. Further, some studies report no correlation between egg intake and CVD risk (Fernandez and Calle, 2010). Godos et al. (2021) in their meta-analysis found no conclusive evidence on the role of egg in CVD risk. Similarly, meta-analysis conducted by Krittanawong et al. (2021) also suggested no association between higher egg consumption and increased CVD risk, but they found that higher egg consumption was associated with a significant reduction in coronary artery disease Consequently, it has been suggested, that where evident, the harmful effects of eggs on CVD may be attributed to negative dietary patterns associated with high levels of food intake rather than egg consumption (Fardet and Boirie, 2014).

From the evidence above, it is inferred that the effects of egg consumption on health outcomes are multifaceted and vary among individuals. Consequently, more research is needed on this subject. In the absence of definitive studies, therefore, dietary recommendations aiming to restrict egg consumption should not be generalized for all, as there seems to be considerable evidence that healthy populations experience no increased risk of developing diet-related chronic disease by increasing egg consumption (Fernandez, 2006).

3.2 Egg allergies

Allergies are another important risk often associated with consumption of eggs. Egg allergies are immune responses triggered by proteins found in eggs, mainly ovalbumin, ovomucoid, lysosome, ovomucin and ovotrasferrin (Heine et al., 2006). Egg allergies are common in children, with various reported prevalence rates: 1.3-2.5% among children under 5 years of age in Japan (Nishino et al., 2022), 8.9% among one-year-olds in Australia (Loh and Tang, 2018), 0.07% to 2.18% among two-year-olds in Europe (Xepapadaki et al., 2016), and 3 to 4% among 0 to 2 year

olds in China (Lee et al., 2013). In the US, egg allergies are the second most common food allergy in children after cow's milk, with a prevalence of 0.9% among all children and 1.3% among children under the age of five (Samady et al., 2020). These allergies can manifest as immediate-type reactions, such as hives, swelling, and anaphylaxis, or delayed-type reactions, including gastrointestinal symptoms and atopic dermatitis (Loh and Tang, 2018; Lunhui et al., 2021). Allergic reactions to eggs can cause physical discomfort, anxiety, and social limitations (Morou et al., 2021). Individuals with egg allergies may have an increased risk of developing allergies to other foods, such as milk, peanuts, and tree nuts (Jo et al., 2019). Sensitization to egg proteins can also occur through exposure to other allergenic sources such as chicken serum albumin (De Silva et al., 2018).

Various published studies, predominantly from MHICs, show that introducing eggs to infants does not increase the risk of allergy incidence or egg sensitization and, in fact, may reduce the risk of egg allergies later in life. Bellach et al. (2017) did not find any evidence that egg introduction to 4–6-month-olds prevented egg allergy in Germany. However, Natsume et al. (2017) conducted a RCT in Japan among infants 4-5 months of age, assigning them to 50 mg of egg powder per day from 6-9 months and 250 mg per day thereafter until 12 months of age, concluding that early egg treatment is a safe and effective way to prevent egg allergy in high-risk infants. Likewise, in their systematic reviews and meta analyses, Burgess et al. (2019) and Al-Saud and Sigurdardóttir (2018) concluded that introducing eggs to 4 month olds and 3-6 month olds was associated with reduced risk of egg allergies. Wei-Liang Tan et al. (2017) found that introducing egg whites to the diets of infants reduced sensitization to egg whites by 9.8% in Australia.

4 Barriers to egg consumption and solutions

Despite their nutritional advantages and relative availability and affordability compared to other ASF, the per capita consumption of eggs is still low in many countries, especially in LMICs. For instance, the per capita egg consumption in the United States in 2020 was 286 eggs a year (Snibbe, 2021). In contrast, the average long term per capita egg consumption in Sub-Saharan Africa is estimated to be 44 eggs (Vincent, 2023). In Africa, based on 24 hour recall prior to the survey, only 12.6% of children reported egg consumption, and in India, the corresponding number was just 14.7% of children, a level much lower than other South Asian countries (25.0%) (Morris et al., 2018). Only 9 out of the 43 countries in the Sub-Saharan Africa consume a yearly average of 2 kg of eggs per person, equivalent to 30 to 40 eggs, and in many countries, including Burundi and Rwanda) consumption is much lower (Júlia Pié Orpí, 2020). A study in Ethiopia found out that only 20% of households consumed eggs one to two times per week (Daba et al., 2021). Another study in Burkina Faso found out that eggs were amongst the least consumed foods in 618 children studied and only 6.6% women gave eggs to their breastfed children (Bougma et al., 2023).

4.1 Low availability

Numerous factors contribute to the low consumption of eggs in LMICs. Generally, the productivity of poultry in LMIC is low, particularly among indigenous breeds, which are hardier and disease resistant, thus often favored. The low productivity of local breeds, limited supply of quality feed, low adoption of best management practices, underdeveloped veterinary services, and generally high and increasing cost of production are the main reasons for the low levels and efficiency of egg production in these countries (Bachewe et al., 2017; Birhanu et al., 2023), which both contribute to low availability.

4.2 Low affordability and increasing production cost

Low-income households consume lower amounts of eggs compared to higher income countries. A study in Ethiopia found low egg consumption in infants and young children was associated with low economic status, indicated by wealth and occupation (Kase et al., 2022). Similarly, in India, per capita income is a determinant of egg purchase probability and consumption (Umanath et al., 2016).

Generally egg consumption is found to be highly correlated with affordability and nationwide availability, both of which are related to the price of eggs (Morris et al., 2018). Studies report that eggs are more expensive sources of calories than staple cereal crops and that this difference is higher in LMICs. For instance, while in MHICs, egg are 2.3 times as expensive source of calories as the cheapest cereal, reflecting the increased poultry productivity overtime and large economies of scale (Narrod et al., 2007), in Latin America, Eastern Europe and Central Asia, the relative prices are three to five times higher; and in sub-Saharan Africa, eggs are 9.5 times as expensive as cereals (Morris et al., 2018).

The low affordability of eggs is primarily attributable to the high and increasing production costs. The cost of poultry feed has been continuously increasing in several African countries, thus increasing the cost of poultry products (Conway, 2019; Wongnaa et al., 2023). In Nigeria the price of feed ingredients has risen by over 168% in the last 3 years (2019-2022) threatening many poultry farms (Poulty World, 2022). Notable increases in price of poultry feed have been reported in other African countries, including 350% in the past year in Ethiopia, forcing the closure of 15 large commercial poultry farms (Business Info Ethiopia, 2022).

Global factors such as COVID-19, the Russo-Ukrainian war, and other local conflicts have also compounded the problem of high prices of livestock feed and, hence, egg prices. For instance, in Bangladesh, broiler chicken and egg prices increased by 40% and 30%, respectively, following the COVID-19 pandemic (Amin et al., 2023). Severe outbreaks of bird flu in the United States and France, together with breakdown of global market networks due to the Ukraine war, tightened global egg supplies and raised prices, especially in LMICs that depend on imported eggs (Polansek and

de la Hamaide, 2022). Table 1 shows recent increases in prices of poultry feed and eggs in LMIC.

4.3 Food taboos, restrictions, and allocation biases

Communities all over the world have various taboos or restrictions against consumption of various types of foods. Some cultures have restrictions on egg consumption for some members of the household or community (Madzimure et al., 2011); such taboos on egg (and poultry) consumption that target pregnant women are common in many cultures (Washington, 2015; Schnefke et al., 2019). For example, women are discouraged from eating eggs when pregnant because they are thought to increase fetal growth and cause labor pain and difficult birth in many countries (Meyer-Rochow, 2009; Arzoaquoi et al., 2015; Chakona and Shackleton, 2019; Tsegaye et al., 2021). Other reasons for taboos against egg consumption by pregnant women include perceptions that they have adverse effects on mental health and cognitive development of newborns in Kenya (Kariuki et al., 2017), cause early deaths among infants in Ethiopia (Zerfu et al., 2016), and cause development of bad habits among children in Ghana (Gadegbeku et al., 2002). In many cultures, the avoidance or restrictions usually target a certain age, gender, or reproductive status, often pregnant women. However, in some countries, the restriction applies to members of the whole community. For example, in India, consumption of non-dairy ASF (including eggs) is forbidden because of religious beliefs and the idea of non-violence among Jains and upper caste Hindus, respectively. Such taboos restricting or regulating consumption of nutritious foods such as eggs based on gender or age have been described as traditional mechanisms by which members of households with the highest decision power, mostly men, control the allocation of nutritious foods (Blum et al., 2023). Hence most of the egg taboos tend to favor men over more vulnerable groups such as women, particularly pregnant women and children (McNamara and Wood, 2019).

TABLE 1 Recent increases in poultry feed and egg prices in selected countries.

Country	Increase in price of poultry feed and time frame	Increase in price of eggs and time frame	References
Nigeria	168% between 2019-2022	37.40% between 2019-2022	(Poulty World, 2022)
Ethiopia	45-55*% between 2020-21	46% between 2020-21	(Business Info Ethiopia, 2022; Negash, 2022)
China	4.3-6.6% between 2021-22	N/A	(Doris, 2022)
US	N/A	60% between 2021-22	(Swann, 2023)
Bangladesh	70% between 2021-22	17% in a month Feb-March 2023	(Financial Express, 2023; TBS News, 2023)
Kenya	31% between mid-2022 to early 2023	26% between mid-2022 to early 2023	(Capital FM, 2023)
India	25-30% in 6 months in early 2022	20.7% between 2021-22	(CNBC TV-18, 2022; Nahata, 2022)
Pakistan	32% between 2018-2020	5.2% between 2018-2020	(Tribune, 2021)
United Kingdom	N/A	20-27% between 2020-23	(Davey, 2022; Julia, 2023)
Ghana	N/A	25-35% between 202-21	(Kinsley, 2021)

*Increase is for all animal-source foods. N/A, not cited.

4.4 Limited knowledge of nutrition

Limited knowledge of nutrition among parents and caregivers can contribute to inadequate feeding practices, including the lack of diversity in complementary diets for children (Waswa et al., 2015). In Ethiopia, 53.4% of children did not consume eggs in a seven-day study period and the probability of a child consuming eggs during the study period was 4.33 times higher when caregivers had some college education compared with no education (Kase et al., 2022). In Ghana a very low per capita consumption of eggs (about 12 eggs per year) was attributed in some communities to lack of education and misconceptions about the health benefits of eggs (Abive-Bortsi et al., 2022).

High cholesterol intake concerns are common reasons for limited consumption of eggs among communities and households who have adequate access to eggs (Kralik et al., 2020; Sanlier and Üstün, 2021), and even among educated consumers in developing countries (Abive-Bortsi et al., 2022).

4.5 Tackling barriers to egg consumption

Both demand and supply side policies can serve as strategic solutions to removing barriers to egg consumption in LMICs (Headey, 2018). Supply-side policies, including those targeting agriculture, trade, value chain policies, and investment, can help drive down the relative price of feed, poultry production, and ultimately eggs, thereby increasing egg affordability. Further enabling policies that provide incentives, the requisite training, and affordable resources to farmers and value chain agents for increasing poultry production can increase egg availability. In addition, demand-side policies through nutritional counselling and media campaigns, including behavior-change campaigns, social protection programs, inclusion of eggs in school meals, etc. can remove the cultural barriers and taboos and significantly foster and facilitate egg consumption in LMICs (Lutter et al., 2018; McKune et al., 2020). Such social marketing and behavior change messaging strategies can be particularly successful when they account for cultural norms and involve individuals respected by the community. For instance, McKune et al. (2020) successfully increased egg consumption among 6- to 12-month-olds in Burkina

Faso who rarely ate eggs (from 0 to 6 eggs per week) by involving village chiefs in a culturally tailored behavior-change campaign.

5 Conclusion

This paper presents a review of evidence-based literature on health benefits, risks and barriers to egg consumption in LMICs. While the health benefits of egg consumption in infants and young children are better documented, few studies from LMICs exist on benefits in pregnant and lactating women and adolescence or adulthood, emphasizing the need for more studies that focus on life stages outside of infancy and childhood. Studies on the risks of egg consumption in LMICs are also limited, and those available from MHICs are largely inconclusive for health risks including cholesterol, cardiovascular disease, and allergies. Early introduction (3 to 6 month) of eggs to infants is associated with reduced egg allergies. Barriers hindering the consumption of eggs in LMICs include high feed costs, unavailability, unaffordability, cultural beliefs, and social norms. These barriers vary across communities and primarily limit consumption of eggs among women and children. Given the health benefits of eggs, it is imperative that governments enact and or implement policies that 1, make egg consumption more affordable in LMICs, 2, provide enabling environments, which increase poultry production and egg availability, and 3, enhance understanding about the nutritional importance of eggs in the diet while countering sociocultural norms that restrict egg consumption by children and pregnant women who need them most. In addition, tailored behavior-change campaigns may be needed to break the cultural barriers, norms, or taboos that limit egg consumption.

Author contributions

AA: Conceptualization, Formal Analysis, Methodology, Supervision, Validation, Writing – review & editing. SM: Conceptualization, Formal Analysis, Methodology, Supervision, Validation, Writing – review & editing. CT: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft. MB: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft.

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Conflict of interest

AA serves on the Advisory Committee of Protein Pact.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be constructed as a potential conflict of interest.

Publisher's note

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