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Backyard poultry farming with improved germplasm: Sustainable food production and nutritional security in fragile ecosystem

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Approximately 3 billion people were unable to afford a healthy diet in 2019 because of poverty and inequality. Most of these people live in Asia and Africa. Furthermore, 30% of the world population was affected by moderate to severe food insecurity in 2020, and most of this population lives in low- and middle-income countries. The world is at a critical juncture, and there is an urgent need for transformative food systems that ensure the empowerment of poor and vulnerable population groups, often smallholders with limited access to resources or those living in remote locations, as well as the empowerment of women, children, and youth (FAO, 2018). The backyard poultry production system (BPPS), as practiced by 80% of the world's rural population, can be that transformative change in low- and middle-income countries. Although the BPPS has low productivity, it still plays an important role in the food and nutritional security of rural people living in fragile ecosystems. Backyard poultry has been recognized as a tool for poverty alleviation and women empowerment besides ensuring food and nutritional security for rural poor. Poultry meat and eggs are the cheapest and best source of good quality protein, minerals, and vitamins. The introduction of improved backyard poultry germplasm has improved the productivity of this system in resource-poor settings and thereby improved the income and nutritional security of poor households. With these birds, the availability, access, utilization, and stability of food security have improved at household and national levels. Diseases, predation, non-availability of improved germplasm, lack of access to markets, and lack of skills are the major constraints to the adoption of improved backyard poultry. These constraints can be addressed by involving a network of community animal service providers. The improved backyard poultry germplasm will dominate the backyard poultry production system in the future and will be a tool for ensuring food and nutritional security on a sustainable basis, more particularly in low- and middle-income countries.

KEYWORDS

backyard poultry production system, improved germplasm, food and nutritional security, women empowerment, sustainability

Introduction

Around the world, more than 780 million people live in extreme poverty with <$1.90 per person per day, an amount that is impossible to support a healthy livelihood in any part of the world (https://www.actionagainsthunger.org/). As a result of the high cost of healthy diets, coupled with persistently high levels of income inequality, ∼3 billion people were unable to afford a healthy diet in 2019. Most of these people live in Asia (1.85 billion) and Africa (1.0 billion). In addition, the number of undernourished people in the world continued to rise in 2020. More than half of the world's undernourished are found in Asia (418 million) and more than one-third in Africa (282 million). Also, approximately 720–811 million people in the world faced hunger in 2020. Furthermore, 30% of the world population was affected by moderate to severe food insecurity in 2020, and most of this population lives in low- and middle-income countries (FAO et al., 2021). The world is at a critical juncture, and there is an urgent need for transformative food systems that ensure the empowerment of poor and vulnerable population groups, often smallholders with limited access to resources or those living in remote locations, as well as the empowerment of women, children, and youth (FAO, 2018). The backyard poultry production system, as practiced by 80% of the world's rural population (Wong et al., 2017), can be a transformative change in low- and middle-income countries.

Poultry is the world's primary source of animal protein (FAO, https://www.fao.org/poultry-production-products/products-processing/zh/). Globally, poultry meat is expected to represent 41% of all the protein from meat sources in 2030. In lower income developing countries, poultry meat is cheap as compared with other meats, while in high-income countries, poultry meat is preferred because white meat is considered a healthier food choice (OECD-FAO Agricultural Outlook 2021–2030).

In poultry production, the most primitive (BPPS) and most advanced (highly mechanized and integrated system) production systems exist side by side (Thieme et al., 2014). The latter uses the latest innovation and technologies and is capital intensive, whereas the former is a low-input and low-output system. Backyard poultry production systems, mostly composed of chickens, account for the majority of the poultry population in low- and middle-income countries (Gilbert et al., 2015; Wong et al., 2017; Rajkumar et al., 2021). Although the BPPS has low productivity, it still plays an important role in the food and nutritional security of rural people living in fragile and resource-poor ecosystems (Wong et al., 2017; Chaiban et al., 2020; FAO and IFAD, 2022). Because of its low-input and low-output nature, a considerable yield gap exists in the BPPS.

Backyard poultry is being practiced in all developing countries and plays a crucial role in poor rural households (Alexander et al., 2004; Alders, 2012). Backyard poultry is a source of scarce animal protein in the form of meat and eggs (FAO, 2013). Besides, they can be sold or bartered to meet emergency family needs such as medicine, clothes, and school fees (Alders et al., 2018). Backyard poultry helps in pest control, provides manure, converts kitchen waste into good-quality protein, and is required for religious and social ceremonies. In resource-poor regions, backyard poultry is owned and managed by women and is often essential element of female-headed households (Alders and Pym, 2009; Bagnol et al., 2013). Backyard poultry is an available and accessible form of livestock in rural and resource-poor areas and, therefore, is a significant source of economic, nutritional, and food security for the poorest of households (Alders and Pym, 2009; Wong et al., 2017). In particular, it significantly improves the livelihood and food security of women, children, the elderly, and the chronically ill (Kumaresan et al., 2008; Wong et al., 2017).

The productivity in terms of meat and eggs of backyard poultry is lower than that of commercial poultry, and traditional backyard poultry production systems are unable to meet the demand (Alders, 2012; Singh et al., 2018b). Chaiban et al. (2020) observed that backyard poultry production systems are highly heterogeneous in terms of size, age, accessibility, management, opportunities, and challenges. The farm location affects market access and influences opportunities available to farmers, resulting in further diversity in farm profiles. Furthermore, with the increasing human population and industrialization, there will be an increase in demand for sustainable animal source foods for human consumption.

Backyard poultry farming with improved productivity through appropriate interventions can be a source of a sustainable food production system (Singh et al., 2018a; Rajkumar et al., 2021). One such intervention is the introduction of improved backyard-type stock in rural and tribal areas. In the recent past, there has been much focus on improved poultry varieties suitable for backyard production in Africa and Asia. These varieties, with higher production potential even on a low plane of nutrition, were developed specifically for backyard production in resource-poor areas and fragile ecosystems (Singh et al., 2018a; Rajkumar et al., 2021). Other interventions include skill enhancement, health prophylaxis measures, implementation of on-farm biosecurity, and efficient market linkages. Through the education and empowerment of farmers, the farmer field school (FFS) approach can contribute to strengthening the knowledge of holistic agroecosystem management, improving decision-making skills, facilitating group collaboration, and encouraging local innovation, particularly by women and young people (FAO and IFAD, 2022).

The present review is an attempt to appraise the status of the backyard poultry production system vis-a-vis improved backyard poultry germplasm and its impact on nutritional and food security, women empowerment, and sustainability. Furthermore, major constraints for the expansion of improved backyard poultry production systems are also discussed.

Backyard poultry production system

Backyard poultry production systems are integrated with human livelihoods for thousands of years, providing income, and food and nutrition security to the rural poor (Alders and Pym, 2009; Wong et al., 2017). Backyard poultry constitutes 50–80% of total poultry in several developing countries. Local poultry constitutes 80% of poultry production in sub-Saharan countries (Desha et al., 2016), with Nigeria known to have 180 million local chickens (Pym and Guerne-Bleich, 2006). In India, backyard poultry is 317 million, and it has increased by 45% in the last decades and now contributes 35% of the total poultry population (20th Livestock Census, Government of India). Backyard poultry farming contributes around 70–80% of the total poultry population in China. In Vietnam, a majority of poor people keep poultry for their meat as well as subsidiary income (Epprecht et al., 2007). Backyard poultry converts waste material such as kitchen waste, vegetable waste, green grass, earthworms, and insects, into high-quality animal protein for human consumption (Alders et al., 2018). Backyard poultry is recognized as an entry point into the livestock production system, which is associated with breaking out of poverty traps (Gueye, 2000; Thieme et al., 2014; Wong et al., 2017).

Backyard poultry is characterized by the rearing of native or indigenous or improved poultry in the backyard (Kumaresan et al., 2008; Chaiban et al., 2020). The number of birds varies depending upon the natural feed base available. Supplementary feeding is also being practiced as and when available (Thieme et al., 2014; Wong et al., 2017). Birds are housed at nighttime only in the locally made chicken coup, whereas in the daytime, chickens are let free for scavenging (Alders et al., 2018). Backyard poultry production is commonly associated with the integrated farming system model with crops, vegetables, fisheries, and other livestock species (Alders and Pym, 2009; Wong et al., 2017). In this system, animal health prophylaxis and biosecurity are minimally applied (Conan et al., 2012; Samanta et al., 2018). There is high mortality because of diseases and predation (Alders, 2012; Chaiban et al., 2020). Chickens are consumed by households, and surplus birds are sold locally. Surplus male birds are consumed or sold in the market at 1.5–2 kg body weight, whereas females are reared for further propagating the flocks. Indigenous female poultry lays 30–80 eggs in three to four clutches in a year (Singh et al., 2018b). The brooding efficiency of native or indigenous birds is very high and incubating 15–20 eggs at one time. In general, the production of indigenous birds is low and further constrained by diseases and predation (Alders and Pym, 2009; Wong et al., 2017).

Backyard poultry production is classified into small-scale extensive scavenging, scavenging, semi-intensive, and small-scale intensive (FAO, 2014) systems. Rajkumar et al. (2021) classified the backyard poultry production system in India into traditional backyard system (<20 birds with little or no input), semi-intensive farming (50–200 birds under semi-scavenging conditions), small-scale intensive farming (200 or more birds with improved birds under a high-input system), and native chicken farming (indigenous birds with a run area and complete ration). Thieme et al. (2014) classified the backyard poultry production system into small extensive scavenging (1–5 adult birds), extensive scavenging (5–50 birds), semi-intensive (50–200 birds), and small-scale intensive production (>200 broilers or >100 layers). The type of backyard poultry production system is based on the availability of poultry germplasm, marketing avenues, availability of natural food base resources, food habits of the population, etc. (Thieme et al., 2014; Chaiban et al., 2020).

Importance of backyard poultry farming

1 Backyard poultry can survive in harsh and inclement climatic conditions. They are resilient to climate change and better adapt to different environments.
2 Backyard poultry birds convert waste material such as kitchen waste, vegetable waste, and green grass into high-quality animal protein.
3 Backyard poultry farming involves minimal initial investment.
4 It provides employment to the rural poor farmers, women, unemployed youth, and old members of the family along with subsidiary income.

5 Eggs and meat from backyard poultry farming fetch a high price as compared to those from commercial poultry farming.
6 Produce of backyard poultry is a source of good-quality animal protein and hence a source of food and nutritional security to vulnerable communities.
7 Backyard poultry may well-integrate with other agricultural operations such as poultry–fish integrated farming system.
8 Manure from backyard poultry is a rich source of soil nutrients and can be utilized to enhance soil fertility.
9 Women empowerment: Backyard poultry are generally owned and managed by women of the household. the sense of ownership and income from backyard poultry empowers rural women.
10 Conservation of biodiversity: Backyard poultry consists of native or indigenous birds, which are well-adapted to the local climate and are resistant to diseases. There is high genetic and phenotypic diversity in indigenous chickens. this can be utilized as a base resource for further improving the productivity of backyard chickens.

Backyard poultry production with improved germplasm

The productivity of the backyard poultry production system can be improved by the introduction of improved germplasm (Table 1) or by adopting improved management practices (Singh et al., 2018b; Chaiban et al., 2020). In the case of improved poultry germplasm, there is a need to develop birds with genetic potential for enhanced growth and egg production. Also, the birds should resemble the indigenous birds with multicolored plumage, longer shanks, higher productivity, adaptability to varied agroclimatic conditions, and better immunity (Kumaresan et al., 2008; Rajkumar et al., 2021). In addition, the improved dual-purpose birds should be able to perform on a low plane of nutrition in the backyard production system. Also, the flavor and texture of meat should be similar to local chicken. Improved poultry germplasm suitable for the backyard production system can be developed either through selective breeding in native or indigenous birds or through crossbreeding of indigenous birds with exotic germplasm. The former method is slow, but changes in production will be permanent without losing the peculiar character of indigenous birds (Padhi, 2016). Also, once selected for higher growth and egg production, further propagation can be carried out at the farmer level. In the case of crossbreeding, improved and native germplasm are crossed, and the heterosis of two breeds is exploited, which results in higher productivity. Although it has been successfully used to enhance the productivity of backyard poultry in Asia and Africa mainly because of the shorter time required for evolving improved germplasm (Singh et al., 2018b; Rajkumar et al., 2021), however, there are inherent problems of crossbreeding. There is segregation of genes, which results in a decrease in productivity in a future generation; therefore, farmers depend on suppliers for regular supply of these birds. Also, the introduction of crossbred poultry in native breeding tacks of indigenous poultry poses serious threats to them and may lead to dilution or erosion of native germplasm. Nonetheless, with due care and a suitable breeding policy, improved dual-purpose poultry has played a significant role in the improvement of food and nutritional security of rural farmers, particularly in low- and middle-income countries (Singh et al., 2018a; Rajkumar et al., 2021). In India, the breeding policy of the Government of India and ICAR envisages avoiding the introduction of the improved varieties in the home tracts of the recognized chicken breeds, which will prevent the genetic erosion of native breeds (Rajkumar et al., 2021). There are several improved poultry germplasms developed in different countries for the backyard production system. Rajkumar et al. (2021) reported that high-yielding poultry varieties, which resemble native poultry, transformed backyard poultry farming into a highly remunerative farming activity in India. Chaiban et al. (2020) reported that because of the increase in poultry meat demand, backyard poultry farms are transforming themselves into semi-intensive (50–200 birds) backyard farms mainly with the help of improved birds and commercial feed.

In our previous study (Singh et al., 2017), we reported that Vanaraja, dual-purpose improved backyard poultry, performs well in sub-tropical to the sub-temperate climate in the Indian Himalayan ecosystem. In this study, body weight at 24 weeks varied from 1.7 to 2.7 kg in different climatic and production systems. Similarly, 72-week hen day egg production varied from 90 eggs to 112 eggs. Singh et al. (2018a) reported that the Vanaraja chick's survivability up to 4 weeks was 96% in the summer season and 83% in the winter season in sub-temperate climatic conditions.

Further, Singh et al. (2018b) found 95% survival of the chicks of improved dual-purpose backyard birds Vanaraja and Srinidhi in a hot humid sub-tropical climate. Also, the hen day egg production was 140 eggs and 195 eggs for Vanaraja and Srinidhi birds, respectively. The eggs and meat of these birds reared in the backyard farming fetches premium prices due to high consumer acceptability even in the urban sectors, where plenty of eggs and poultry meat from commercial units are available. Besides a stable supply of high-quality animal food, backyard poultry production promotes income opportunities, particularly for the weaker sections in the tribal areas. Backyard farming fulfills a wide range of functions, e.g., the provision of meat and eggs, food for special festivals, chicken for traditional ceremonies, pest control, and petty cash, utilizing minimum inputs, minimum human attention, and causing less environmental pollution (Singh et al., 2018b). Furthermore, Singh et al. (2019) reported that the net income per bird was significantly higher (Rs. 995.97 only) in Vanaraja than in local birds (Rs. 287.22 only). In

TABLE 1 Growth and egg production performance of improved backyard poultry germplasm.

SI No.	Improved backyard poultry	Type (egg/meat/dual)	Body weight female	Body weight male	Egg production	References
1.	Kuroiler	Dual	953–1,766 gram at 20 weeks age	1,109–1,785 gram at 20 weeks age	98–115 up to 45 weeks of laying	(Kassa et al., 2021)
2.	Sasso	Dual	1,052–1,748 gram at 20 weeks age	889–2,111 gram at 20 weeks age	98–112 up to 45 weeks of laying	
3.	Sasso-R	Dual	903–1,330 gram at 20 weeks age	913–1,624 gram at 20 weeks age	86–100 up to 45 weeks of laying	
4.	Sasso	Dual	2,730 gram at 20 weeks age	2,980 gram at 20 weeks age	229 eggs per hen per year	(Aman et al., 2017)
5.	Fayoumi	Egg	1,215 gram at 26 weeks age	–	150 eggs per hen per year	(Samson et al., 2013)
6.	Vanaraja	Dual	1,613 gram at 20 weeks age	2,216 gram at 20 weeks age	137 eggs per hen per year	(Singh et al., 2021)
7.	Srinidhi	Dual	981 gram at 20 weeks age	2,288 gram at 20 weeks age	202 eggs per hen per year	
8.	Sonali	Egg	1,180 gram at 20 weeks age	–	156 eggs per hen per year	(Rahman et al., 2017)
9.	Gramapriya	Egg	1,780 gram at 20 weeks age	–	256 eggs per hen per year	(Rajkumar et al., 2018)
10.	Rainbow rooster	Dual	1,650 gram at 20 weeks age	–	163 eggs per hen per year	(Islam et al., 2017)

another study in India, Vanaraja poultry farming was found more profitable than native poultry, with 46.78% more net returns from a unit of 20 birds with a benefit-to-cost ratio of 2.84 in the backyard production system (Baruah and Raghav, 2017). Kumaresan et al. (2008) found that village poultry is an important income source for household expenses in India and that improved dual-purpose birds can be employed to improve traditional free-range poultry production.

Da Silva et al. (2017) proposed the identification, selection, and introduction of tropically adaptable semi-scavenging dual-purpose poultry breeds to improve the productivity of BPPS in Tanzania. Currently, efforts are being made to introduce those dual-purpose breeds with higher genetic potential for growth and egg production and adaptability to varied agroclimatic conditions in the backyard production system (Guni et al., 2021). Dana et al. (2010) reported that although farmers preferred native poultry for rearing because of their adaptation to the local climate, however, low productivity of indigenous poultry warrants the development of improved dual-purpose poultry based on native germplasm. Similarly, Desta (2021a) stated that the indigenous village poultry production system has low productivity; however, it has the potential to achieve profitable and sustainable production through the genetic improvement of indigenous chicken. Desta (2021b) proposed enhanced management, selection strategies, and genetic crosses including the crossing of commercial chickens with red jungle fowl to sustainably intensify the indigenous village chicken production system. In Uganda, a dual-purpose chicken, Kuroiler, has been successfully evaluated under on-farm conditions in scavenging management systems (Galukande et al., 2016).

Kuroiler and Sasso, two improved dual-purpose poultry for the backyard production system, are getting popular in Tanzania compared to the local chicken because of more meat and egg production performance (Sharma, 2011; Getiso et al., 2017). The Kuroiler breed is a cross of several pure genetic lines of chickens, including White Leghorn, Rhode Island Red, colored broiler, and local Desi chickens, followed by selection for high production performance and ability to thrive in the village environment under scavenging or semi-scavenging rearing systems (Sharma, 2011). Kuroiler birds recorded higher body weight gain than indigenous chickens raised under scavenging conditions by rural households in Uganda (Sharma et al., 2015). Sasso breed of poultry was developed in France for extensive production systems through an intensive selection of traditional colored lines of chickens (SASSO, 2014). In Tanzania, Andrew et al. (2019) reported that the net present value, net cash farm income, and the highest probability of attaining economic return were highest in rearing Sasso strain, followed by Kuroiler, and the local chicken was economically least viable. Their study recommends that the improved poultry birds should be promoted for adoption to increase household income for improved livelihood along with education on technical know-how on good farming practices; feed formulations, medication; and shelter for improved productivity (Andrew et al., 2019). In eastern Tanzania, Guni et al. (2021) revealed that the performance traits of the Kuroiler and Sasso breeds are different in lowland and highland ecology, and therefore, knowledge of breed performance in relation to agroecological differences is critical when introducing improved poultry breeds to a different agroclimatic zone. Rajkumar et al. (2021) reported several improved poultry varieties suitable for backyard rearing developed in India. These include Vanaraja, Gramapriya, Srinidhi, Giriraja, Kuroiler, Rainbow, and Rooster. These varieties lay 110–180 eggs in one laying cycle in backyard conditions. The success of these varieties has been reported in India and Africa by several studies (Singh et al., 2018a,b; Andrew et al., 2019; Sanka et al., 2020; Guni et al., 2021; Rajkumar et al., 2021).

Nutrition and food security

The high cost of healthy diets coupled with persistently high levels of income inequality puts healthy diets out of reach for ∼3 billion people, especially the poor, in every region of the world in 2019. Most of these people live in Asia (1.85 billion) and Africa (1.0 billion), although a healthy diet is also out of reach for millions living in Latin America and the Caribbean (113 million) and Northern America and Europe (17.3 million). The number of undernourished people in the world continued to rise in 2020. Approximately 720–811 million people in the world faced hunger in 2020. More than half of the world's undernourished are found in Asia (418 million) and more than one-third in Africa (282 million). Now, moderate to severe food insecurity affects more than 30% of the world population, and most of this population lives in low- and middle-income countries. Poverty and inequality are underlying structural causes of food insecurity and malnutrition. Income inequality in particular increases the likelihood of food insecurity, especially for socially excluded and marginalized groups (FAO et al., 2021).

Severe energy deficiency has been reported in 34% of the human population in South Asia and 59% in sub-Saharan Africa. People in these regions obtained their energy mostly from staple foods (cereal grains, grain legumes, starchy roots, and tubers) and consume a small quantity of low-quality protein. The per capita consumption of egg and animal protein in these regions is low as compared to the world average (FAO, 2013). There is a need for a transforming food system that can provide nutritious and affordable food for all and become more efficient, resilient, inclusive, and sustainable. The food systems need to provide decent livelihoods for the people who work within them, in particular for small-scale producers in developing countries.

Because of its low rearing cost, backyard poultry is being reared by the poorest of the poor households for their food and nutritional requirement. In general, poultry meat and eggs are consumed globally without any religious or social taboo. Backyard poultry converts kitchen or agricultural waste into quality animal protein for human consumption, which is much needed by poor households in developing countries (FAO, 2013). Poor households generally consume cereals that have less bioavailable protein and are deficient in vital minerals and vitamins. Poultry egg has 87 net protein utilization (NPU), an index of quality protein, and poultry egg and meat are rich sources of essential amino acids (FAO, 2013). Besides fulfilling the protein requirement of humans, eggs and poultry meat are concentrated sources of micronutrients and, therefore, are valuable food for alleviating under-nutrition and malnutrition in developing countries.

Meat and eggs from backyard poultry are the cheapest source of high-quality animal-based food, densely packed with essential macro- and micronutrients (Wong et al., 2017). Poultry meat is a valuable source of highly digestible proteins of good nutritional quality, B-group vitamins (mainly thiamin, vitamin B6, and pantothenic acid), and minerals (like iron, zinc, and copper) (Bruyn et al., 2015; Réhault-Godbert et al., 2019). Foods with high bioavailability of nutrients are important for infants and young children, pregnant and lactating women, and elderly and ill people (Olaoye, 2011).

Eggs are a rich source of essential nutrients and vitamins (except vitamin C) to meet human nutrition requirements (Vizard, 2000; Réhault-Godbert et al., 2019). The egg has a balanced and diversified nutrient content with high bioavailability, which makes it high-valued basic food for consumption (Réhault-Godbert et al., 2019). Eggs have been recognized as the lowest cost source of protein, vitamin A, vitamin B12, riboflavin, iron, and zinc (Drewnowski, 2010; Réhault-Godbert et al., 2019) and are also a good source of folate, selenium, vitamin D, and vitamin K (Applegate, 2000; Abeyrathne and Ahn, 2015). Besides, the egg is a good source of bioactive compounds, which are essential for human health.

Singh et al. (2018b) reported that improved backyard poultry contributed significantly to the food and nutritional security of tribal farmers in mountainous regions of northeast India. Wong et al. (2017) reported that backyard poultry contributes directly and indirectly to the food and nutritional security of poor rural households. Backyard poultry are available in vulnerable areas and are a rich source of the nutrient. Additionally, backyard poultry does not compete with humans for feed, thereby improving the availability of densely packed nutritious food to rural poor at a minimum cost (Wong et al., 2017). Poultry meat and eggs provide more protein than swine, cow milk, beef, and lamb per unit of intake. Thus, greater availability and affordability of poultry meat and eggs could contribute to enhanced nutrition for poor rural people, particularly in vulnerable ecology. Rajkumar et al. (2021) emphasized the importance of improved backyard poultry farming for the nutritional and livelihood security of rural farmers in India. It was earlier reported that animal source food improves the nutritional status and linear growth of children (Murphy and Allen, 2003). Thus, the overall benefits of backyard poultry in resource-poor regions are much greater than being an available food source alone. Therefore, increased backyard poultry production with improved germplasm could help improve the nutritional status of rural communities as poultry products are often the only source of animal protein for resource-poor households (Gueye, 2000).

Women empowerment and sustainability

More than 30% of women in Africa and Asia were affected by anemia, compared with only 14.6% of women in North America and Europe. At the global level, the prevalence of moderate or severe food insecurity was 10% higher among women than among men in 2020 (FAO et al., 2021). Backyard poultry is a valuable enterprise because of its role in alleviating poverty, securing food supply, and promoting women empowerment (Rajkumar et al., 2021). Backyard poultry in low- and middle-income countries are mainly managed and owned by women of the households in rural areas (FAO and IFAD, 2022). The fact that women own a large proportion of backyard poultry emphasizes its importance as a means of improving their livelihoods. Income from the sale of poultry products is often the main source of income for female-headed households, whereas male-headed households usually have multiple income sources. Women's income often contributes more to improvements in household health, education, and nutrition status than men's income and has a positive impact on household food security (FAO and IFAD, 2022). In Africa, most women have access to backyard poultry but do not have full control over ownership and decision-making, thereby depriving them of economic benefits (Gueye, 2000). In view of this, Gueye (2000) recommended that backyard poultry development programs should be more women-friendly in order to facilitate women's participation. In India, the rearing of Haringhata black (native poultry) with improved management practices empowered the tribal women economically (Gupta et al., 2021). Also, the position and involvement of women farmers in family affairs have got positive and significant improvement. The adoption of improved management practices of backyard poultry has resulted in increased flock size, increased household income, increased household food security, and increased decision-making power for women (Alders and Pym, 2009). In Africa, women were able to purchase goats and cattle by selling excess poultry, thereby empowering them with the resources that were previously denied to them. In Bangladesh, the rearing of improved hens for table egg purposes under the backyard production system improved the economic status of rural women folk (Alam, 1997). Similarly, in Bhutan, backyard chickens also act as a source of protein for the female members of the household during pregnancy and post-parturition periods (Tashi and Dorji, 2014). This will help in reducing food insecurity, alleviate poverty, and will promote gender equality. Therefore, the greater empowerment of women through backyard poultry farming may contribute significantly to alleviating poverty, enhancing food security, and promoting gender equality (Alders et al., 2018; FAO and IFAD, 2022).

The BPPS is low-input-based and utilizes feed that is not used for human beings, thereby making it economically sustainable, although its productivity is low. However, backyard poultry has more environmental impact in terms of greenhouse gas emissions and manure production because of the long life cycle of backyard poultry compared to broilers (Gerber et al., 2013). Still, the other aspects of backyard poultry, including nutrient recycling, pest management, and improvement in soil fertility, were not considered in environmental impact studies. It was reported that long-term poultry manure application benefited crop yield, soil health, and farm economics (Hoover et al., 2019). Also, backyard poultry reduces environmental pollution by converting kitchen waste into animal proteins. The production of eggs and chicken locally will reduce transportation-related carbon emissions and thereby minimize the carbon footprint of the backyard poultry production system (Samanta et al., 2018). However, there is no study documenting the environmental impact of these improved backyard poultry. Nonetheless, improvement in management and productivity of BPPS with improved germplasm will further lower the adverse environmental impact.

Constraints and challenges to improving the backyard poultry production system

1 Non availability of improved germplasm: Backyard poultry is reared by rural poor farmers in remote and disadvantageous regions. These regions are generally the least developed and also experience extreme weather conditions. Also, the produce from backyard poultry is less than commercial poultry. Thus, it does not attract investment from industry, thereby; leaving the farmers to depend on government institutions for the supply of chicks. As the rural farmers are not equipped with good infrastructure including electricity in these regions, there is high mortality of chicks during unfavorable weather conditions. Therefore, a timely supply of improved germplasm will go a long way to improving the productivity of the BPPS across the globe as is the case in

India (Singh et al., 2018b). In the author's experience, the survival of the birds in the BPPS increased with the supply of grown-up chicks (4–6 weeks of age) to the farmers. Also, on-farm research should be undertaken on improved germplasm before introduction in farmers' fields. It is important to mention here that improved germplasm should not be introduced in core breeding tracts of native or indigenous poultry.

2 Skill deficiency: Although backyard poultry is being practiced by farmers for ages, there is a constant need to upgrade the knowledge and skills of rural farmers. improved poultry germplasm requires scientific management practices to realize its full genetic potential. The success of the Bangladesh model to improve backyard poultry production was largely attributed to the skill enhancement of farmers before the introduction of improved poultry (Alam, 1997). Therefore, farmers, particularly women, should be exposed to different training modules, including brooding, housing, nutrition, and health management.

3 Diseases, predation, and biosecurity threats: In developing countries, backyard poultry represents a majority of stocks reared by farmers with minimum input. Birds are reared with minimum biosecurity, and they are exposed to wild birds, vermin, and predators and, therefore, are predisposed to disease outbreaks (Conan et al., 2012; Samanta et al., 2018). Also, some diseases such as Newcastle Disease (ND) or Highly Pathogenic Avian Influenza (HPAI) are zoonotic in nature and can have fatal consequences for poultry as well as humans (Conan et al., 2012; Wong et al., 2017). Alders et al. (2010) reported that ND is the most common cause of mortality in the BPPS, which can sometimes result in 100% mortality. Similarly, HPAI was found to have adverse effects on backyard flock size, livelihoods, and food security of households (Alders et al., 2013). Also, in the BPPS, predation accounts for the loss of chicks and adult birds, and losses can be sometimes as high as 50–70% (Ahlers et al., 2009). To reduce the disease burden of ND in the BPPS, vaccination by trained community animal health workers was proposed as a key strategy (Alders et al., 2010; Bagnol et al., 2013). Although it is very difficult to implement full biosecurity measures in the backyard poultry production system, disease knowledge, vaccination, and proper housing can significantly reduce the losses to the households (Conan et al., 2012). In India, Samanta et al. (2018) proposed the biosecurity strategy for backyard poultry including daily cleaning of the utensils with ash, offering potable drinking water to birds, preparation of feed with boiled water, daily change of drinking water in the trough, a sprinkling of detergent water left after washing of clothes in the scavenging area, disposal of carcasses by garden burial, washing of the eggs, and storage of the eggs in a cold temperature maintained by indigenous structures.

4 Lack of veterinary health services: Although the requirement for veterinary health services in BPPS Is low, it is not easily available when required. In developing countries, because of a lack of resources and infrastructure in remote areas, cold chain facilities and vaccines are also not available to the farmers. All these adversely impact farmers' access to information regarding disease outbreaks, biosecurity measures, and timely availability of medicines and vaccines (Alders et al., 2010). To address these issues, it was suggested to form networks of community animal health workers, where training and information are exchanged between veterinarians and communities regarding vaccinations and disease control (Alders et al., 2010; Bagnol et al., 2013). Involving women in skill and training programs can have a positive impact on disease control and vaccination in the backyard poultry production system.

5 Lack of access to market: Backyard poultry production is mostly practiced in rural areas which are far away or poorly connected to the market. Although the produce from this system is natural or organic in nature, lack of access to the market prohibits the premium price to the farmers. The poultry and eggs from this system are generally sold in the local market in villages or towns where farmers do not get a better price. In the author's experience, when improved poultry germplasm was introduced for backyard production in a village, the availability of meat and eggs was considerably increased; however, the market price declined because every household has surplus produce. In this context, the co-operative model of marketing or making self-help groups and linking them with the urban market is a viable alternative. if market innovations are not adopted, there are chances that the BPPS will face fierce competition from commercial poultry producers as was the case in Thailand (NaRanong, 2007). Therefore, projects on improvement in productivity of backyard poultry must invariably include the forward market linkage of the producers.

6 Backyard poultry and zoonosis: Infectious diseases such as Highly pathogenic avian influenza A (H5N1) can be transmitted from poultry to humans and can cause lethal infection in humans (Shanta et al., 2017). Besides, poultry is a source of several pathogenic enteric bacteria that are of zoonotic importance; however, very little is known about the occurrence of zoonotic pathogens in backyard poultry. Pohjola et al. (2016) Reported that backyard chickens are a reservoir of *Campylobacter Jejuni* strains and also carry *L. monocytogenes*, *Campylobacter coli*, *Yersinia pseudotuberculosis*, and *Salmonella enterica* and non-pathogenic *Yersinia enterocolitica*. Backyard chickens have free access to the outdoors, which can increase the

risk of contact with zoonotic pathogens transmitted from wild birds and other animals. furthermore, the birds live in close contact with humans and other livestock and therefore increase the chance of direct or indirect spread of infection (Behravesh et al., 2014). Batz et al. (2012) Reported that *Salmonella*, *Campylobacter*, and *E. Coli* are the most important poultry and poultry meat-related foodborne biological hazards to public health. To reduce the risk of diseases spread from backyard poultry, it is important to educate and make aware all the stakeholders.

7 Backyard poultry as a source of antimicrobial resistance: Antimicrobial resistance (AMR) remains a growing threat to human and animal health. globally, over 70% of antimicrobials produced are used in food and animal production systems (Van Boeckel et al., 2019; Hedman et al., 2020). As backyard poultry production systems are generally practiced in resource-poor setting which involve zero to low input. In these resource-poor setting, antibiotics are not easily available, thereby minimizing the chance of their use (FAO, 2015, 2021; Wong et al., 2017). However, if available, there are high chances of indiscriminate use of antibiotics in these settings as farmers are not well-aware, and veterinary extension services are also poor (Barroga et al., 2020; Hedman et al., 2020). The use of antimicrobials can increase with an increase in intensification of the backyard production system and subsequent linkage with the market (Samanta et al., 2018). Similar findings were reported from other south asian countries (Coyne et al., 2019). In the philippines, Barroga et al. (2020) reported the use of critically important antimicrobials on backyard poultry farms. These family-operated micro-enterprises could potentially promote the risk of AMR and zoonosis exposure to community members due to the close proximity of production animals and surrounding human populations (Wuijts et al., 2017; Hedman et al., 2019). Hence, there is a need to educate the farmers regarding the use of antimicrobials in the backyard production system along with strengthening the animal health services. moving forward, a supportive environment will be needed, which includes regulations controlling use, improved systems for monitoring use, financial incentives, raising healthy chicks in stress-free environments, and minimum use of antimicrobials (Lhermie et al., 2017; FAO et al., 2021).

Conclusion

Backyard poultry farming provides food and nutritional security besides generating income and employment for the most vulnerable communities in developing countries. For them, backyard poultry is the first and last asset to be used in times of distress. In particular, they significantly improve the livelihood and food security of women, children, and the disabled. Backyard poultry production systems are known for their low productivity, which can be improved through the implementation of scientific measures in management, improvement in genetics, or improvement in health management. In recent times, the introduction of improved backyard poultry germplasm has revolutionized backyard poultry farming in Asia and Africa. These improved backyard poultry systems have characteristics similar to the native birds and are, therefore, preferred by rural farmers. The improved backyard poultry germplasm has given a ray of hope to the rural poor; however, there exist several constraints for these birds to realize their full potential. This includes but is not limited to the non-availability of improved germplasm, lack of skill, disease outbreaks, poor market linkages, and absence of veterinary health services. There is a need to focus on ecology-specific technology and to avoid the introduction of improved backyard germplasm in breeding tracts of native poultry. Involving the local community at every step of backyard poultry farming is the best approach to gain maximum from new technologies.

Author contributions

MS, RM, RP, and NP conceptualize and design the work. MS and RY wrote the first draft of manuscript. RY, VS, RKa, RKu, CS, MB, and SB review and edited the manuscript. DR and VM supervise the project and reviewed the manuscript. All authors viewed and approved the final draft of manuscript.

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Conflict of interest

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

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